Interpreting the Emergence and Development of High Technology Electronics Industry Clusters in Selected Second Tier Global Regions

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Abstract

The thesis focuses on the high technology electronics industry and why and how electronics manufacturing firms emerged, developed and evolved endogenously into dense industry clusters in a limited number of selected, small and relatively isolated second tier cities. These developments occurred in small regions rather than in large established industrial centres. The high technology electronics industry typically produces small volumes of highly complex, high value-added, customisable, intellectual property-based products and systems for commercial, industrial and professional applications in sectors including food, health, security, transport, government, communications, manufacturing, defence, education and research.

The high technology electronics industry developed in parallel to the large, typically multinational firms, which mass-produce high volumes of standardised consumer electronics products for personal communication, information and entertainment. The parallel development of these two sectors provides significant contrast since the high technology electronics industry, although significantly larger in revenue and employment than the consumer electronics sector, is less understood by governments and communities.

The research examines the widely studied high technology electronics industry in Silicon Valley, California; Cambridge, UK and Austin, Texas, that by incorporating technologies developed in their universities the industry emerged and evolved over decades into dense, interconnected regional clusters of typically smaller firms and related organisations. Knowledge obtained from these exemplar clusters assists the understanding of the origin and development of high technology electronics clusters in the second tier regions of Adelaide and Christchurch. The thesis analyses and quantifies these antipodean electronics industry clusters and adds to the growing literature describing the endogenous emergence and self-organised development of technology-based firms into clusters in small and relatively remote second-tier cities and without the involvement of universities. Endogenous cluster development is contrasted with electronics industry clusters created by government programs in selected regions.

The contribution to knowledge is consistent with and builds on the work of Porter (1990b) and Mayer (2011). The thesis recognises that a stimulus other than universities occurred in Adelaide through the establishment in 1947 of Australia's defence research and development laboratories and in Christchurch through the 1954 start-up of a two-way radio manufacturing firm. Through spin-outs and start-ups the electronics clusters in these two second tier cities have reached the highest density in their respective nations, comparing favourably with the leading global electronics industry clusters.

The thesis recognises that in small cities proximity to industry peers facilitates trust and collaboration, and that ethical and reliable behaviour of cluster members is essential in these close-knit communities. The thesis provides case studies of firm and cluster origin and development with cross-regional data comparisons and regional location quotients. Australian statistics on location quotients are not published for the electronics industry and Australian governments generally appear to be unaware of the economic value of the high technology electronics manufacturing industry.

With knowledge of electronics industry origin and cluster development government and industry can develop policies and programs for its sustainable development and its major role in the transition of the regional economy of Adelaide from its past dependence on industrial-age manufacturing to its future through knowledge-age industry.

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List of Abbreviations

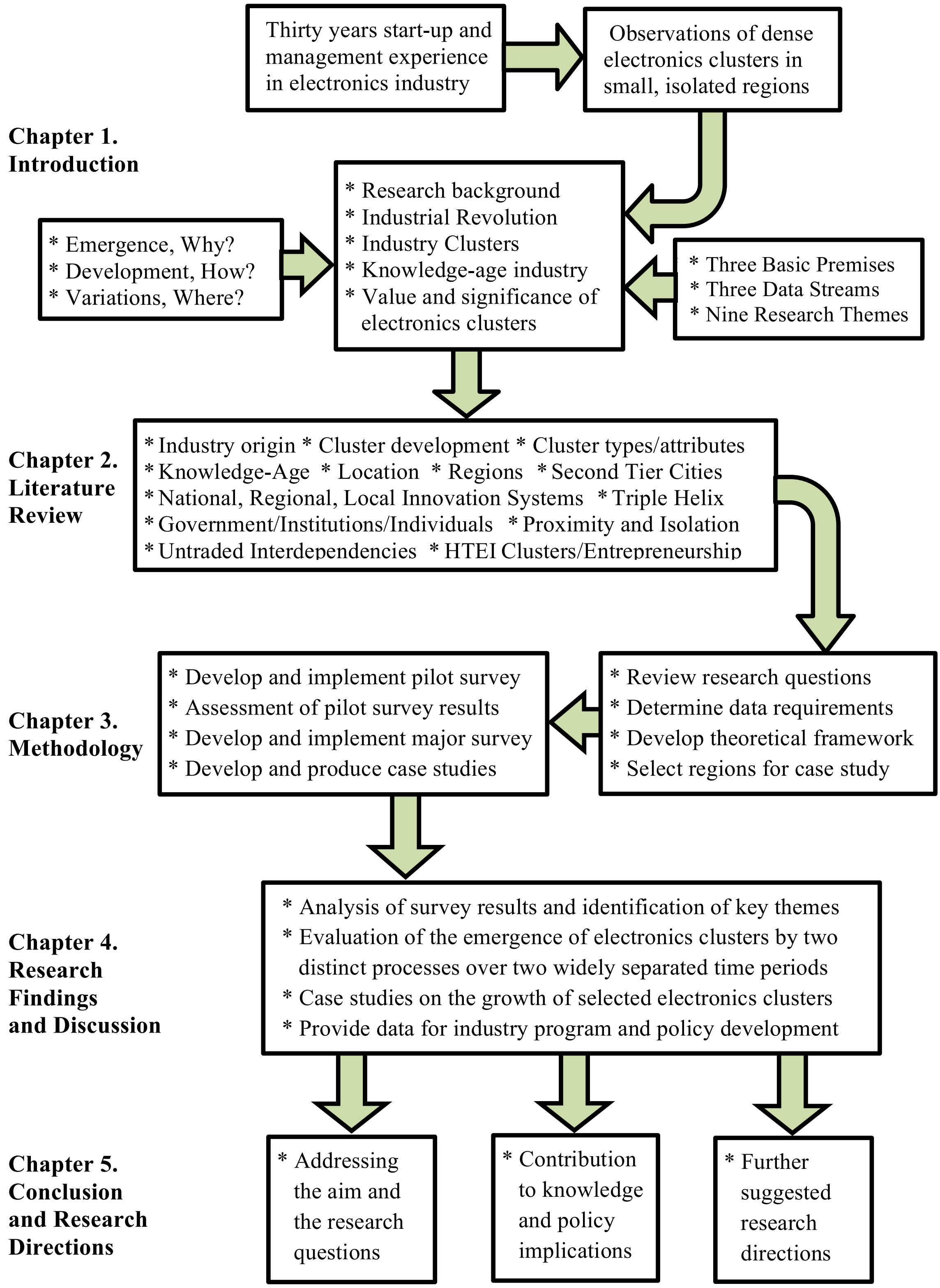
ABS	Australian Bureau of Statistics
AEEMA	Australian Electrical and Electronics Manufacturers Association
ANZSIC	Australian and New Zealand Standard Industry Classification
ATI	Austin Technology Incubator
AWA	Amalgamated Wireless (Australasia) Ltd
CAGR	Compound Annual Growth Rate
CEO	Chief Executive Officer
CIC	Cambridge Instrument Company Ltd
CSI	Cambridge Scientific Instruments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTT	Canada's Technology Triangle
DEC	Digital Equipment Corporation
DETE	Department of Enterprise, Trade & Employment, Ireland
DME	Distance Measuring Equipment
DSTO	Defence Science and Technology Organisation
EASA	Electronics Association of South Australia
EIAA	Electronics Industry Action Agenda
EIA	Electronics Industry Association

EU	European Union
FDI	Foreign Direct Investment
FTC	Federal Telegraph Company
Forfás	Board for Enterprise, Trade, Science, Technology and Innovation
GACC	Greater Austin Chamber of Commerce
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GFC	Global Financial Crisis
GOVERD	Government expenditure on research and development
GSP	Gross State Product
HETI	High Technology Electronics Industry
HTO	High Technology Organisation
IC	Integrated Circuit
IC^2	Institute for Innovation, Creativity and Capital, University of Texas at Austin
ICT	Information and Communications Technology
IDA	Irish Development Authority
ILS	Instrument Landing Systems
IT	Information Technology
IP	Intellectual Property
IPO	Initial Public Offering
JVSV	Joint Venture Silicon Valley,
LFR	Less Favoured Region
LIS	Local Innovation System
LQ	Location Quotient
LRWE	Long Range Weapons Establishment
MCC	Microelectronics and Computer Technology Corporation - Austin, Texas
METI	Ministry of Economy, Trade and Industry, Japan
MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry, Japan
MNC	Multi-national Company
MSA	Metropolitan Statistical Area (USA)
MSTC	Master of Science in Technology Commercialization (Adelaide and Austin)
NAICS	North American Industry Classification System
NIS	National Innovation System

NOMIS	National Online Manpower Information System
NTB	New Technology Based [Firms]
RIS	Regional Innovation System
SIC	Standard Industrial Classification (UK)
R&D	Research and Development
SME	Small and Medium Enterprises
SRI	Stanford Research Institute (Palo Alto)
STC	Second Tier City
TNC	Transnational corporation
TIA	Technology Industry Association
UK	United Kingdom
UN	United Nations
USA	United States of America
UT	University of Texas
VC	Venture Capital
WIGO	What is Going On
WRE	Weapons Research Establishment

Research Plan Diagram

Interpreting the Emergence and Development of High Technology Electronics Industry Clusters in Selected Second Tier Global Regions



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Ronald Grill

Chapter 1: Introduction

1.1 Background to the Research

This thesis is driven by an enduring and compelling question:

> *If we could know why successful electronics manufacturing firms emerged in small, relatively remote 'second tier' cities and how, over many decades these firms coalesced endogenously through self-organisation into high density clusters, then with this knowledge, industry and government could develop policies and programs to facilitate the long-term sustainability of the industry.*

During more than thirty years of the establishment and management of electronics manufacturing and marketing companies and the concurrent development of electronics industry associations it was observed that dense concentrations of predominately smaller electronics design and manufacturing businesses and related organisations had emerged and flourished in a limited number of small regions in developed nations. These aggregations of interconnected and mainly locally owned businesses, named as *clusters* (Porter, 1990b) appeared to be firmly connected to their host communities. Furthermore, the highest density clusters appeared to have emerged endogenously and developed essentially without government planning or assistance over a period of fifty to more than one hundred years.

However, the origin and development of these dense electronics industry clusters had not followed the previously established pattern of industry agglomeration in large cities. Counter-intuitively the most successful electronics industry clusters were identified not in major cities, but in relatively small cities that are also relatively separated both physically and economically from their major national populations. The emergence and development of electronics industry clusters is examined here in selected regions of developed countries

The term cluster was used by Michael Porter in his book '*The Competitive Advantage of Nations'* (1990b) and his widely used definition (2000a:16) is adopted in this thesis:

"Clusters are geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g. universities, standards agencies, trade associations) in a particular field that compete but also cooperate."

The topic arose naturally from decades of industry engagement and observation of the author that provided an *industry-based* perspective; it was not derived from an established literature-based methodology.

It is important to provide the contextual background on the use of the word *electronics.* Key definitions and descriptions are shown here, further distinctions will follow later:

1. Electronics is a ***technology****:* The term *electronics* is defined as: "*the science and technology concerned with the development, behaviour, and applications of electronic devices and circuits"* (Collins, 2009).

2. Electronics is an ***industry****:* The electronics industry is defined as "*the manufacturers of electronic products considered collectively"* (Collins, 2009).

3. Electronics is also an ***enabling technology*** which is critically important to other *knowledge-age* industries and to the education, research, commercial, government and community sectors by facilitating communications, transport, commerce, defence, science, environment, health and indeed most human activities in *post-industrial society* (Bell, 1974).

This research is concerned with clusters in one particular sector of the global electronics industry, termed here as the *high technology electronics industry* (HTEI, hereafter). High technology is defined as *"advanced technological development, especially in electronics"* (Oxford, 2008). However, this definition does not distinguish between the high technology, low-volume, professional, commercial, industrial electronics sector - the subject of this research - and the high-volume *consumer* electronics industry sector. Discussion later in this chapter will provide further distinction between the two sectors.

The thesis aims to contribute to the cluster origin debate and to add to the understanding of the unplanned emergence and self-organised development of dense HTEI clusters, particularly in smaller and relatively isolated places described as *second tier cities* (Markusen and DiGiovanna, 1999; Deegan, 2005) or *second tier regions* (Mayer, 2011). Second tier cities are further discussed in Section 2.10 Second tier cities are defined as:

"*…cities outside the capital city whose economic and social performance is sufficiently important to affect the potential performance of the national economy."* (ESPON, 2012a:2).

Successful HTEI clusters in the United States of America (USA, hereafter), United Kingdom (UK, hereafter) and Europe (EU, hereafter) are well-represented in the extensive cluster literature and well-recognised by their communities and governments. Knowledge of these well-researched clusters can inform the study of the origin and development of successful clusters in less-studied second tier cities including two HTEI clusters, one each in Australia and New Zealand. While these two clusters employ the highest proportion of their nation's HTEI workforce they are not well-recognised in the limited and incomplete literature or by their government or community. Knowledge of their origin and development could facilitate development of policies and programs for their long-term sustainability.

There is a dual focus to this thesis. First it explores the emergence of clusters of the HTEI in selected second tier cities that are separated from the major centres of economic activity normally associated with the metropolitan or capital cities in developed countries.

A general question may be posed; *why did this particular form of modern industrial activity take root and grow in these small, provincial or 'second tier cities'?*

Another general question takes us to the second focus of the thesis; *how did this particular modern kind of industrial activity develop and what form did it take?*

A discussion on these questions will assist the understanding of the significance of these dense, high technology electronics clusters to the future of manufacturing industry generally and particularly to the future of new forms of manufacturing in the *'knowledge-age'*. These two questions, lead to a third question: *what variations of the cluster model have developed?*

Since the discussion of the concept (Porter,1990a), clusters in the USA, UK and EU have been widely reported and the comprehensive literature analyses the range of cluster characteristics including structure, operation and economic value, but in the twenty-first century the question of *why* these successful clusters came into existence remains unresolved. There is no general agreement on the "*origin"* of clusters (Menzel et al, 2010). Feldman and Braunerhjelm (2006:1) state that there is *"little understanding"* of how successful clusters come into existence. Mayer (2011) posits that the majority of cluster studies do not satisfactorily explain why some locations develop agglomeration economies and she highlights the evolution of successful clusters in small regions, not traditionally regarded as high technology centres and these clusters are also relatively undiscovered. Industry life cycle (Audretsch, 1987; Klepper, 1997) and cluster life cycle have been researched in USA and UK (Menzel and Fornahl, 2010; Martin and Sunley, 2011). The sectorial development of city economies and industry evolution through "*path dependent"* processes is reported and particularly in Cambridge by Martin and Simmie (2008).

Since the Australian and New Zealand HTEI clusters that emerged and developed endogenously fifty or more years ago and developed independently are relatively unrecognised it is plausible that these clusters could continue on their natural evolutionary trajectory and mature, eventually stagnate and decline (Klepper, 1997; Menzel and Fornahl, 2007; Mayer, 2011).

Knowledge of the nature of the endogenous origin and the independent development of HTEI clusters could be valuable in the facilitation of their nurture and their long-term sustainable development.

1.2 Basic Premises of this Research

The first premise of the thesis is that electronics technology and the electronics industry are fundamental to the maintenance and development of our current civilisation. Electronic products and systems guard our health, wealth and safety, provide our communications and entertainment and facilitate the creativity and productivity of our communities. Electronics is critical to the improvement of the living standards in developed and developing communities and without electronic products, systems and services, current standards of living, particularly in developed nations would be unsustainable.

Electronics is a vital part of everyday life, and *"... electronics exhibits a crucial enabling role, it provides components and equipment found in almost all other industries"* (Walsh et al, 1994:11). This statement by economist, Professor Clifford Walsh highlights the penetrating influence of the *enabling* function of electronics technology, but it is emphasised here that in addition to the important function of *enabling* other industries and activities; the electronics industry is a major manufacturing industry designing and manufacturing and marketing its own products. Manufacturing is defined as: "*the making of useful products by hand or machine"* (Oxford, 2008).

The second premise is that the *value-added* by manufacturing is important to all economies and that the value-added by knowledge-age manufacturing and particularly by high technology electronics manufacturing achieves productivity levels significantly beyond those attainable by *industrial-age* manufacturing (Kruger, 2008).

The third premise is that the electronics industry and electronic systems and technologies are critically important factors in the *transition* of developed economies from their past dependence on *industrial-age* manufacturing to their future through *knowledge-age* industry.

1.3 Primary Research Streams and Data Sources

This thesis follows three primary streams. First it attempts to interpret the phenomenon of the emergence of dense clusters of high technology electronics businesses in selected second tier regions.

The second stream seeks to identify and characterise the factors that have assisted and the factors that have inhibited the development of these high concentrations of electronics businesses in the selected regions.

The third stream analyses and characterises the variations of electronics industry cluster types and their growth trajectories.

To understand the origin and development of HTEI firms and clusters an extensive literature review was undertaken on the well-researched regions of USA, UK and EU and the lesser researched HTEI industry in the Asia-Pacific region.

To confirm the perspective obtained from the literature review, to appreciate the regional context and to achieve a *connected* understanding of the origin and development of the industry a small series of structured, face-to-face interviews was conducted in 12 selected cities in USA, UK, EU and Asia.

The knowledge obtained from the literature and from these confirmatory interviews of HTEI organisations in the well-researched regions assisted the understanding of the evolution of the industry and its clusters in the less-researched regions.

The limited literature on HTEI firms and clusters in New Zealand and the less complete literature on the Australian HTEI were reviewed and large gaps were found in the available data and information on the origin and development of the HTEI in both countries.

A larger series of structured, face-to-face interviews obtained data and information on the origin and development of the HTEI in six less-researched antipodean cities, with the largest number of interviews conducted in Adelaide; the least researched of the 18 HTEI clusters selected for the research.

All interviews in the 18 second tier regions in 8 countries on 4 continents were conducted with a structured agenda of 50 discussion topics to obtain information and data on start-up motivation, location, technology resources, operation and external influences on the entities.

While this research evolved from an industry perspective, the extensive literature review and a small series of confirmatory interviews in USA and UK greatly assisted the understanding of the data from the major survey which produced new knowledge on the origin and development of HTEI firms and clusters in the selected Australian and New Zealand cities.

The largest number of the interviews was with founders or managers of HTEI firms in each of the 18 regions and a smaller number of interviews with related government, research and industry organisations provided an understanding of their engagement in the process.

The data are presented in three case studies of HTEI cluster regions to compare and contrast firm and cluster origin and development processes. The principal case study analyses a group of five successful, dense, endogenous HTEI clusters in selected small and globally dispersed second tier regions.

The second case study analyses less successful and less dense HTEI clusters in five cities with a range of population. The third case study analyses the HTEI in eight regions where government policies and programs were implemented for the development of the HTEI in 'created' clusters. Inter-regional comparisons within the case studies and cross-case comparisons are discussed in Chapter 4.

The 'firm' is used hereafter to describe all business entities whether incorporated companies or unincorporated businesses and including entities involving one person and up to and including multinational companies (MNC's hereafter).

1.4 Research Context

This thesis codifies the narrative of the origin and development of electronics industry firms that have emerged and formed into clusters with a primary focus on selected *'second tier'* regions. The thesis attempts to add to the theoretical discourse regarding some leading concepts of industry development. In the extant literature and in this thesis four key terms are widely used in discussion on the discovery or creation of technologies, their development and implementation and their economic exploitation. The following definitions are adopted (Oxford, 2008):

Invention: *The action of inventing something, typically a process or device; the design of something that has not existed before.*

Innovation: *The making of changes in something established, especially by introducing new methods, ideas, or products.*

Entrepreneur: *A person who sets up a business or businesses, taking on financial risks in the hope of profit.*

Commercialisation: *The management or exploitation (in an organization, activity, etc.) in a way designed to make a profit.*

These key terms describe the four steps in a *sequential* process, where each subsequent step is reliant on the previous step; the linear model of innovation (Feldman, 1994b). The process begins with the envisioning or *invention* of an original concept and this step may also include the original discovery of an existing, natural phenomenon. The invention step is related to the *research* step in the *research and development* process.

The *innovation* step incorporates the invention or discovery in the concept of a new or improved product, process, or service. The innovation step is related to the *development* step in the research and development process. In this thesis *product* is used to also include *service*.

The next stage is the *entrepreneurial* process of the identification and validation of a market and the marshalling of the required human, intellectual and physical resources.

In the *commercialisation* stage the identified resources are acquired and applied and the business and management structures are created for the sustainable, profitable manufacture and distribution of the product. While there is considerable overlap of the four steps, this discussion illustrates the activities and their sequential relationship.

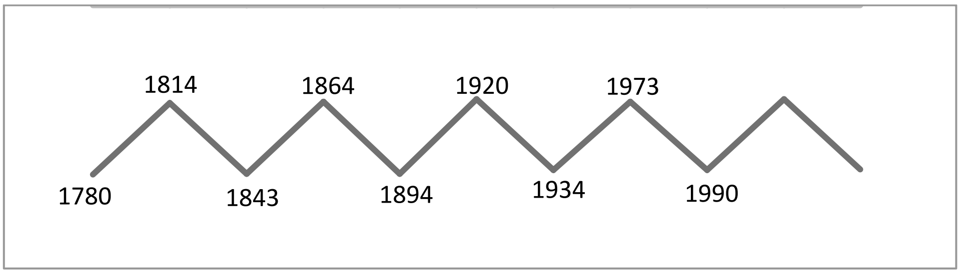
Research for the thesis pays detailed attention to the spirit and the form of inter-organisation and inter-personal relationships in the high technology sector of the electronics manufacturing industry in the selected regions that, taken together, represent an advanced stage of industrial development, giving meaning to such terms as '*knowledge as a resource',* '*knowledge-era'* (Savage, 1990) and the '*knowledge-age'* (Bereiter, 2002).

This research affords an opportunity to reflect further on the nature of industry clusters and their role in industry development, and possibly to contribute toward theory-building around the seminal work of Michael Porter.

1.5 From the Industrial-Age to the Knowledge-Age

In the mid eighteenth century total national output began to grow in England (Deane, 1979) and later in Europe and USA (Teich and Porter, 1996). Waves of technological innovation spawned new manufacturing processes and industries that attracted trade-related businesses to the growing towns and cities during the *Industrial Revolution.*

Figure 1.1: An Approximation of the Peaks and Troughs of Industrial Development.



Source: Beckman (1988).

This unplanned and initially unnoticed development (Hartman, 1967; Honour, 1977; Hudson, 1992) is variously dated as *"mid eighteenth century"* (Deane, 1979) or 1760 (Toynbee, 1884; Ashton, 1948) or 1776 (Roe, 1916; Hulse, 1999) or *"late eighteenth century"* (Mantoux, 1928). New materials, machines, products and industries developed (Flynn, 1966), and by the early nineteenth century the "*factory system"* was visible (Mantoux, 1928:489).

1.5.1 Industrial Districts

Adam Smith noted the aggregation of trade-related businesses (1776:125) and the circulation of industry information (1776:59) in the natural agglomerations named *industrial districts* by Alfred Marshall (1890). In these industrial districts hand labour and craft workshops competed with new machines in the factories of growing firms agglomerated in regions with natural endowments including materials, energy resources, rivers and ports.

Understanding the endogenous aggregation of trade-related firms in industrial districts assists the understanding of the coalescence of knowledge-age firms in their linear descendants - *industry clusters* - in other places where physical resources are augmented by knowledge; the major resource in the physical and biological science-based industries.

1.5.2 Industry Clusters

Late in the twentieth century clusters of *knowledge-age* HTEI firms were reported in unexpected regions, however, these clusters had emerged decades earlier, endogenously and unnoticed and formed around the intellectual resource requirements of the firms, whereas the agglomerations in Industrial Districts had formed around the physical resource requirements of the firms. Clusters as described by Porter (1998c) are also reported in a number of industries and economies (HMSO, 1988; Malmberg and Maskell, 2002; Newlands, 2003; Perry, 2005; Barry, 2006; Motoyama, 2008). HTEI clusters exhibit many of the characteristics previously reported in the industrial districts of the eighteenth and nineteenth centuries. Porter (2000a:16) notes: *"The intellectual antecedents of clusters date back at least to Marshall, 1890.*"

Two central characteristics differentiate knowledge-age HTEI clusters from industrial-age manufacturing. First, HTEI clusters include large numbers of small, agile, locally owned and managed businesses unlike the large vertically integrated firms of the mass production industrial-age. Second, HTEI cluster firms typically concentrate on product design and marketing while outsourcing intermediate processes including product assembly, logistics, system and compliance testing. These subcontract relationships are dependent on proximity, economic value and trust (Ganesan, 1994; Fukuyama, 1995; Porras et al, 2004).

The outsourcing of production and services to local cluster firms is also dependent on information sharing and Ganesan (1994) notes the necessity of trust for communication, knowledge exchange, and that trust between people and firms develops over time and is strengthened by successful ongoing collaboration (Foray, 1991).

Many aspects of clusters are widely studied, including operation, employment and wealth-creation, economic development value and life cycle (Klepper, 1998; OECD, 1999; Enright, 2003; Wolfe and Gertler, 2004; Casper, 2007). However, limited attention has been applied to the actual *origin* of clusters. As recently noted by Mayer; "*Cluster evolution is an understudied area"* (2011:26) and Feldman and Braunerhjelm (2006:1) note the limited understanding of *"how successful clusters come into existence."* The emergence and development of HTEI clusters and cluster types is discussed further in Chapter 2.

1.5.3 The Knowledge-Age

During more than two hundred years manufacturing progressed through waves of new technologies and industry structures; from the cottage to the craft workshop and to standardised, high volume and automated factory production. During the twentieth century while traditional manufacturing continued, the knowledge-age emerged unseen, with new technology-based industries employing higher skill levels, customisation and the reconfigurable processes of *'flexible specialization'* (Piore and Sabel, 1984). A cumulative process of *"snowballing"* is also reported (Cooke et al, 2007:138) with knowledge created during previous waves of innovation incorporated in subsequent developments (Mensch, 1979; Von Hippel, 1982). This may be a key factor in HTEI cluster development. Knowledge-age industries now generate increasing levels of employment and wealth (Storper and Scott, 1990) through the high value that is added in their intellectual property-based products (MacBryde et al, 2011).

During the industrial-age wealth creating industries employed land, labour and financial capital and natural resources as their factors of production. Now, knowledge is *"the primary resource"* (Drucker, 1992:95). Industries including aerospace, biotechnology, electronics, information technology, nanotechnology and telecommunications are the major knowledge-age industries. While the focus of this research is on the electronics industry, flexible specialisation and customisation are common to all knowledge-age industries and are a differentiator of knowledge-age industries from those of the more rigid and standardised processes of mass production in industrial-age manufacturing.

The progress of humankind from the cave to the moon and beyond has been underpinned by evolving waves of new technologies. During the twentieth and twenty-first centuries electronic technologies have enabled and accelerated that progress and boosted the knowledge-age with the highest recorded standards of living for the people of developed nations and rising standards of living for many in developing nations.

1.6 From Industrial-Age to Knowledge-Age Industry

The factory system of the late eighteenth century brought together machines, manufacturing processes, collaboration and competition *"through independent undertakings"* (Mantoux, 1928:27). The selling price of industrial-age products depends principally on the cost of labour, material, and other inputs required for their production, transport and distribution (Mill, 1849). Where there is no restriction on the use of commonly available product and production knowledge, the selling price achievable by all manufacturers will be influenced by their productivity and the forces of supply and demand.

The basic machines of the industrial-age continued into the nineteenth century (Boodish, 1949) when newly developed precision machine tools produced component parts to such close tolerances that these parts became interchangeable (Ames and Rosenberg, 1968). This development enabled mass production of a rapidly expanding range of precision mechanical consumer goods including, sewing machines, timepieces, firearms and motor vehicles (Rosenberg, 1970). Through the twentieth century mass production of high volumes of standardised products and mass marketing brought increased sales, lower unit costs and further development of technologies, new products and increasing demand.

Each new development brought additional investment and employment opportunities (Savage, 1990). Later waves of industrial processes built on the achievements of preceding developments in a continuous cycle (Von Hippel, 1982).

In the late twentieth century the internet, low-cost transport and communications and new technologies forever changed industry in the developed and the developing nations. The current era with its knowledge-focus is described as "*the third wave of human socio-economic development"* (Savage, 1990), following the agricultural-age and the industrial-age. In a *third wave* economy data, information, images, symbols, culture, ideology and values are "*actionable knowledge"* (Dyson et al, 1994). Covey (2010) states that each stage of the transition from the agricultural-age to the industrial-age to the knowledge-age has made man fifty times as productive as he was during the prior age.

In the knowledge-age the traditional factors of production land, labour and financial capital are employed and augmented by human services, innovation and entrepreneurship (Black, 2003). Productive wealth is now based upon the ownership or control of knowledge and the ability to use that knowledge to create or improve goods and services. Typical product improvements in the knowledge-age include cost, function, reliability, suitability, timeliness of delivery and security (Savage, 1990). In the knowledge-age additional value and often greater value is added by such intangibles as design and the exclusive use of technology.

While capital in the industrial-age was based on tangibles including land, machines and materials, in the knowledge-age these assets also have value, but its intellectual assets typically have higher value than the physical assets of a firm. Location of industrial-age manufacturing was similarly based on tangible factors, in knowledge-age manufacturing and particularly in HTEI manufacturing intangible factors dominate. Industry location factors are discussed in Chapter 2 and selected location parameters are measured in six antipodean HTEI regions and reported in Chapter 4.

Manufacturing in advanced economies is now in transition from the past reliance on industrial-age technologies, products and processes to the new opportunities available through knowledge-age industry. The new flexible and customised manufacturing paradigm does not replace the mass production of standardised products, but provides additional opportunities for designers, manufacturers, investors and consumers and for continued innovation (Savage, 1990).

Several levels of skill are employed in manufacturing and these are relevant to this discussion. At the lower end of the scale is the *'know what'* level of training required to operate a machine where the machine is pre-set to perform a specific function; this is typical of mass production in the industrial-age. The trade or craft person has a higher level of skill and the '*know-how'* to operate and to set a range of machines and the craft skill to use hand tools and measurement to produce a wide range of items, typically from a design or an engineering drawing. At a higher level of skill are the knowledge workers, typically research scientists or design engineers, the *'Creative Class'* (Florida, 2002) who possesses the *'know why'* and who contribute the concept and the design of a new or improved product.

Just as the industrial-age replaced many of the previous production processes and brought new products and increased levels of productivity, so the arrival of the knowledge-age has introduced new methods, materials, processes and products, but has surprisingly continued others that have remained relevant to low-scale manufacturing.

Mass production of standardised industrial-age products continues and these processes have moved from many advanced nations to low labour-cost locations, but the older established skill-based or craft system of production has been retained in developed nations (Jacobs, 1969) to deliver constantly evolving, customised products to meet changing needs (Piore and Sabel, 1984). Flexible manufacturing and reconfigurable processes can produce small volumes of high technology products and a high level of customisation of these products is the norm (Searjeant, 1986). The paradox of low-volume production in an era of high volume mass production is a function of the skill of the *knowledge worker* (Drucker, 1946).

Governments in advanced nations encourage high volume manufacturing industries to move away from low skill, low value products and practices (MacBryde et al, 2011). The Australian and USA Governments have recently produced reports encouraging the commercialisation of the research conducted by universities, publicly funded research institutions and industry (Cutler, 2008; DIISR, 2012; Bonvillian, 2012). Firms in the UK are encouraged to move up the value chain and reap the benefit of high skilled, knowledge-intensive industry (Porter and Ketels, 2003; Livesey, 2006; Lawton Smith, 2007). While some overlap of production methods remains, the transition from industrial-age to knowledge-age manufacturing continues and observations and predictions of its trajectory abound (Machlup, 1962; Bell, 1974; Rogers, 1983; Dyson et al, 1994; Storper, 1997a; Nelson, 2000b).

Transition through the evolution of new technologies is ongoing; wireless telegraph technology led to radio, television and mobile communication; the transistor replaced most electron tube applications and led to integrated circuits, microelectronics and microprocessors. Computers incorporating these devices have grown more powerful, smaller and portable and reduced in price by an order of magnitude over the past decade. Jet engines, communications and surveillance systems, many developed for military applications now facilitate low-cost and safe global air transport of passengers and cargo.

More than two centuries of evolutionary changes have moved humankind from horsepower through steam power to fission power and from the telegraph to radio and to the ubiquitous electronic systems in use today. While innovative technology-based processes and products are emerging from knowledge-age companies and research establishments at an ever increasing pace, their proximate communities are often unaware of the existence of the knowledge-age industry activities in their midst or of the employment, wealth and competitive advantages of the transition from industrial-age to knowledge-age industry. *"The information technology revolution has raised the pace of technical change for a generation, creating a need for more flexible small-batch production systems, a better-educated more innovative workforce, and more creative management."* (Keeble, 1989:153). Governments and industry organisations in advanced economies have a role in facilitating the transition from industrial-age to knowledge-age industry and the promotion of the benefits to their communities from these new industries with their competitive advantages. This *'Third Industrial Revolution'* (Rifkin, 2011) while relatively unrecognised in some HTEI regions combines intellectual capital with traditional factors of production to deliver new customised products faster while reducing cost and time to market, increasing returns by value-adding through innovation in design, manufacture and business model.

1.7 Intellectual Property and Knowledge-Age Industry

The economic activities of the industrial-age and the knowledge-age share one important activity; both sectors manufacture products. In knowledge-age manufacturing, as with industrial-age manufacturing value is added by the traditional process of assembling materials or components into products, however, in knowledge-age manufacturing much greater additional value is added by the intellectual property (IP, hereafter) in the design of the product, in its manufacturing processes and by the IP, often as embedded software in the delivered product. A defining characteristic of all knowledge-age industries and particularly of the electronics industry is the high proportion of IP employed by its design and manufacturing firms across the spectrum of their activities.

An important characteristic of knowledge-age industries is the high cost of design and development of their products when compared with the comparatively low cost of their *reproduction* by highly automated processes. While this unusual characteristic of knowledge-age or high technology manufacturing is shared across all high technology sectors, Oakey (1995) posits that there is little in common between biotechnology, electronics and software firms. While their products and markets are diverse the selling prices of their IP based products are typically a significant multiple of their input costs. This contrasts with industrial-age manufacturing where products are typically based on design and process knowledge that is available to competitors, so competition drives productive efficiency. The price premiums on high technology products can fund additional research to drive further product development and productivity. The economic value of IP in knowledge-age products and their higher returns have created a new industrial paradigm.

Intellectual property is defined as: "*intangible property that is the result of creativity, such as patents, copyrights*" (Oxford, 2008). This definition of IP includes *'patents and copyrights'* which introduces the concept of the *protection* of IP. This protection can provide knowledge-age firms with a major advantage over competitors in their industry and over other industries and particularly over industrial-age industries which use design, material and process knowledge that is often widely available, or not considered to be *novel* and therefore not patentable.

Knowledge-age products are, however, typically based on IP which is unique to or which can be protected by the owner of the IP or the designer of the product. The ability to protect the IP provides knowledge-age manufacturers with the right to exclusively possess and to profitably exploit their protected technologies.

The IP assets of knowledge-age companies can be managed through the range of statutory or common law provisions, including patent, trademark or design registration or by copyright, circuit layout and other rights. Where similar or substitutable products use commonly available design, material or production knowledge and do not possess the novelty or inventiveness required for the protection of any IP by patent, such products and designs may be protected by design or trademark registration.

With some knowledge-age products and particularly with software the high cost, the complexity of the patent process and the need for up to 20 years of IP protection is eschewed, and instead these firms adopt a *trade-secret* process including nondisclosure or confidentiality agreements and employment contracts to manage their IP during the comparatively short period of the expected life of the IP in the product.

The ability to protect and manage IP assets provides two important benefits to knowledge-age firms. First, firms are encouraged to research technology concepts and to protect the resultant IP and to develop new technologies into products and services, or to licence the rights to others who will exploit the technology with the knowledge that the IP can be protected through to the profitable exploitation of the technology in a product or service.

Second, a manufacturer incorporating protected IP in a product can expect to recoup all or a proportion of the significant levels of funds placed at risk by their investment in research and development of the protected technology and the design of new and innovative technologies and products.

Patents and other available statutory and common law provisions apply only to *codified* knowledge, but a significant volume of the intellectual capital of a knowledge-age firm is the *tacit* knowledge of its owners and individual employees and since it cannot be physically secured it is difficult to control. Employee mobility in knowledge-age industries including the electronics industry is relatively high, and particularly high in the electronics clusters in some of the regions included in this study. In these regions the unauthorised and uncontrolled circulation of knowledge and particularly tacit knowledge is relatively common, (Rogers, 1983).

While the circulation of IP and other company information would be considered undesirable by business owners, some positive benefits from informal information circulation have been reported, particularly in the world's largest electronics cluster in Silicon Valley (Saxenian, 1994). This paradox, which is an important characteristic of the electronics industry, is discussed in Chapter 4.

The economic value of IP in manufacturing and particularly electronics manufacturing is illustrated by a report (BankBoston, 1997) on the performance of high technology businesses established by alumni and faculty of the Massachusetts Institute of Technology (MIT, hereafter). In 1996 there were 4,000 such MIT related firms which produced US$232 billion annual revenue and employed over one million people worldwide. Almost 60 per cent of these firms were electronics manufacturers, the remainder were engaged in the biotechnology, software, medical or engineering fields. This report is discussed in Chapter 4. in section 4.4.1 headed Boston.

With the exclusivity of the IP and its protection secured by its owners, knowledge-age products with superior or unique performance can be sold at premium prices which can be a significant multiple of the tangible input costs (Shapiro and Varian, 1999; Mohr, 2001). Conversely, with industrial-age products developed from commonly available design, material and process knowledge - so that operational exclusivity or functional superiority is rare - competition is often based on incremental differences in product features or performance (Porter, 1998b).

Where such products are produced in high volumes, competition typically relies on cost differentials in production methods, economies of scale or material and labour costs (Kotler, 1997; McNally et al, 2010). Where competitors have access to the materials, labour and production facilities and design information to produce an undifferentiated, competitive product, and where there is no restriction on the use of design and manufacturing knowledge, the selling price achievable by all manufacturers will tend to be regulated by lowest cost producer. While it is defined as *intangible*, IP is a highly valuable asset of knowledge-age companies. IP can be the most valuable asset of a biotechnology, software or electronics company and their IP is frequently more valuable than their *tangible* assets. But, this high value is usually not evident in financial records which are produced for purpose of compliance with government regulations and tax laws. The value of IP is unfortunately not well understood or highly regarded by financial institutions or investors in some economies.

The Economist (2005) estimated that up to 75 per cent of the value of USA public companies in 2005 was based on their IP, up from 40 per cent in 1980. Knowledge-age industry provides an ever widening range of previously unimagined products which improve the lives of people across nations. These IP-based products and services generate new opportunities for wealth and employment creation (Savage, 1990) and for the development of the modern '*knowledge economy',* the term used by Drucker (1968) and attributed by him to Machlup (1962).

1.8 The Evolution of Electronics as a Technology and as an Industry

The foundations of electronics technology were laid in the early nineteenth century through a slow and discontinuous process with individual contributions of many scientists and experimenters scattered around the globe, working independently. In 1820 Danish scientist Hans Oersted established the link between electric current and magnetism (Wilson, 2008; Brain et al, 2007) and the phenomenon of electromagnetic induction was demonstrated in 1821 by English physicist Michael Faraday (Cobb, 2009). Maxwell's theory of the existence of radio waves (Maxwell, 1865) was confirmed in 1884 by Hertz (Mulligan, 1989). In 1897 Cambridge Professor John Joseph Thomson discovered the sub-atomic particle later named the 'electron' which confirmed the theories of their existence of Maxwell (Falconer, 1987; Navarro, 2006). Marconi demonstrated the commercial potential of the technology by the transmission of wireless telegraph signals across the English Channel in 1899 (Hong, 1996; Bowers, 2004) and across the Atlantic Ocean in 1901 (Weightman, 2003).

The two element thermionic diode was patented by Fleming in 1904 (Bowers, 2004), and the three element triode was patented in 1908 by De Forest (Brittain, 2005; Ganssle, 2006). These two critically important developments, in which electrons flow unidirectionally in a vacuum, led to the name of the technology as 'electronics' (Bowers, 2004).

Wireless communication for civilian and military use and radio for information and entertainment were the first commercial applications of the new technology in the early twentieth century (Juniper, 2004). Porter (1990b:197) states *"... the rapid development of electronics during the war for purposes such as radar led to a boom after the war in many electronics-related industries."* Radar and digital computers were developed during the Second World War and television broadcasting was established in USA, Canada, UK, Continental Europe and Australia by the mid twentieth century.

A major development of the modern electronics industry was the first semiconductor, the transistor in 1947 (Riordan, 2007). New semiconductor developments followed quickly; the silicon transistor in 1954 (Chelikowski, 2004; Lecuyer, 2007) and the integrated circuit (IC, hereafter) in 1958 (Goodwin, 1989). In 1961 the monolithic silicon IC was developed at Fairchild Semiconductor by Robert Noyce, who later co-founded Intel (Berlin, 2005). Semiconductors changed the trajectory of the electronics industry and, over time, improved most other industries which now rely on electronic systems or on electronics as an enabling technology. Compared to electron tube-based products, transistor-based products consume a fraction of the power, produce a fraction of the heat and are a fraction of their size and weight allowing battery operation and total portability.

The USA Apollo Moon Landing Project announced in 1961 required on-board electronic navigation, communications and computing systems of small size, low weight, low power consumption and low heat dissipation to operate in a hostile temperature and vibration environment. To meet these stringent requirements the electronics industry developed a totally new range of microelectronic components and systems.

The first commercial microprocessor was released by Intel in 1971 and today industry, defence, government and our communities enjoy the benefits of the amazing array of microprocessor and microelectronic enabled commercial, professional and consumer products including computers, mobile phones, satellites and the vast range of services enabled by electronic systems that enhance our modern way of life. These microelectronics-based products that now underpin our civilisation are the long-lasting community dividend from the Apollo Project.

1.9 The Global Electronics Industry

The revenue of the global electronics industry was US$2.172 trillion in 2012 (Custer, 2013). As an indication of the scale of this industry, global electronics industry revenue was greater than the revenue from global automotive manufacturing in 2011 and greater than the total revenue of all manufacturing in USA in 2011 (United Nations, 2012).

The global electronics industry is comprised of thousands of businesses spread across developed and developing countries (Sturgeon and Kawakami, 2010). These firms are engaged in the design and production of products, components and sub-assemblies and some of these *intermediate goods* are transported across borders before finished goods are assembled and shipped to final markets (Feenstra, 1998; Brülhart, 2008). Table 1.1 below shows that the value of intermediate goods movements by the global electronics industry and the global automotive industry.

Table 1.1: Global Trade in Manufactured Intermediate Goods (MIG) (1988 and 2006)

Industry	**1988** MIG Trade US$ m	Global Share MIG Trade %	**2006** MIG Trade US$ m	Global Share MIG Trade %	Annual MIG Growth %
Electronics	162,980	8.1	1,670,940	17.4	13.8
Automotive	167,506	8.3	824,392	8.6	9.3

Source: World Bank Global Electronics Industry-Value-chains Report (Sturgeon and Kawakami, 2010)

The value of electronic intermediate goods was similar to that of the global automotive industry in 1988, but by 2006 the value of global electronics intermediate goods shipments was more than double that of the intermediate goods shipments of the automotive industry.

1.10 Two Electronics Industry Sectors

The global electronics industry operates in two distinct sectors which manufacture products for two separate markets. The differentiators of the two sectors include their products and the application of their products, the scope and the scale of their operation, the place of product design and the place of product manufacture.

1.10.1 The Consumer Electronics Industry

The first of the two electronics industry sectors considered here is generally known as the *consumer electronics* sector and its ubiquitous products are widely recognised. This sector mass-produces large quantities of standardised electronic products which are seen and used regularly in communities worldwide and which are sold in retail stores or online mainly for household and personal use. Examples of consumer electronic products include television, radio, digital cameras, games and entertainment systems, household and mobile computing and personal communications products. Consumer electronics products are sold under widely recognised global brand names, including Apple, Nokia and Sony.

The large multinational companies engaged in this sector typically research, develop and design their consumer electronic products, in developed countries which have traditionally been the major markets for these mass-produced products. The assembly of high-volumes of consumer electronic products; computers, phones, entertainment and household items has largely moved from the high labour cost countries including USA, Japan, Europe and Australia to subsidiaries or contract manufacturers in low labour cost countries, typically in Asia (Shin et al, 2009).

1.10.2 The High Technology Electronics Industry

The second sector of the electronics industry considered is described here as the HTEI, the *high technology electronics industry*. This sector is also described as the '*electronics applications'* sector (Arthur D Little, 1992) and is known, particularly in USA as the '*electronic hardware'* sector (Sturgeon and Kawakami, 2010). The definition from the *Electronics Industry Action Agenda* and is adopted in this thesis:

> *"The group of companies which design, produce, service, install and distribute products and systems made from electronic components and which may contain embedded and loaded software to provide an operational device or network. It also includes companies that provide services to support the production of electronic components.*" (EIAA, 2003).

The HTEI sector designs and manufactures relatively small volumes of highly specialised, complex, often customised, high value-added, IP-based electronic products and systems. Products of the HTEI sector include equipment and systems for avionics, data processing, telecommunications, business, industry, medical, automotive, defence, environment, education, research and scientific applications.

Counter-intuitively, the lesser-known HTEI sector generates substantially more revenue and employs substantially more people than the ubiquitous consumer electronics sector. More than 86 per cent of the US$2.172 trillion global electronics industry revenue in 2012 (Custer, 2013) was produced by the relatively unseen HTEI sector, while less than 14 per cent of the revenue of the global electronics industry was produced by the consumer electronics sector (Custer, 2013).

The iceberg analogy may be applied here; the mass-market, consumer electronics sector is the smaller, visible part while the high technology sector of the electronics industry is the substantially larger, but unseen sector.

While Breheny and McQuaid (1978) and Oakey (1995) queried the validity of the term '*high-technology'* the economic value of the global HTEI has developed substantially in the decades since these contributions and the more precise definition of the HTEI discussed above in this section (EIAA, 2003) is applicable to the sector studied in this thesis, rather than the broader and less definitive *'high technology'* term.

The global HTEI sector includes large MNC's and some of these make products for both the HTEI and the consumer electronics sector, including Hewlett Packard, Toshiba and Philips. However, the vast majority of global HTEI employment and wealth is generated by its many thousands of typically privately owned and locally managed, small and medium enterprises (SME's, hereafter). These firms are known to people within the HTEI and particularly to the worldwide users of their products. But, since these HTEI products are not sold in retail stores or advertised in the public media and because the general community has limited contact with HTEI products the names of the firms and their products are relatively unknown even in the communities where their products are designed and manufactured and, despite the relatively large proportion of people employed in HTEI cluster firms in some of these communities.

As with the consumer electronics sector, the research, development and design of HTEI products is typically undertaken in developed countries which are still the major markets for HTEI products.

However, unlike the consumer electronics sector, which typically assembles its products in low labour cost countries; most of the manufacturing of the smaller quantities of highly specialised and customised HTEI products is undertaken in developed countries. The better control of the manufacturing of the complex products and the security of the IP are major factors in the retention of HTEI production in the country of their designer firms.

While competition drives the high-volume, consumer electronics sector to reduce production costs by moving to low labour cost countries these pressures are not dominant in the HTEI sector which typically sells its products at significantly higher margins, based on the exclusivity of the IP employed in the design and manufacture of the product, therefore, the higher cost of assembly labour in developed countries is not disadvantageous.

Designers of electronics products do not usually produce their own components, but are reliant on the makers of their essential parts, particularly microprocessors and memory *chips*, but these components are also available to competitors. The release of new components, such as faster microprocessors or high capacity memory devices can enable an unknown competitor to launch a superior product, based on the higher performance components.

Both the consumer sector and the HTEI sector of the electronics industry employ large numbers of engineers and scientists with similar training and skills who incorporate many of the same science-based technologies in their product designs. Both sectors use many of the same material inputs, components and similar manufacturing processes to produce vastly different products in vastly different quantities for their disparate applications.

Most of the design and development in both the high volume consumer electronics sector and low volume HTEI sector is undertaken in many of the same developed countries, so the bidirectional flow of information and tacit knowledge resulting from employee movement and between the sectors is highly beneficial to both sectors (Saxenian, 1994).

The HTEI invests a higher proportion of its revenue in research and development, than in most other industries, which is a desirable attribute, however, Oakey (1995:3) warns against the use of this metric as *"surrogate for high-technology growth."*

High value-adding, high research and development (R&D, hereafter) intensity and highly-paid employees illustrate the economic and community value of the HTEI. Another desirable characteristic of the HTEI is the considerable proportion of their production which is exported to developed and developing countries.

1.11 Focus on High Technology Electronics Industry Clusters

This thesis is concerned with only one of the two electronics industry sectors discussed above; the relatively unrecognised HTEI which is characterised by the high technology, low volume and the high value-adding of this electronics design and manufacturing sector. The focus of the thesis is not primarily on the industry itself or its technology or its products, but on the phenomenon of the emergence and development of HTEI firms that have coalesced endogenously into dense, self-organised clusters in a limited number of relatively small and comparatively isolated second tier regions in developed countries. These dense clusters are not evenly distributed across nations; indeed most second tier cities in developed countries do not have dense HTEI clusters (Romanelli and Feldman, 2006). However, the most successful HTEI clusters with the highest density appear to be not located in the large primate cities, but in a few relatively small, pleasant and comparatively isolated second tier cities.

Klepper (2001, 2009a) and Sporck (2001) discuss entrepreneurial spinoffs as a factor in the rapid evolution of a sector of the HTEI, semiconductors in Silicon Valley. Spin-offs in other industries are analysed (Klepper, 2006). Xerox has been a source of numerous Silicon Valley spinoff firms (Chesbrough and Rosenbloom, 2002) and the BankBoston Report (1997), discussed earlier shows the economic value of MIT spinoff firms. Data on the origin and development of HTEI firms and clusters in these and other selected regions will be analysed in Chapter 4. Bresnahan et al (2001) identify sources of cluster success as managerial capability, skilled labour supply and connection to markets by HTEI firms in regions that are also included in this thesis, including Silicon Valley, Cambridge and Ireland. Interviews and data collection are discussed in this paper, but no data are provided.

The life cycle of clusters is well researched in USA, UK and EU (Martin and Sunley, 2003, 2011; Menzel and Fornahl, 2011). A link between industry life cycle and geographic proximity is identified by Audretsch and Feldman (1996b) who note the propensity for innovative activities to cluster geographically and to be shaped by the stage of the industry life cycle. The theory of knowledge spillovers suggests that geographic proximity matters the most where tacit knowledge generates innovative activity (Audretsch and Feldman, 1996b). Martin and Sunley (2011) also propose that an alternative to the preferred approach to the idea of a cluster 'life cycle' is an 'adaptive cycle' model that has been developed in evolutionary ecology. Knowledge of these characteristics in the HTEI clusters in the well-researched regions will assist in the understanding of the origin and development of HTEI firms and their clustering in the relatively unknown regions selected for this research.

1.12 Characteristics of the High Technology Electronics Industry

Firms in the HTEI sector possess these four essential characteristics of a high technology industry (Rogers and Larsen 1984:29):

> *1. Highly skilled employees, many of whom are scientists or engineers;*
> *2. A fast rate of growth;*
> *3. A high ratio of R&D expenditures to sales; and*
> *4. A worldwide market for its products*

A World Bank Policy Research Paper, referring to the HTEI sector states: "*The electronics hardware industry is the world's most important goods-producing sector"* (Sturgeon and Kawakami, 2010:2) and quotes Mann and Kirkegaard (2006) that it employs more people and generates greater global revenue than any other industry and its products enhance productivity in other sectors and stimulate innovation across entire economies.

A characteristic of the electronics industry is its departure from the *classic economics* concept of providing products to address a gap in a market, described as *"an opportunity for supplying a new commodity that will meet a real want"* (Marshall, 1890:297). Rather than focussing on existing, but unsatisfied markets, HTEI firms often *create* new markets by producing products based on the designer's ability to visualise and research the *latent* demand for a new class or type of product or service that will become an *actual* demand when the product is revealed (Jolly, 1997).

The products of the HTEI consist of electronic components, which are interconnected in *circuits* and typically integrated with dedicated, pre-installed and *embedded* software. This integrated hardware and software configuration produces a high-technology electronic *system* typically for the control of other processes or systems, including electrical or mechanical devices or for the management of data and information. The embedded software manages the operation of the typically microprocessor-based hardware and the relationship between the hardware and its embedded software is one of total interdependence; neither can operate without the other; the hardware and software are sold as an integrated system and neither can function in isolation.

The software which is embedded in high technology electronic systems is created by the hardware designer or design team as an integral task in the product design process and the embedded software is specific to the hardware for which it is designed. This embedded software is unseen by the user of the system and it is inaccessible to the user and, most importantly, the embedded software is not available for sale separately.

The embedded software is a key factor in the performance of the system and its security is carefully guarded by the owners of its IP. While the embedded software described here is delivered, pre-installed and supplied as an integral part of the electronic hardware product, that software is an integral part of the HTEI sector and included in this research. It is emphasised that software that is sold as a discrete product is not included in the HTEI sector, but is included in the *software industry,* discussed below in Section 1.13.2

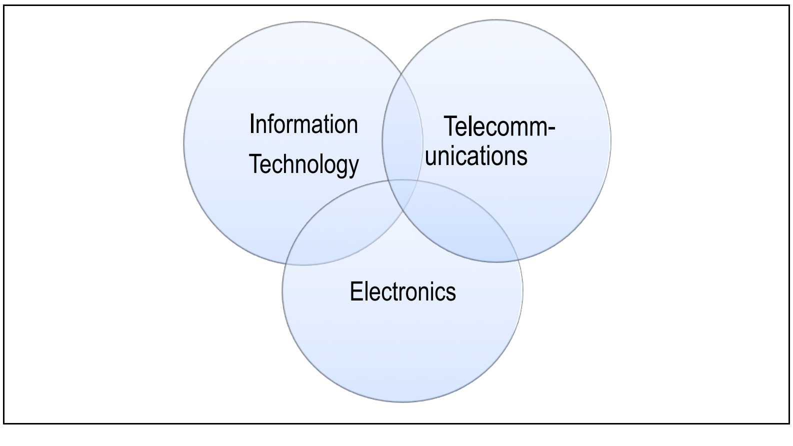
1.13 Demarcation of the Research Area

The discussion above establishes the distinction between the consumer sector and the HTEI sector of the electronics industry and differentiates the software that is embedded in HTEI products from software that is sold as a product. A further delineation of the context of this research first requires the introduction of a relatively new and overarching concept which incorporates three industry sub-sectors.

1.13.1 Information and Communication Technology

While the HTEI studied here is a large, well established and autonomous industry that designs, manufactures and markets its own products, the HTEI is also considered, typically by governments to be part of the larger *information and communications technology* (ICT, hereafter) sector. The ICT concept (Stevenson, 1997) is widely used in continental Europe, (OECD, 2002) and in USA, UK and Australia.

Figure 1.2: The Interdependent Relationship of the Three Elements of the ICT Sector



The ICT concept incorporates three separate technologies; electronics, information technology (IT, hereafter) and telecommunications. All ICT applications rely on electronics. Typical ICT applications include data transmission and storage, email and the Internet. Figure 1.2 below illustrates the interdependent relationships in the ICT sector. It is noted that not all electronic devices and not all electronic technologies are involved in ICT. Non-ICT applications of electronics include medical, industrial, automotive and some military equipment and all applications where no *external communication* of information or data occurs. The ICT concept now generally replaces the former descriptor of *Information Technology and Telecommunications.* While electronics, IT and telecommunications are separate industries, each with their own research, development, products, services and markets, each is also dependent to a degree on its relationship with the other two sectors and both the IT and telecommunications sectors are significantly dependant on electronics technology, products and systems.

1.13.2 The Software Industry

Software is defined as: *"programs and other operating information used by a computer"* (Oxford, 2008). The software industry that creates and sells software as a discrete product, is part of the IT sector and is not included in this research.

Software industry firms produce programs including operating systems and application programs for business, government, education, entertainment, communications, scientific and other applications. These software programs operate on compatible electronic hardware systems, including computers which are typically produced by firms considered to be not part of the software industry. Software producers include Microsoft, Symantec and Adobe.

1.13.3 The Electrical Industry

This research is not concerned with the *electrical* industry, but the distinction between the electrical industry and the electronics industry is important. This distinction is often not well understood by people not involved in the industry, even in communities where large clusters of electronics firms are established.

The electrical industry generates, distributes and controls the use of electrical energy, at one fixed frequency and at significantly higher current and voltages levels than those used in the electronics industry. Electrical energy is supplied by cables to domestic, industrial and commercial users at voltages in the order of one hundred to four hundred volts. Electrical energy is distributed over long-distances and to high demand users at higher voltages, up to hundreds of kilovolts. In sharp contrast, electronic systems operate at low voltages - in the order of microvolts to a few volts and at low current levels - in the order of microamps to milliamps and, importantly over a wide range of frequencies - from sub-audio to terahertz and beyond. Electronic systems consume relatively small amounts of electrical energy and many are powered by self-contained, replaceable or rechargeable batteries.

1.14 The Research Problem

Electronics industry clusters are extensively researched in many northern hemisphere regions, particularly in USA, UK EU. Parameters including structure, growth and development characteristics of the HTEI clusters in Silicon Valley, Cambridge, Austin, Ireland, Scotland and Singapore are extensively researched. Their economic and social value is regularly measured and is well-known to their communities and to regional and national governments.

Data from these six regions and nations shows resilient growth of HTEI employment over time. However, the HTEI in other developed countries is less studied, but the limited available data shows that Christchurch has a significant proportion of New Zealand's HTEI employment (Saunders and Dalziel, 2003) while incomplete data from Australia shows that Adelaide has an unusually high proportion of national HTEI employment (TIA, 2012).

Both Adelaide and Christchurch are relatively small cities and both are relatively remote from their major national populations. Both are second tier cities, yet both have a cluster with the highest proportion of their national HTEI employment. These regions are prime candidates for a study of their HTEI, particularly since these regions are relatively unrecognised by their regional and national governments and their local communities.

The research problem is distilled into three research questions:

1. *Why* did HTEI firms emerge and cluster in 'second tier' regions?
2. *How* have endogenous HTEI clusters developed in these regions?
3. *What* variations exist between the HTEI clusters in regions that emerged endogenously and those created by government action?

1.15 The Value of the Research

In the high wage economies of developed nations both revenue and employment from industrial-age manufacturing are declining as these activities move to low wage locations. However, manufacturing remains important to all economies for its value-adding to the material and labour inputs to its products.

Manufacturing is important to developed economies and particularly where high value is added through the creation of knowledge-age products and services. The future for high-wage economies will be enhanced by a planned transition from their dependence on industrial-age manufacturing to knowledge-age industry.

Clusters are critical drivers of regional economic development (Porter, 1998c) and of employment (Florida, 2002), particularly in knowledge-age industries. Successful knowledge-age clusters generate high incomes and high rates of wealth and employment growth (Spencer et al, 2010) and successful clusters benefit other industries in their region (Delgado and Porter, 2012). It is known that successful electronics clusters emerged endogenously and were already well established before the phenomenon was recognised by their communities or governments (Levi, 1980) and before the cluster concept was described (Porter, 1990a).

While the structure, characteristics, and performance of clusters have been widely researched, knowledge of their origin is incomplete (Braunerhjelm and Feldman, 2006; Fornahl et al, 2010; Mayer, 2011**).** The origin of HTEI clusters is discussed in section 2.5.3.

Through case studies this thesis seeks to interpret the phenomenon of the emergence and development HTEI firms and dense electronics clusters in selected cities and to provide new knowledge on the origin and development of HTEI clusters in second tier regions. This knowledge may inform the creation of policies and programs to facilitate the transition from a dependence on industrial-age manufacturing to knowledge-age HTEI manufacturing in the selected regions. This knowledge may also contribute to the creation of industry and government policies and programs to facilitate the sustainability of HTEI clusters in the selected regions and possibly also in other regions and other industries.

Knowledge-age manufacturing and particularly HTEI manufacturing is frequently under-reported in government data, therefore the economic and social value of these industries is underestimated by regional governments and communities. The critical role of the HTEI as a wealth and employment generator and in the transition from a reliance on industrial-age to knowledge-age industry is therefore underestimated and consequently, undervalued.

The problem of the low recognition of the value of knowledge-age manufacturing was highlighted by Professor Goran Roos in his '*Adelaide Thinker in Residence'* Lecture in Adelaide on 7 February, 2012 (Roos, 2012). Professor Roos stated that although Australian Government data show that manufacturing produced approximately 10 per cent of Australia's Gross Domestic Product (GDP, hereafter), the real figure could be closer to 40 per cent if all purchased inputs to the manufacturing process are included as part of the manufacturing process, and not measured as they are frequently as *services.* The recognition by governments and communities of the real contribution of 'knowledge-age' industry is restricted by these statistical systems that cannot identify or measure its economic value.

1.16 Contribution to Knowledge

The thesis will provide a quantitative and a qualitative interpretation of the origin and development of HTEI firms and their coalescence into clusters in selected regions which aims to contribute to the theory of technology industry and cluster development. The data on which these interpretations will be developed will be obtained, where available from government and industry sources and augmented by surveys and personal interviews in selected regions as discussed in Chapter 3 and reported in Chapter 4.

The thesis seeks to interpret the emergence and development of dense electronics clusters in selected, relatively small and relatively isolated regions. It provides new data, information, insights and interpretation of the phenomenon of the endogenous emergence and development of successful HTEI clusters in second tier regions and confirms and extends recent findings of endogenous cluster development in USA second tier regions. An addition to the general theory of cluster development is advanced, particularly in second tier regions.

1.17 Outline of the Thesis

The motivation and the premises on which the thesis is based and its objectives are outlined and the development of electronic technologies and the emergence of the electronics industry are discussed. The abundant literature is reviewed, particularly, the development of clusters in USA, UK and EU in relatively small cities that are also relatively isolated from their major national populations. The literature and surveys assist the understanding of endogenous cluster evolution in these well-researched regions and guide the interpretation of the research in less-researched regions in Australia and New Zealand.

The limited literature on the development of dense HTEI clusters in New Zealand and the sparse literature on the Australian HTEI are reviewed and the gaps in the available data and information on these regions have informed the development of appropriate surveys.

Five HTEI cluster regions are selected for the principal case study, based on the high proportion of HTEI employment in those regions when compared with the proportion of employment in the same industry in their host nation.

Each of the five cities selected has a relatively small proportion of its national population; each is relatively remote from major national populations and each has their nation's highest proportion of HTEI employment. Two of the five selected HTEI clusters in the principal case study are located in USA and one is located in each of the UK, Australia and New Zealand.

Five generally larger cities are included in a second case study and the endogenous development of these regional clusters will be compared with the clusters in the principal case study. These case studies assist the resolution of the first two research questions.

A third case study includes eight cities in which government policies and programs have been implemented to *create* clusters of electronics firms.

Findings from the three case studies assist the understanding of the variations between the endogenous clusters in the first two case studies and the created clusters in the third case study. The new knowledge will assist with the resolution of the third research question. The methodology adopted for the selection of the HTEI cluster cities is discussed and the extensive interview process is described in Chapter 3.

Available HTEI data from government and industry sources are analysed and augmented by the results of surveys and personal interviews with HTEI representatives. The HTEI clusters in selected regions are analysed and an addition to the theories of the origin and development of HTEI firms clustered in second tier regions is advanced.

Conclusions on the origin and development of HTEI firms clustered in the selected regions are presented and further directions for the research are proposed.

1.18 Chapter Summary

Electronics as a technology and the electronics industry are fundamental to the maintenance and development of our current civilisation. Electronics is now the largest global revenue and employment generating industry. Traditional industrial-age manufacturing and high volume consumer goods manufacturing tended to follow the pattern of the Industrial Revolution by aggregating in large cities. Counter-intuitively the HTEI has formed into dense clusters that have emerged endogenously and developed over decades through self-organisation in a limited number of small, pleasant and relatively remote regions.

This low-volume, high technology, IP-based industry thrives in developed nations where it leads the transition from industrial-age manufacturing to a new future through knowledge-age industry.

Selected HTEI clusters are examined to understand the origin of the firms and the endogenous emergence and development of their clusters. Variations are studied between these endogenous clusters and those *created* more recently by government policies.

New knowledge will be available to inform the development of government policies and industry programs to facilitate the sustainable future of these clusters and may encourage further research on cluster emergence and development.

The following chapter reviews the extant literature generally on clusters, cluster origin and clustering and particularly in second tier cities and in the HTEI sector of the global electronics industry. Understanding of the literature and particularly the origin and well-researched development of HTEI clusters in Silicon Valley, Cambridge and Austin will assist development of the empirical phase of this research by providing the separate contexts in which these clusters developed. This understanding will inform the further stages of this work.

Chapter 2: Literature Review

2.1 Introduction

In this chapter the extant literature on cluster origin and development is reviewed to understand what is known and what must be established by empirical methods in the selected regions to address the three research questions raised in the previous chapter. Those three questions are restated:

1. *Why* did HTEI firms cluster in the selected regions?
2. *How* have HTEI clusters developed in the selected regions?
3. *What* variations exist between the HTEI clusters in the regions that emerged endogenously and those created by government action?

The influences, processes and outcomes of the coalescence of firms and particularly HTEI firms in clusters are reviewed and areas of incomplete knowledge are identified for further study in specific regions. The review commences with the start-up of the individual firms that may later merge their interests with others to form HTEI clusters.

2.2 Creation of New Firms

Entrepreneurs as they create and pursue opportunities can be the drivers of the extraordinary wealth creation (Timmons and Spinelli, 2004). Where do these entrepreneurs come from? Klepper (2001) notes that many spinoff entrepreneurs come from incumbent firms in the same industry. Motivation for new firm start-ups include the lure of potential wealth (Schumpeter, 1908) or recognition as a successful entrepreneur (Ernst and Young, 2012). Job creation or self-employment are reported as motivators of *'the entrepreneurship event'* (Shapero, 1984). While systematic knowledge of how entrepreneurs start and grow businesses is limited (Bhide, 2000), the importance of spinoffs in exploiting the skills of their founders acquired in their prior employment is reported (Klepper, 2001; 2009c).

The start-up drivers of new firms can be positive or negative. The positive motivators or '*pull'* factors attract those with an idea or a technology for a business or a new or improved product, process or service, including those who may be employed but are drawn to the challenge of the creation of a new venture.

The negative factors '*push'* those who are unemployed (Caliendo and Kritikos, 2010), or employed but dissatisfied (Block and Koellinger, 2009) or those who face corporate downsizing (Mayer, 2011), or the possibility of unemployment (Feldman, 2001). Unstable corporate conditions and restructuring are a major *'push'* factor (Atherton, 2003). These negative factors '*push'* people to build their own future through self-employment.

2.3 Creation of New Technology-Based Firms

These same '*push'* or' *pull'* start-up drivers also influence individuals or groups to create *new technology-based* firms (NTB, hereafter) firms around new or improved technologies (De Silva and McComb, 2012; BarNir, 2012). The task in these enterprises is to move the idea *'from mind to market'* (Jolly, 1997).

The capability and success drive of entrepreneurs are important and can be more important than a novel idea or a new technology; "*never underestimate the role of passion"* (Preston, 2003:16). The belief of the entrepreneur in the business concept or the technological *idea* and the desire to develop it to a commercially sustainable level provides a powerful motivation (Del Giudice and Straub, 2011) and *"the passionate behaviour of the founders"* is a key determinate in high tech start-up success (Preston, 2003).

Until the mid-twentieth century most manufacturing wealth was created by large and typically vertically integrated companies which focussed on efficient production of high volumes of standardised products. However, through the 1980s and 1990s the USA Department of Commerce found that half of all innovation and 95 per cent of all radical innovation came from small USA firms and that most current innovation was based around technologies (Timmons and Spinelli, 2004). High technology industry growth is four times faster than the overall economy (DeVol, 1999).

NTB firms are founded on a range of technologies including electronics and other branches of engineering and science including the physical and biological sciences. Oakey (1995:18) found that 49 per cent of 43 biotechnology start-up entrepreneurs came from higher education or government establishments while only one of his sample of 44 electronics start-ups came from the public sector.

Oakey found that the *"established nature"* of the electronics industry contrasts with the "*comparatively new"* biotechnology industry with less established firms. Oakey also found that '*product exploitation'* was the reason for new firm formation in 41 per cent of his sample of 71 NTB start-ups and '*freedom'* was the motivation in 34 per cent of these start-up entrepreneurs, with some significant regional variations.

A UK survey (DTI, 1994), reveals that high technology organisations (HTO's hereafter) have a success rate of 70-80 per cent compared to 35 per cent for all other start-up organizations. The products of HTO's are electronics, information technology, computers, bio-pharmaceuticals and future energy. (Baruch,1997).

The success rate of NTB firms was also reported as higher than for non-technology based firms in a study of more than 9,600 West German firms showing that NTB firms achieved higher growth rates than non-innovative firms and the net employment effect of those NTB firms was positive, but this does not hold for non-innovative young firms, where employment decreased over the same 6 year period (Almus and Nerlinger, 1999).

A study of 250 NTB firms founded between 1960 and 1969 on the San Francisco Peninsular (including Silicon Valley) shows that by 1976 the median firm in the study was seven years old and 49.6 per cent of these continued as independent firms and 21.2 per cent had been acquired while 29.2 per cent had been discontinued. While two thirds of all USA firms in these surveys failed in four years, two thirds of NTB firms survived 7 or more years (Cooper and Bruno, 1977). However, a study of 11,000 firms (Audretsch, 1991) shows that their survival in the ten years 1976 to 1986 was relatively independent of the technology-base of the firm. Taken together these four studies suggest that the probability of success of NTB firms is at least equal to or higher than non-technology firms.

2.4 Creation of High Technology Electronics Industry Firms

New HTEI firms are a sub-set of NTB firms. Motivating factors for HTEI start-ups include entrepreneurial opportunities based on new technologies (De Silva and McComb, 2012; BarNir, 2012) and spin-out firms created by former company employees are a major factor in the development of the HTEI (Mayer, 2011). Oakey (1995:18) found that 82 per cent of his survey of 44 UK electronics firms had *"spun-off"* from other pre-existing electronics enterprises. Motivations for the creation of new HTEI firms also include, job creation, fame, self-employment and financial reward. However, a strong motivating factor reported in HTEI start-ups is not fortune, fame, employment or altruism, but the determination of the HTEI start-up entrepreneur to see their technology *idea* developed and successfully implemented. Belief in the technology as a major driver in HTEI start-up firms is reported in Cambridge (Cattermole and Wolfe, 1987), in Christchurch (Green, 2005), in Silicon Valley (Berlin, 2005), in Austin (Smilor et al, 1989) and expressed as "*the desire to work at the technological frontier"* (Baron and Hannon, 2002:10).

Robert Noyce who developed the monolithic silicon IC in 1961 at Fairchild and co-founded Intel Corporation in 1968 was motivated by the '*pull'* factor; his belief in the technology, but he was not particularly interested in creating wealth (Berlin, 2005). These two factors; a belief in the technology and ambivalence on the issue of wealth while uncommon in the HTEI in the USA are measured in more than 200 founders of HTEI firms interviewed in six cities in Australia and New Zealand and discussed in Chapter 4.

Noyce was also motivated by the '*push*' factor; dissatisfaction at Fairchild, which he had co-founded after leaving employment at Shockley Semiconductor Laboratory where he was dissatisfied with the management style of the founder William Shockley (Lecuyer, 2007). The *'push'* factor had twice impelled him to leave a company. first to find an alternative workplace and later to create his own.

University faculty are also motivated by *'pull'* factors to leave secure employment to create new start-up firms to exploit technologies they have developed (Utterback, 1994), which can raise IP ownership issues (Klepper, 2001). Purchase or licencing of publicly funded technologies can be facilitated by the Bayh-Dole Act in USA (Siegel et al, 2007; Aldridge and Audretsch, 2011). Similar legislation applies in Europe (OECD, 2003) and in Australia IP is accessed by negotiation (McBratney and Tarr, 2010).

Initial funding of small HTEI start-up businesses is typically provided by the engineer or scientist turned entrepreneur from their own savings or credit cards (Elston and Audretsch, 2009) and *bootstrapping* [1] is a common practice (Nesheim, 2000). The start-up literature also identifies *friends, family or fools* as sources of start-up funding (Kotha and George, 2012). *Business Angels* [2] typically provide both funding and business advice (Mason and Harrison (2004), while venture capital (VC, hereafter) and government funding are available in some economies to technology start-ups (Feldman and Kelly, 2002).

Silicon Valley start-ups have, since the late 1950s had access to increasing sources of VC funding and often at a relatively early stage of their development (Florida and Kenney, 1988). The VC industry was active in funding many of the semiconductor start-ups in Silicon Valley which flourished from the 1950s (Saxenian, 1994; Berlin, 2005). By the mid-1970s HTEI firms and VC firms each contributed to the success of the other in a "*virtuous circle"* (Kenney and Florida, 2000:99). Subsequent waves of start-ups have benefitted from the increasing availability of competitive venture funding and the management capability of VC firms in Silicon Valley (Hellmann, 2000).

While venture capital firms grew in number and in capability in Silicon Valley, from the 1950s these funds were less readily available in other parts of the USA. Virtually no venture funding was available in the Washington DC region until 1980 (Feldman, 2001). Availability of venture funding before 1980 for technology-based start-ups was also limited in the UK (Sweeting, 1991) and particularly in Cambridge until 1980 (Segal Quince, 1985).

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[1] Bootstrapping: Starting with existing resources to create something more complex and effective (Oxford, 2008).
[2] Business Angel: An investor in a business venture, especially one in its early stages (Collins, 2009).

While the literature on the early VC industry in the USA is extensive; on the UK it is less detailed and on Australia and New Zealand it is limited. VC was not readily available in Australia and New Zealand before the 1980s and by comparison with Silicon Valley, the Australian VC market is small and relatively underdeveloped (Cumming et al, 2009).

In the regions discussed above the strategies of the start-up firms are influenced by the availability of funding. Where venture funding is readily available as in Silicon Valley, HTEI start-up firms have tended to rely on these sources and as firms funded by VC succeed, the availability of venture funding tends to increase (Zider, 1998). In Australia it is usual to use VC to fund later growth and not for HTEI start-ups.

HTEI firms have been established to commercialise technologies developed by individuals or at commercial laboratories or universities and at publicly funded research institutions (Hayter, 2010). Such firms have been established in regions including Silicon Valley, Cambridge, Edinburgh, Austin, Christchurch and Adelaide and many of these firms are discussed in Chapter 4.

Examples include Hewlett Packard which was started in Palo Alto, California by two postgraduates from Stanford University (Malone, 2007); Cambridge Scientific Instruments, which was developed by a graduate of the University of Cambridge (Cattermole and Wolfe, 1987; Segal Quince, 1985) and Wolfson Microelectronics evolved from the University of Edinburgh (IEE, 2004). The very successful Tracor Corporation was formed in Austin, Texas in 1955 by three graduate scientists from the University of Texas at Austin (Kleiner, 1983; Smilor et al, 1989).

Codan, the largest locally owned Adelaide HTEI company was formed in 1959 by three graduate friends from the University of Adelaide (Wood, 2004; Codan, 2009, 2012). Tait Electronics was started in 1954 in Christchurch by a former Air Force communications officer and is the largest HTEI firm in the New Zealand electronics industry.

However, Angus Tait had no university training and the firm had no university involvement in its start-up (Green, 2005). Each of these companies has been pivotal in the development of the HTEI cluster in their region and their individual contributions are discussed in Chapter 4.

Factors including HTEI start-up motivation, location, technology source, markets and the influence of government and institutions will be measured through a process discussed in Chapter 3 and compared across a number of selected regions in Chapter 4.

2.5 Clusters: Definition and Description

The cluster definition adopted for this thesis shown in Chapter One (1.1) is restated here:

> *'Clusters are geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (e.g. universities, standards agencies, trade associations) in a particular field that compete but "also cooperate."* (Porter, 2000a:16)

This definition includes two characteristics that are particularly relevant to clusters of HTEI firms. First, the physical proximity and interconnectedness of the firms, research and industry organisations that facilitates knowledge exchange (Arikan, 2009) and particularly tacit knowledge exchange (Nuur, 2005). Second, competition and cooperation of cluster firms which act together to improve both firm and cluster performance (Porter, 2000a). However, this general definition does not include two salient characteristics that are important to HTEI clusters in small, second tier regions that are distant from major populations: the commitment of employees to the region (Markusen, 1999a) and the development of specialised regional labour markets (Bathelt and Taylor, 2002).

Two distinct processes of cluster origin and development recur in the literature and these two processes are widely separated in time. In the earlier process clusters typically emerged endogenously and developed through self-organisation and became self-sustaining over several decades, as described and defined by Porter (1999b). In the later process government bodies seek to 'create' clusters through policies that include firm attraction and development assistance programs. The 'created' cluster process and its application are discussed in Section 2.5.9.

2.5.1 Alternative Cluster Terminology

The term *cluster* has been widely used in the economic development literature since its use by Porter (1990b). But these aggregations have since been named *system areas* (Garofoli, 1991); *innovative milieu*, (Camagni, 1991); *regional clusters* (Enright, 1996); *industrial systems* (Malmberg, and Maskell, 1997); *technology districts* (Storper, 1997b); *innovative clusters* (Simmie and Sennet, 1999); *local innovation systems* (Cassiolato et al, 2003); *industrial clusters* (Morosini, 2004) and *localized systems of production* (Torre, 2006). This process is also described as a *'spontaneous or naturally occurring alliance configuration'* (Adobor, 2006).

These descriptors are used by these authors in various contexts, however, Porter's *cluster* term, defined above is widely accepted in the extant literature and is adopted for this thesis.

2.5.2 Endogenous Clusters

While the term cluster has been widely used since it was revived by Porter (1990a), the endogenous clusters operating today have two key characteristics observed by Adam Smith: geographic concentration of firms in the same industry (1776:125) and the circulation of industry information within these proximate groups (1776:59). Alfred Marshall observed: *"the concentration of large numbers of small businesses of a similar kind in the same locality"* (1890:277) which he named "*industrial districts"*. The linear relationship of the clusters of the twentieth and twenty-first century and Marshall's eighteenth and nineteenth century industrial districts is reported: *"The Marshallian industrial district represents the historical conceptual antecedent of most cluster studies"* (Giuliani, 2005:270).

Agglomeration of interdependent, industry-related, competitive and complementary firms, universities and industry organisations are prominent characteristics of clusters discussed in the growing regional economic development and industry cluster literature, particularly in the past two decades. However, geographic concentration of groups of humankind in related, cooperative and productive aggregations predates the recent cluster literature and the contributions of Adam Smith and Alfred Marshall.

During the '*Neolithic Revolution'* (Clark, 1969; Fagan, 1979) organised communities cultivated crops, domesticated animals and traded surpluses. The exchange of knowledge and the development of tools and technologies facilitated the making of useful items for consumption and specifically for trade (Diamond, 1997).

Concentrations of craftsmen with related and complementary skills emerged in Europe from the eleventh century and observation, analysis, mathematics and experimental testing of devices and theories contributed to the development of science (Clegg, 1979). The Norman smiths who immigrated in the eleventh century were described as "*the mechanical faculty of Lancashire"* (Marshall 1890:269), and by the seventeenth century craft workshops were established in England (Langton, 1984).

Marshall's observation that good ideas are *"taken up by others"* (1890:271) and Schumpeter's (1939) report that developments '*bunched'* together to produce rapid economic expansion, illustrate the collective dimension of clusters. Technological innovations cluster spatially and commercial breakthroughs often stem from long chains of inventions, rather than from a single revolutionary idea (Hall, 1998). Incremental and bunched development is particularly evident in the relatively short history of the development of HTEI clusters.

The same iterative characteristic is also present in contemporary clusters across many industries; as they move forward in time they tend to gather knowledge, momentum, cohesion and additional participants. "*The cluster of competitive industries becomes more than the sum of its parts. It has a tendency to expand as one competitive industry begets another.*" (Porter, 1990b:151).

Kamath et al (2012) state that Marshall (1890) provided the early foundations of modern cluster theory with his observations that mutual knowledge and trust reduces local transaction costs and the effect of skill and qualification transfer within a localised workforce. Together these promote innovation and the *'diffusion of innovations'* amongst firms in clusters (Rogers, 1983).

The endogenous cluster origin process is described in the literature as a *'bottom-up'* process (Parker, 2001; Atherton and Johnston, 2008). Doeringer and Terkla (1995) cite economic benefits from agglomeration observed in clusters including lower transportation and transaction costs and access to a skilled labour force. The availability of a skilled labour force is attractive to employers, which in turn creates more jobs, in a *"virtuous self-reinforcing circle"* improving the opportunities for employment in the industry and the region (Feldman, 2001:887). DeBresson and Hu (1999:27) note that Schumpeter (1912) introduced the term '*innovation clusters',* and the linear relationship of clusters and industrial districts is noted by Porter (2000a:16): "*Clusters have long been part of the economic landscape, with geographic concentrations of trades and companies in particular industries dating back for centuries.*" The cluster is a *"rediscovery of Marshall's ideas"* (Martin and Sunley, 2003:7). Industrial districts and industry clusters are not isolated cases *"but a general phenomenon of industrial organisation"* (Brenner, 2004:1).

A central characteristic that is shared by Porter's industry clusters and Marshall's industrial districts is their unplanned, endogenous origin and self-organised development. However, an important difference between Porter's clusters and Marshall's industrial districts is that Porter's definition includes universities, industry associations and standards agencies, which by 1990 were more important to industry, particularly to technology-based industry than in 1890. Apart from this evolutionary difference, the clusters of today have strong similarities to the industrial districts of the eighteenth and nineteenth centuries. The technologies, the manufacturing processes and the products have changed almost beyond recognition, but the agglomeration benefits that brought manufacturing firms, people and organisations together in Alfred Marshall's (1890) industrial districts remain as central characteristics of the industry clusters of today and particularly in the HTEI clusters selected for this research.

Clusters emerge in proximity to key network nodes or *"hubs"* (Cooke, 2010) and this characteristic is analysed in the clusters in two of the case studies reported in Chapter 4. Clusters also emerge and evolve to serve the interests of their participants. That the characteristics of the clusters of today are so similar to those of Marshall's (1890) industrial districts indicates that over time participants in various parts of an industry will tend to work with their contemporaries in a spirit of '*co-opetition'* [*co-op*eration and comp*etition*] (Nalebuff and Brandenburger, 1996) while also motivated by their own 'e*nlightened self-interest'* (de Tocqueville, 1875).

While there are many similarities in the characteristics of the nineteenth century industrial districts and the clusters of today, one major distinction exists. The electronics industry clusters of today did not emerge in Birmingham, Bradford or Manchester or other cities of the Industrial Revolution, nor do they dominate the large industrial cities of this century.

Agglomerations of electronics firms are found today in all developed nations, but the HTEI clusters with the highest employment density are found in relatively small cities which are also relatively isolated from major national populations and many of these regions have limited or no prior industrial-age manufacturing tradition. Silicon Valley (Saxenian, 1994) and Cambridge (Segal Quince, 1985) developed unique, localised industrial systems where these had not previously existed. Romanelli and Feldman, (2006) incisively note that when a new industry comes into being many regions will host new firms while clusters will emerge only in a limited number of these locations. The origin and development of HTEI firms and clusters is compared in across five Australian cities and reported in Chapter 4.

Fornahl et al (2010) quote Krugman (1991:35) that the reason for localisation *"can be traced back to some seemingly trivial historical accident"* and Kamath et al (2012:186) quote "*chance"* as a factor, which is also discussed by Porter (1990b:124). In each of the five HTEI regions included in the principal case study in this thesis, it is evident that a "*chance"* or a *"serendipitous event"* (Maggioni, 2006:237), created the conditions for the emergence of the cluster. Within this environment it can be speculated that the particular cluster emergence *event* may have been the first meeting of people from proximately located, otherwise independent firms or organisations in a region who had a need or want to collaborate to solve a particular business or technical problem or to simply *talk* to a contemporary about common business, technical or other interests. The propensity for people in related industries to aggregate in particular places and to work together may also be influenced by their desire for achievement, security or creativity or other '*needs*' identified by Maslow (1943).

The now substantial literature describes the attributes of clusters in many industries and includes extensive analysis of clusters of electronics firms and related organisations in many global regions with a primary focus on cluster history and industry structure, characteristics, competitiveness, performance and economic value.

However, more than two hundred years after aggregations of industry were observed (Smith, 1776) and more than one hundred years after these aggregations were described, as industrial districts (Marshall, 1890) and more than twenty years since '*industry clusters'* were described by Porter (1990b) there is a surprisingly limited understanding of the *origin* of these successful clusters (Braunerhjelm and Feldman, 2006; Menzel et al, 2010; Mayer, 2011). Benneworth et al (2003) ask weather clusters are a theory or a practical phenomenon and define five distinct theoretical elements of clusters, clustering and cluster activities, organisation and policy.

Perry (2005:142) notes that *"At some stage a person or a group of persons started an activity that subsequently became a community specialization."* It is noted that only limited attention has been applied to the *origin* of clusters; "*Cluster evolution is an understudied area"* (Mayer, 2011:26). Feldman and Braunerhjelm (2006:1) importantly state that there is *"little understanding of how successful clusters come into existence."* In a recent publication Mayer (2011:26) states that cluster evolution is an understudied area and asks "… *how clusters actually become clusters?"* Porter's *"cluster theory"* does not explain their formation and early growth (Martin and Sunley, 2003) or the dynamic aspects of cluster development (Lorenzen, 2005).

Recently Menzel et al (2010:1) noted that the strong research focus on the way clusters function contrasts with *"… a disregard of the questions how spatial concentrations actually come into being…"* They add that few studies exist on the emergence of clusters,[3] and explain that an emerging cluster is hard to detect and can sometimes only be described in hindsight, as in Bresnahan et al (2001).

Two competing explanations of the evolution and growth of endogenous clusters are examined by Mayer (2011:27). The first quotes Porter, (2000a; 2000b) that clusters simply "*bubble-up"* because of physical proximity to factors including agglomeration economies and the value from technological spillovers, labour market pooling and a rich supplier industry stimulating further firm growth (Klepper, 2010). These also contribute to *"path-dependent"* processes and *"increasing returns"* (Arthur, 1987, 1994).

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[3] Braunerhjelm and Feldman (2006) is an exception noted by Menzel et al (2010).

Mayer's second explanation is that clusters grow through spin-offs, supporting the observations of Klepper (2001, 2009a, 2009b, 2011) and through entrepreneurship and these processes develop regional agglomeration economies over time.

Mayer notes that existing firms are a source of entrepreneurship and they can function as "*surrogate universities*" (2005, 2011: 48, 2013) which can act unintentionally as incubators for their employees who later exploit their knowledge and experience in their own spin-off ventures. Cluster formation is also described as a "*sequential process with an evolutionary logic*", which once established benefits from a virtuous self-reinforcing process (Feldman, 2001:861).

Important characteristics of the Industrial Revolution described by Phyllis Deane (1979) persist in the technology-based industry clusters of today. These include the widespread and systematic application of modern scientific and empirical knowledge and specialisation in the provision of the requirements of national and international markets. Deane also listed capital intensive production systems, while in the knowledge-age this has widened from physical capital to include intellectual capital.

The emergence of new social and occupational classes noted by Deane during the Industrial Revolution continues today with increasing numbers of engineers, scientists and technologists swelling the "*Creative Class*" (Florida, 2002).

The predominantly young, professional, well-educated knowledge-workers of the 'Creative Class' have transport and communications options and now readily move within nations and internationally to join large or small firms or research institutions which offer challenging and rewarding employment, particularly in locations that also provide a fulfilling lifestyle (Florida, 2000, 2002), and a range of alternative '*job-hopping*' employment options, such as those in Silicon Valley (Lorenz, 1992; Benner, 2002).

It is noted that clusters evolve and develop at the local level: *"Competitive advantage is created and sustained through a highly localized process"* (Porter 1990b:74). The proximity between cluster firms was also found to be important in stimulating interaction and cluster firm performance (Amin and Wilkinson, 1999).

The relationship of geographical proximity and trust between technology firms and their network partners is noted by Bruneel et al, (2007). The creation of trust through "*closeness*" and its development by planned or unplanned interaction was identified as a major factor by Gertler (1995).

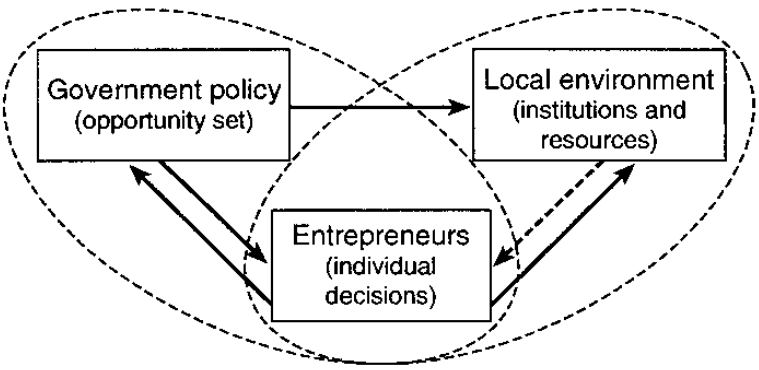
The actions of entrepreneurs and how external factors, influence the formation and location of high-technology clusters are examined, including "*constructive crises and new opportunities*" by Feldman et al (2005:129). Highly relevant to this thesis, Mayer, addressing cluster emergence in second tier regions asks "*how can we theorise the process by which Austin evolved as a location for high tech activity.*" (2011:26). Austin is one of the five regions selected in the principal case study conducted for this research and personal interviews were conducted in Austin in 2006 with industry, university, research institutions and civic agency representatives and elements of the origin and development of the Austin HTEI are discussed in Chapter 4.

While cluster *development* is well-researched in exemplar regions including Silicon Valley, Cambridge and Austin, the literature is sparse on the origin of HTEI clusters in other second tier regions: *"Second tier high-tech regions have not received much attention in the literature"* (Mayer, 2011:14).

One noted characteristic of HTEI clusters is that many entrepreneurs in small cities are reluctant to leave the region because they like to live and conduct business near their homes (Mayer, 2011:126). This cluster factor is measured and results are discussed in Chapter 4.

An industry cluster is an agglomeration of mutually reinforcing firms and aligned interests (Feldman et al, 2005). Figure 2.1, below shows the interdependent relationship between entrepreneurs, government policy and the local environment, including the social and commercial institutions, physical and human capital resources. (Feldman et al, 2005:132).

Figure 2.1: Factors in the Formation of the Region.



From: Feldman et al (2005:132)

Endogenous clusters become established over decades, each with a set of tacitly agreed, self-regulating norms, yet during the early years of their existence these clusters are often not recognised by governments or communities (Levi, 1980).

The cluster which developed in California's Santa Clara Valley - then better known for its fruit and vegetables - became known as Silicon Valley after it was given that name in 1971 by technology journalist Don Hoefler (Malone, 2002). While its existence as an agglomeration of technology development was not widely recognised during its early decades, the recent literature is extensive. The endogenous emergence and development of clusters is assisted and relationships deepened through more frequent face to face contact and by successful business transactions between cluster participants. Asheim and Isaksen (2002:77) state that "*several authors simultaneously point to an increased importance of place-specific and often non-economic factors"* in the creation of sustainable competitive advantage in their analysis of the successful electronics industry cluster in the small community of Horton, Norway.

Relationships based on regular personal contact are more easily conducted in places with smaller populations and lower traffic densities, and consequently more frequent opportunities for personal interaction. The importance of this factor is measured and discussed in relation to regions selected for case studies in Chapter 4.

A small but growing number of recent studies have added new insights to the dynamic nature of the origin of industry clusters in second tier regions and these studies agree on four key assumptions (Mayer, 2011:28). First, clusters can be triggered by chance, (Porter, 1990b: 124) such as the location of a start-up in the home town of an entrepreneur which can attract others to the region (Boschma and Lambooy, 1999:414).

The second key assumption of Mayer is that entrepreneurship drives cluster growth and the "*entrepreneurial spark"* (Feldman and Francis, 2002) accentuates the spin-off processes in cluster formation that is required for a cluster to enter a sustainable growth trajectory (Feldman and Braunerhjelm, 2006:3). Entrepreneurship is also reported to be a critical element in cluster formation (Feldman et al, 2005; Braunerhjelm and Feldman, 2006).

The third key assumption of Mayer is that while clusters can be initiated by '*chance',* entrepreneurship drives cluster development. Cluster development also needs institutional and social structures and the development of labour pools and existing and new firms (Bresnahan et al, 2001). The fourth key assumption of Mayer is that clusters evolve through four distinct phases: emergence, growth, maturation and specialisation, and stagnation and decline (2011:28). Mayer notes that in second tier high tech regions clusters that grow through the spin-off processes will develop agglomeration economies over time through entrepreneurship and quotes Benneworth (2004) that the spin-off process leads to the "*densification of the entrepreneurial environment*." (2011:27).

Klepper (1997) finds synergies in the life cycles of products and industries and Menzel and Fornahl (2010) conclude that the cluster life cycles have four stages; *emerging, growing, sustaining and declining* which aligns with the four stages described by Mayer (2011): *emergence, growth, maturation and specialisation, and stagnation and decline*. Klepper (2011) refers to Marshall's (1890) work and posits that skilled labour, learning and the location of suppliers are the three major benefits for firms in clusters.

It is noted that the phenomenon of the self-organisation of technology clusters in smaller or second tier cities is now receiving the attention of scholars since the introduction of the concept of technology clusters in 'second tier cities' (Markusen, 1999a). It is also noted that much of the literature on cluster origin and second tier cities and particularly involving technology clusters has been published only recently (Braunerhjelm and Feldman, 2006) Fornahl et al, 2010; Mayer 2011). Path dependency (Martin and Sunley, 2006; Martin and Simmie, 2008) and the presence of key institutions (Mayer, 2011) are identified as factors in cluster origin, and it is noted by Braunerhjelm and Feldman (2006:10) that chance events or policy initiatives *"frequently had a different intention than the support or development of a cluster."*

This factor is identified in Adelaide with the establishment of a major Federal Government laboratory in 1947 for defence research and development, which over the following decades became the Defence Science and Technology Organisation (DSTO, hereafter), a significant source of technologies and trained staff, both of which have assisted the growth of Adelaide's HTEI cluster. The establishment of a two-way radio manufacturing business in Christchurch in 1954 has unintentionally produced many of the spin-out firms that populate its HTEI cluster (Green, 2005). These two relatively unrecognised HTEI clusters are included in the principal case study, along with the exemplar clusters; Silicon Valley, Cambridge and Austin. It is noted that the two antipodean clusters have evolved through a very different process to the three USA and UK clusters discussed above.

The presence and creative involvement of a research intensive university has been widely reported in the origin and development of HTEI clusters, particularly in Silicon Valley, Cambridge UK, Austin, Texas and Boston MA (Saxenian, 1994; Sainsbury, 2007; Bramwell and Wolfe, 2008; Gagné et al, 2010). However, in other successful HTEI clusters the involvement of a research university is reported to be less significant (Mayer, 2007, 2009).

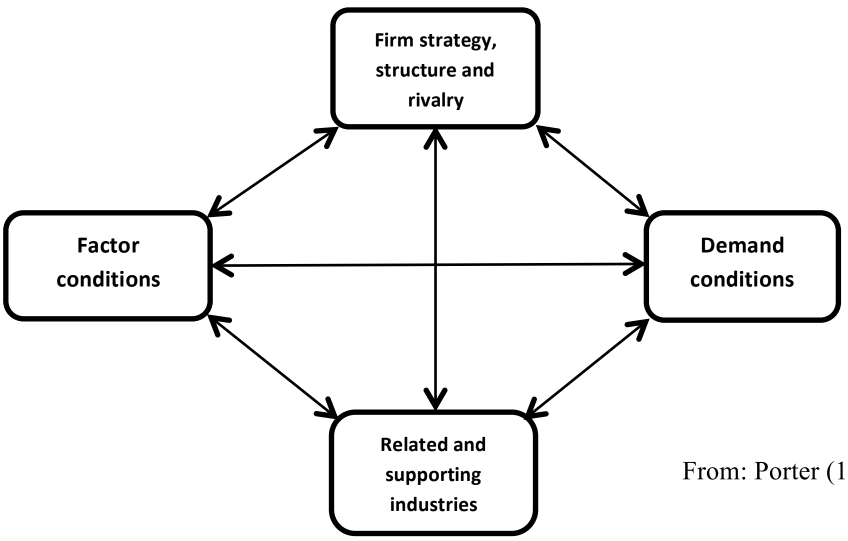
Dense clusters of high technology firms are reported in Portland, Oregon; Boise, Idaho and Kansas City, Kansas (Mayer, 2011), none of which has a major research intensive university. It is argued by Mayer that the endogenous emergence and development of these three successful second tier regional clusters without significant university involvement shows that the presence of a research university is "*neither necessary nor sufficient"* for regional high technology cluster development (Mayer, 2011:4).

A similar finding was made by Feldman (1994a) and Bresnahan et al *"a university per se is not essential to the emergence of a successful cluster"* (2001:847). The extensive involvement of universities in the origin and development of HTEI clusters in Cambridge, Silicon Valley and Austin is widely reported and will be reviewed in the principal case study. The involvement of universities on HTEI cluster origin and development in Adelaide and Christchurch will be measured in a survey process which is described in Chapter 3 and findings are discussed in Chapter 4.

A range of other key factors are measured to develop an understanding of *why* HTEI firms were started and *how* they developed over time in these two small and isolated antipodean cities and how they coalesced over decades into the highest density HTEI clusters in their respective nation.

Porter (1990b) argues that sustained prosperity at national, state, regional and city level is most likely in industries or industry segments where the determinants of the system are most favourable and where they exist in close proximity to each other. These determinants are shown in a *diamond* relationship (Porter, 1990b: 72), see Figure 2.2 below.

Figure 2.2: The Porter Diamond: *'The Determinants of National Advantage'*



From: Porter (1990b:72)

Porter's diamond model illustrates the four main '*determinants of national advantage': Factor Conditions* - labour, capital, etc. - *Demand Conditions* especially domestic demand;

the context for *Firm Strategy, Structure and Rivalry,* and *Related and Supporting Industries,* including the strength and quality of linkages. In Porter's model of industry competitiveness, clusters represent the dynamic interplay between geographically proximate competitors, related and supporting industries, demanding and discerning customers and an institutional infrastructure that supports industry specific innovation (Lindsay, 2005). Porter argues that firms gain competitive advantage where: *"... their home base supports the most rapid accumulation of specialized assets and skills…"* (1990b:72). Porter adds that: "*In small nations, missing domestic rivalry may sometimes be offset by openness to international competition and global strategies in which the nation's firms meet foreign rivals in many countries"* (1990b:146). In Australia's small market "*Australian firms need to develop offshore markets to grow"* (Freeman et al, 2006:39). Yetton et al, (1992: 104) note that in Australia *"...small domestic demand may simply force companies to explore foreign markets at an earlier stage in their development."*

This 'early export' factor is present in the HTEI in Adelaide and illustrated in the unexpected findings of a group of 22 researchers from the University of Texas at Austin on a visit to research the technology resources and capability of Adelaide in 2001. This research group found many small and young Adelaide HTEI firms were exporting at an earlier stage of their development than was observed in firms of similar size and age in Austin (Gibson and Gurr, 2001). Silicon Valley and many other successful HTEI clusters also share an important characteristic reported by Porter (1990b:655) "*Government policy had little to do with the beginning of Silicon Valley."* Porter (2000a: 26) also notes "*Most clusters form independently of government and sometimes in spite* of *it."* However, government research funding in the 1950s greatly assisted the growth of technology-based firms in Silicon Valley and the development of research capability at Stanford University (Morgan, 1967). While the majority of the relevant literature analyses clusters in USA, UK and Europe, a similar observation in New Zealand shows that most clusters: *"including the Christchurch electronics cluster form and develop not through the actions of any government but by a random combination of local factors or advantages"* (Brown and McNaughton, 2003a: 120).

Two factors not found in *industrial districts* are highly relevant in the electronics cluster regions selected for case studies in this thesis. These factors which are usually mutually exclusive have been observed to operate together in all of the clusters selected for the principal case study in this thesis. These factors are: *proximity* and *isolation.* Both of these factors, counter intuitively, act together in the five regions selected for this case study; two in USA and one each in UK, New Zealand and Australia. The influence of these two relatively unreported factors on the selected clusters is discussed below in Section 2.23.

2.5.3 Cluster Types and Attributes

Four important characteristics are present in the clusters of today and these were also observed in Marshall's industrial districts: *'hereditary skill', 'the growth of subsidiary trades', 'the use of highly specialised machinery'* and *'a local market for special skill'* (Belussi and Caldari, 2009). Markusen (1999a) describes the characteristics of the '*Marshallian'* model as comprising of a specialised range of services, tailored to the needs of the local industry. Examples of these services in HTEI clusters include electronic circuit design, industrial design and environmental testing for compliance with national and international standards. Other services include contract product manufacture and just-in-time logistics management of component supply and product distribution. Each of these services requires a specific set of skills and capital equipment which can be most effectively utilised and provided economically by a specialist firm. In HTEI firms, the use of these external services frees the management and staff of the typically small firm to concentrate on the two critically important and interrelated tasks: product design and marketing.

Scale economies in HTEI clusters are relatively low with substantial trade being transacted, within the district, often entailing long-term contractual commitments. This type of industry cluster induces trusting relationships among participating firms which is facilitated by their close proximity (Niu et al, 2012).

General cluster attributes reported include: "*higher growth of wages"* (Delgado, et al, 2010:1) and high levels of productivity and innovation (Porter, 1998b; Spencer et al, 2010). Kuah (2002) adds personal contact networks and Angel (2000) states that skilled labour markets and firms in clusters grow faster than those not clustered (Swann, 1998). (Delgado et al, 2010:29) state that industries located within a strong cluster *"are associated with higher employment growth, a finding which is robust across different clusters and regions."* Lorenzen (2002) states that these networked relationships facilitate specialisation and innovation and attributes the concept to Adam Smith (1776) and Von Hippel (1982). Strong clusters are also found to foster growth in wages, particularly for scientists and engineers, the number of establishments, and patenting (Cortright and Mayer, 2001). The findings suggest that regional economic development is crucially dependent on the role of clusters. Clusters also provide individuals with *"... more opportunities to acquire knowledge of the business…"* (Perry,2005:75) and to build the confidence through employment to start their own business. However, economic advantages that stem from cluster dynamics *"are not permanent"* (Menzel and Fornahl, 2011) as shown by the contrasting life cycles of HTEI clusters in Silicon Valley and Boston (Saxenian, 1994).

Markusen (1996) describes industrial clusters as economic networks typically populated by SMEs where these firms are specialized in specific value adding activity and linked by economic transactions, long-term beneficial relationships, and a strong social tie to the geographic location. Markusen's *'hypothesised features'* of industrial clusters aligns with many researchers' assertions that industrial clusters can develop and sustain 'regional competitive advantage' (Porter, 1998; Saxenian, 1994, 2001). The selection of HTEI clusters for case studies is described in Chapter 3 and their sharing of Markusen's Type A hypothesised *'new industrial district'* features is discussed in Section 4.3.5.11.

The relationships of the typical HTEI cluster firms are shown below in part A. of Figure 2.3 (Markusen's A, B, C diagram), with many interdependent firms buying and selling from each other with end products exported to customers typically outside of the region (Markusen, 1999a:28). Most of these features are present in the each of the five HTEI clusters included in the principal case study in this thesis. An exception is the labour in-migration rates which are lower in Adelaide and Christchurch than in Cambridge, Austin and Silicon Valley.

Markusen (1999a:23) lists these hypothesised features of the Marshallian Industrial District:

- Business structure dominated by small, locally owned firms
- Relatively low scale economies
- Substantial inter-district trade among buyers and suppliers
- Key investment decisions made locally
- Long-term contracts and commitments between buyers and suppliers
- Low degrees of cooperation or linkage with firms external to the district
- Labour market internal to the district, highly flexible
- Workers committed to the district, rather than to firms
- High rates of labour in-migration, lower rates of out-migration
- Evolution of unique local cultural identity, bonds
- Specialized sources of finance, technical expertise,
  and services available in the district outside of firms
- Existence of 'patient capital' within district
- Turmoil, but good long-term prospects for growth and employment

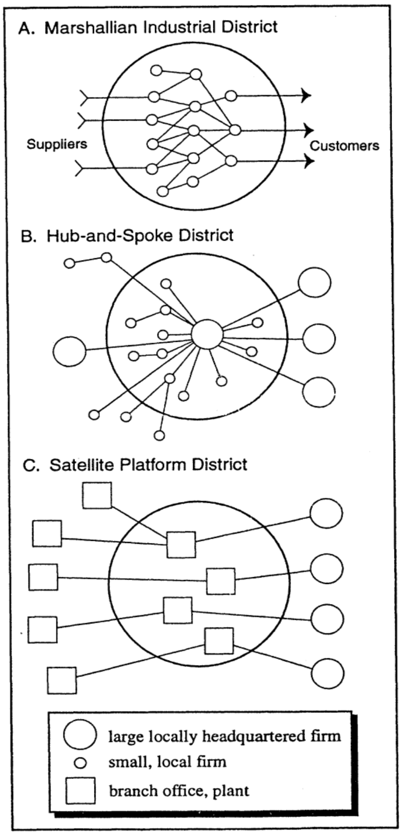
Local industry associations are relied upon by the smaller cluster firms to promote careers in the industry to their local communities, particularly to ensure that students, teachers and parents are aware of the employment opportunities available in the small firms, which average faster growth than the larger firms (Rowe et al, 2004). The larger firms typically provide the majority of the resources of the industry associations and through these organisations the connection is maintained with local and regional governments.

An essential element in a successful, self-sustaining cluster is trust between the participants and this cannot be created in the short-term. Trust in a cluster grows organically and is found to be strongest in clusters where they have grown from the *"bottom-up"* (Markusen, 1999b:65). The development of trust has been found to be strong in second tier cities (Barrell and Littlewood, 2006).

The smaller size, shorter commute distances and lower traffic densities in second tier cities that facilitate meetings are discussed as cluster development factors in Chapter 4. HTEI clusters considered in this thesis typically resemble Markusen's *"Marshallian Industrial District"* model. Figure 2.3 Part A (below) illustrates the inputs of raw materials, business services and the multiple subcontracting interconnections between cluster members and the output of products. This structure is similar to that described by Porter (1990b:179) and also similar to the HTEI clusters examined in the principal case study and discussed in Chapter 4.

The characteristics include the cluster structure and quality of the local labour market, where employees move from firm to firm and where employees and business owners live and work in the same district (Markusen, 1999a).

Figure 2.3: Firm Size, Connections and Local Versus Nonlocal Embeddedness



From Markusen (1996a:27)

These small, locally owned and managed firms, (Fig 2.3, part A) over time develop trusting relationships with customers and suppliers and with other local firms and tend to have more limited dealings with larger local firms and MNC's which are typically more self-sufficient. The smaller firms feel greater empathy with similarly small firms where negotiation is based on a meeting of equals. The social and cultural environment is also reported to be an important cluster success factor. The networks that succeed tend to be those that are regionally-based, often founded upon cultural commonalities and facilitated by geographic proximity. (McDougal, 2007).

While the illustration of the Marshallian Industrial District in this diagram shows only small, local firms these clusters do also include some large locally owned firms and some MNC's.

However, the majority of firms are locally owned and managed SME's and the majority of employees are engaged in smaller firms and it is the interchange between the owners, managers and staff of these smaller firms that facilitates informal information flow, develops trust and provides these clusters with their vibrancy and longevity.

Parts B and C of Figure 2.3 are typical of the structure of industrial-age manufacturing in many regions, with one or more large plants with a number of supplier firms located nearby and remotely (McCann and Arita, 2006). Geographic proximity is important as just-in-time systems function effectively where supply lines are short (Holl et al, 2010). The relatively long and continuous production runs of consumer electronic, electrical products and the automotive industry encourage this structure, but are not useful in the relatively short runs of often customised products that are typical in the HTEI. Similarly, the Satellite Platform District shown at part C. of Figure 2.3 with its branch plants is not applicable to the HTEI,

2.5.4 Clusters in Small and Relatively Isolated Places

The origin and development of HTEI clusters in relatively small and relatively isolated places is a major focus of this thesis. These clusters have recorded strong growth similar to that reported by Markusen and DiGiovanna (1999:3) in clusters of knowledge-age industries in a small number of second tier cities. Mayer "*highlights the evolution of regions that are traditionally not regarded as pioneers in high-tech development and therefore have not received much scholarly attention"* (2011:10). Some of these *'relatively unknown'* regions have growth rates that exceed national industry norms.

It is particularly relevant to this research that the four clusters in Porter's seminal cluster study were located not in major cities, but in relatively small regions which are also comparatively isolated from major national populations (1990b:179). The case studies include Sassuolo, Italy with a population of 41,500 people (2010) and which produced 80 per cent of all ceramic tiles manufactured in Italy. The German printing machine industry, started in the nineteenth century is principally located in three small Bavarian cities Heidelberg, (2010 population 147,000), Augsburg (265,000) and Wurzburg (134,000). These three cities have a total population of about 550,000, or about 0.7 per cent of the German total (CityPopulation, 2010). In Porter's third region, electro-cardiac recording technology was developed in Europe in the late nineteenth century (Rivera-Ruiz, et al, 1927) and the leading USA firm Sanborn Corporation began producing electrocardiographs in 1917 in Waltham, Massachusetts on Boston's 'Route 128' (population 60,300). The Japanese robotics industry began in Kawasaki which has a population of 1.3 million or about 1 per cent of the nation's population. Porter does not emphasise small size or relative isolation in his case study selection criteria; the locations were chosen: *" ... to illustrate the process of creating advantage in very different industry structures, in nations with widely divergent circumstances, and at various times"* (Porter,1990b:179). Porter also notes that "*Competitors in many internationally successful industries and often entire clusters of industries are often located in a single town or region within a nation"* (1990b:154).

The literature also reports the emergence and development of clusters in a range of other industries in small and relatively remote places, and the origin and development trajectories of these industries have many similarities with those of knowledge-age clusters including HTEI clusters in similarly small and isolated places. Among the many reports of industry clusters in small regions Nobel Laureate Paul Krugman discusses Dalton, Georgia, with a population 33,000 (2010) where six of the top twenty USA carpet manufacturers are located with all but one of the rest located nearby (Krugman, 1991: 35). Carpet mills located within a 65-mile radius of Dalton, Georgia make about 85 per cent of the carpet sold in the USA market. The role of Catherine Evans in the origin of the USA carpet industry was serendipitous (Krugman, 1991:60). Most of the manufacture of wind musical instruments in the USA is located in Elkhart, Indiana, with a population of 131,000 (Krugman, 1991: 8).

The literature also identifies long-established and highly specialised industry clusters in other small and relatively isolated places including Gloversville, in New York State which produced half of the leather gloves in the USA in 1900, and almost 90 per cent in 1950 (Trebay, 2009) in a small and a relatively isolated community of 15,000 people, located more than 300 kilometres from New York City. This cluster is based on the skills passed down by generations of Scottish immigrants who settled there in 1760 (Marshall, 1919: 287n). A motorsport cluster in Motorsport Valley® [4] includes 4,500 firms, all within a 50 mile radius of Oxford and the motor racing circuit at Silverstone, Northamptonshire (Henry et al, 1996; Pinch and Henry, 1999; Cooke and Huggins, 2003; Lawton Smith and Waters, 2005; Jenkins and Tallman, 2010). This cluster employs 38,500 people, including 25,000 engineers and invests 30 per cent of its annual revenue in R&D and exports 60 per cent of its £6.0 billion annual revenue (MIA, 2012).

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[4] ® Registered Trademark of the Motorsport Industry of UK, Stoneleigh Park, Warwickshire.

The motorsport cluster produces small volumes of highly customised, high value-added racing cars and mechanical and electronic systems and services for Formula 1 Grand Prix motor racing teams.

Industry clusters in second tier regions are not rare, but in an increasingly globalised world the firms in the five HTEI clusters in the principal case study selected for this research show that their sustainable competitive advantage exists in their locally managed assets including their knowledge, relationships and motivations "*that distant rivals cannot match*" (Porter, 1998a:78). These small regions are gaining wealth and employment from knowledge-age manufacturing at the expense of larger primate cities (Markusen, 1999a:21).

The foregoing examples of clusters in small and isolated places and in industries other than the electronics industry illustrate the diversity of industrial disciplines that are involved in clusters. It is noted that all of the clusters reviewed in this section began through an endogenous process; clusters simply "*bubble-up*" (Mayer, 2011:27) and the literature shows that this endogenous cluster origin process is found across a range of industries (Krugman, 1991, 1998; Porter, 1990b; Pinch and Henry, 1999). These endogenous factors are involved in the origin of the five HTEI clusters in the principal case study in this thesis.

While the literature on clusters in a range of other industries in small places is relatively abundant and while the literature on the development of HTEI clusters in Cambridge, Silicon Valley and Austin is also extensive comparatively little data on the HTEI in Adelaide is available, as shown below in Table 2.1.

Table 2.1: Literature Search: Electronics Industry (EbscoHost, 2004).

Search Phrase	Articles	Earliest
'Electronics Industry USA '	8045	1955
'Electronics Industry Europe'	1639	1959
'Electronics Industry UK '	1304	1964
'Electronics Industry Australia'	1415	1976
'Electronics Industry Adelaide'	32	1991

Table 2.1 shows the number of articles published as at June 2004 when the survey design was developed. The volume of literature available on the industry in USA, contrasts with the limited data on Europe, UK or Australia and the very limited data on Adelaide. Christchurch was included in the research in 2005 and a search produced 48 articles, dated from 1987.

2.5.5 Chance and Government in Endogenous Cluster Emergence

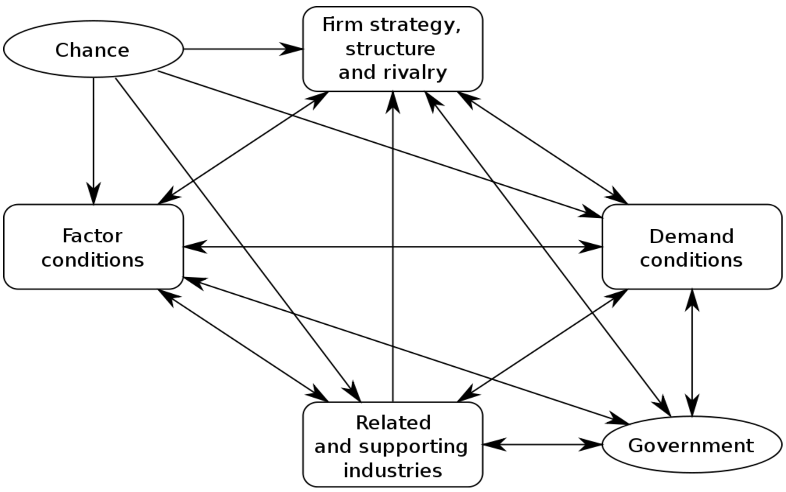
The literature shows that the location of clusters of a particular industry can be influenced by '*chance*' (Porter, 1990b: 124). Frequent literature references are found on the influence of '*chance*' and '*serendipity*' on the origin of industry clusters. Wolfe and Gertler stress "*the relative importance of chance events, or serendipity, as opposed to rational or intentional acts*" (2006:243). Reported cluster emergence influenced by '*chance*' events includes the location of a start-up in the home town of an entrepreneur which can attract others to the region (Boschma and Lambooy, 1999:414) and '*serendipity*' as a factor is reported (Braunerhjelm and Feldman, 2006; Wolfe and Gertler, 2004; Kenney and Patton, 2006).

The historical context is provided by Brown and McNaughton (2003b:109):

> "*The economic theories of Weber and others, grafted on to the Marshallian resource endowments intuitively provide a more complete understanding of a cluster's inception. This is especially so if the concept of serendipity or historical accident is considered.*"

The influences of '*chance*' and also of '*government*' on all four of the determinants of national advantage are illustrated in the enhanced version of the Porter 'diamond' (1990b:127) shown below in Figure 2.4. It is noted from the diagram that while chance can be an influencing factor on all of the determinants of national or regional advantage, that government can both influence and be influenced by these determinants.

Figure 2.4: The 'Complete System' from: *The Competitive Advantage of Nations*



From: Porter, 1990b:127

Chance was a significant factor in the origin and development of the HTEI clusters in all of five regions in the principal case study in this thesis. Each of the clusters has its own origin and development narrative and has benefitted from a singular chance event. The role of chance in the origin of these clusters is discussed in Chapter 4, the discussion is informed by the literature and by data from surveys in these and other regional HTEI clusters.

An element of chance was also a factor in the origin of each of the four clusters described by Porter (1990b) and discussed above. The modern German printing press industry was developed near Wurzburg, on a site provided by the King of Bavaria, and with financial assistance and tax incentives. The industry could have been established in many other places, but the King wanted industry in that region and it has remained in the region.

The example of the carpet industry in Dalton, Georgia, discussed above was based on chance. That industry grew from the hobby of a local girl who revived an older craft technique in 1895 and this one enterprise employed about 10,000 home-based workers in the 1930s (Perry, 2005;1), and grew into the carpet industry cluster (Krugman, 1991: 60).

Servicemen returning to civilian life after the Second World War formed two very significant, but unrelated electronics design and manufacturing businesses. By chance these electronics specialists had gained critically important technical knowledge that was developed during their war service. Tait Electronics was founded in Christchurch, New Zealand (Green, 2005) and Tektronix was founded in Portland, Oregon (Mayer, 2011). Both of these start-ups grew to be the largest HTEI firms in their region and both performed the role of a *"surrogate university"* (Mayer, 2011: 89) by providing employees with training, knowledge and experience and in some cases, assistance to leave their employment and to start their own businesses in the region.

Government policy, such as the establishment of a research institution in a region has been found to create an entrepreneurial opportunity, without that being an objective of the institutions. Such government policies may be seen as 'chance' events as shown in the modified 'diamond' (Porter, 1990b:127) reproduced above in Fig 2.4.

The effect of 'chance' and of 'government' on the development of electronics clusters is discussed further in Chapter 4 and particularly in relation to the emergence of the HTEI cluster in Adelaide, which benefits from the chance selection, in 1947 of Adelaide for the location of a joint British-Australian government defence research facility (Morton, 1989). The location of that research establishment has played the role of a catalyst and of a *'surrogate university'* as described above by Mayer (2011: 89) in the development of the HTEI cluster in Adelaide.

The influence of chance as a factor in small and relatively isolated regions is highly relevant to this thesis and also the effect of *proximity and isolation* in these regions and the influence of these factors on the development of the selected clusters is discussed in in Section 2.23.

2.5.6 Electronics Industry Clusters

Clusters are found in a number of industries and global cities and some of the most successful global clusters are found in the HTEI. The largest and most reported HTEI cluster developed endogenously in the Santa Clara (Silicon) Valley. Major HTEI clusters have also developed endogenously in and around Cambridge, UK and in Austin, Texas.

All three of these clusters emerged and developed in the near proximity and in collaboration with research intensive universities. Stanford University, the University of Cambridge and the University of Texas at Austin are noted for their science and engineering research capability and for the commercialisation of the IP generated by their research. These universities are credited with a major role in the development of their adjacent HTEI clusters.

The history of the origin and development of the HTEI in Silicon Valley is extensively documented from the early twentieth century (Morgan, 1967; Cooper and Bruno, 1977; Tajnai, 1985; Malone, 1985, 2002; Saxenian, 1985, 1994; Brand, 1992; Castells and Hall, 1994; Henton et al, 1997; Henton, 2000; Sturgeon, 2000; Lee et al, 2000; Kenney, 2000; Berlin, 2005; O'Mara, 2005; Lecuyer, 2007; Klepper, 2010). These authors provide a range of analyses of the development of the regional HTEI cluster and insights into the contributions of individuals, companies, universities and government.

The emergence and development of the Cambridge HTEI cluster is extensively documented (Segal Quince, 1985; Cattermole and Wolfe, 1987; Heffernan and Garnsey, 2002; Athreye, 2004; Barrell, 2004; Garnsey and Heffernan, 2005; Keeble, 2012). The history of the development of the HTEI cluster in Austin is also well researched (Kleiner, 1983; Smilor et al, 1989; Oden, 1997; Henton et al, 1997; Engelking, 1999a, 1999b).

HTEI clusters are documented in many cities in Europe and HTEI clusters in Dresden, Germany (Parker and Tamaschke, 2005), Karlskrona, Sweden (Parker, 2006) and Limerick, Ireland (Parker, 2008) are compared in these very few academic publications with the HTEI cluster in Adelaide in Chapter 4. The city of Dresden is growing faster than Berlin (ESPON, 2011), and this second tier city with a population of 523,000 (CityPopulation, 2010) hosts major electronics and physics research institutions including the renowned Fraunhofer Institute for Integrated Circuit Design Automation and the Max Planck Institute, Physics Laboratories and has the highest employment density HTEI cluster in Germany (Gronarz, 2012). Dresden specialises in semiconductor technology and organic electronics.

Karlskrona has an agglomeration of telecommunications firms involving MNC's and large and increasing numbers of SME's and is second only to Stockholm in IT education (Parker, 2006). Shannon/Limerick and four other Irish regional HTEI clusters are discussed in Chapter 4.

HTEI clusters in regions outside USA and Europe are less widely studied. Aspects of the development of the HTEI cluster in Christchurch, New Zealand are reported (Ffwocs-Williams, 1996; BERL, 1998; Brown and McNaughton, 2003a; Saunders and Dalziel, 2003; Tantrum, 2003; Fraser and Kelly, 2004; Green, 2005; Brown, McNaughton and Bell 2010; Saunders, 2010). The HTEI cluster in Adelaide is the least studied of the five clusters discussed in the principal case study in this thesis (Parker and Tamaschke, 2005; Grill and Coutts, 2005 and Parker, 2006, 2008).

Relatively small firms are the majority in most HTEI clusters (Isaksen, 2003). These small and often young firms are typically limited by their lack of resources and when located in a resource-rich environment, *"innovative small firms have a greater chance of finding and utilizing the technical capabilities needed to augment their internal capabilities for innovation"* (Feldman and Kelly, 2002:173). Marshall (1890) emphasizes how important industrial districts are for small firms, which is relevant to the clusters of today.

Through a social division of labour (Bergman and Feser, 1999), these small firms may enjoy the same types of benefits large firms earn through internal scale and it is noted that *"Second tier high tech regions develop unique specializations and competitive advantages"* (Mayer, 2011:1).

An important characteristic of HTEI clusters is their age, but the exact origin date of clusters is not known. The origin of the Silicon Valley cluster is variously suggested as 1909 with the foundation of the Federal Telegraph Company (Sturgeon, 2000), or the appointment of Dr Frederick Terman in 1925 to Stanford University (Malone, 2007), or the foundation of Hewlett Packard in 1939 (Leslie, 2000).

The vast difference in the suggested dates of origin of the Silicon Valley cluster illustrates the difficulty in determining when a particular cluster emerged. This wide time interval relates to the problem in determining *why* a cluster originated; the first of the three research questions posed in this research. The literature on the Silicon Valley HTEI cluster model highlights the widely reported major role of Stanford University in regional cluster development.

However, (Mayer, 2011:26) argues that "… *higher education institutions are neither necessary nor sufficient for the formation of high tech clusters."* This conclusion is reached by analysing the origin and development of high technology clusters in three USA cities; Portland, Oregon; Boise, Idaho and Kansas City, Kansas. Each of these is a second tier city, each is remote from major populations and each has a dense cluster of technology-based industry, but no major university. It is also noted that while both Adelaide and Christchurch have well regarded research universities, neither has the international standing or influence of Stanford University or the University of Cambridge and the University of Texas and in neither city can it be found that the influence of their university is as dominant as the influence of the universities on the HTEI clusters of Silicon Valley, Cambridge and Austin.

2.5.7 Location of HTEI Clusters

"Our existence in time is determined for us, but we are largely free to select our location" (Losch, 1954:3). The focus of the early contributions to the extensive literature on the theory of location of manufacturing industry is on the needs of industrial-age firms including materials, labour, ports, roads, rail, markets and transport as major factors (Weber, 1929; Hoover, 1948; Losch, 1954).

Industrial-age location decisions of manufacturers were based on six major factors: labour costs, proximity to markets, availability of skilled labour, industrial climate, regional tax regime, proximity to materials (Mueller and Morgan, 1962). Only one of these six location factors is now significant in the knowledge-age; the availability of skilled labour.

While engineers and scientists are among the highest paid workers in the knowledge-age the high value of their knowledge creation and the low cost of production or reproduction of electronic products and the low cost and wide availability of transport and communication changes the old equation. The major inputs in the knowledge-age and particularly in the HTEI are people, their ideas and the technologies required to embed these ideas into successful, marketable products and services: *"Knowledge is the primary resource"* (Drucker, 1992:95). Materials and components including microprocessor and memory chips are small and light in weight and relatively valuable and can be airfreighted speedily and economically, so material sources and transport cost considerations of the industrial-age do not adversely impact on HTEI firms. Audretsch and Feldman (2004:2714) note that *"Location and geographic space have become key factors in explanation of the determinants of innovation and technological change."*

Electronic components and finished products have continued to reduce in size and weight which further reduces the cost, to transport these materials, semi-finished or intermediate goods between processing locations and the final products to market (Sturgeon and Kawakami, 2010). The products of knowledge-age manufacturers and particularly the products of the HTEI have relatively high value and low weight (Markusen et al, 1986: 133), so transport costs are less of a burden, therefore location in relation to markets is reduced as a factor. Markets for HTEI products are also broadly dispersed globally and the transport cost on the small, light-weight, high-value products of the HTEI is not a significant factor. A typical HTEI export product with dimensions approximating those of a shoebox and worth US$10,000 can routinely be airfreighted from Australia to the USA or Europe in less than three days for US$100, based on the industry experience of this author.

Knowledge-age industry is increasingly dependent on access to trained and motivated people (Kotkin, 2000). In the knowledge-age the competitive advantage of industries and regions is based on their ability to mobilise the trained people, their capabilities and the resources required to turn innovations into new business ideas and commercial products (Porter, 1994: Florida, 2000). Since the availability of trained and motivated people is the major requirement of knowledge-age industry, firm location is strongly influenced by where those people want to live and work (Florida, 2002). Young knowledge workers, the engineers and scientists of the HTEI who have skills that are in global demand and mobility *"... attach a high priority to cultural, educational and employment opportunities in urban areas"* (Vasko, 1987:277). The 'creative class' has also been studied comparatively in Western Europe and North America (Clifton and Cooke, 2009).

Florida (2002) rated Austin, Seattle, Boston, Washington and the San Francisco Bay Area [including Silicon Valley] as the leading USA technology regions and noted a strikingly strong correlation between regions with large concentrations of knowledge workers, amenities and the environment. Florida (2000) and Oakey (1983) note that locational preferences of technical personnel influence location decisions of firms.

Knowledge workers prefer places with a diverse range of recreational activities including rowing, sailing, cycling, rock climbing and associated lifestyle amenities (Florida, 2000). They are less concerned with 'high' arts and professional sports teams. *"Knowledge workers also prefer progressive regions that are youth-oriented and are supportive of demographic diversity"* (Florida, 2000:6).

This description has a strong similarity with the analysis of a group of 22 researchers from the University of Texas at Austin, who visited Adelaide in July 2001 to research the technology resources and technology industry capability of Adelaide.

The group reported a range of valuable assets including Australia's largest defence research facility, DSTO and a range of highly marketable advantages, including physical assets of beaches, ocean, wine country, "*hike and bike trail",* restaurants, hotels, and wildlife, these add up to an Adelaide Region that is unique in the world (Gibson and Gurr, 2001).

Location is also influenced by the size of firms. Jane Jacobs' analysis of the relationship of manufacturing firms with their host cities shows that large companies with their typically higher degree of vertical integration and strategic self-sufficiency need not be in cities. But, Jacobs argues that for small manufacturers, everything is reversed. Small firms need access to a range of suppliers and technical and business skills and must be sensitive to market demands, and without cities they could not function. Jacobs also notes that while small firms are dependent on the diversity of other city enterprises, they can also add further to that diversity (Jacobs, 1961).

Although written more than fifty years ago, this observation by Jacobs is highly relevant to the HTEI clusters of today, with their high proportion of SME's and interdependent relationships with suppliers and networking associates requiring close proximity. Audretsch and Feldman confirm that high technology sectors depend on knowledge spillovers and that *"proximity and location matter"* (1996a:630), in generating innovation. *"Tacit knowledge is often specific to organisational and geographic locations and this increases its internal circulation but impedes its external accessibility"* (Amin and Wilkinson, 1999: 121). Some regions remain 'sticky' in a 'slippery' world (Markusen, 1996).

The location of a business in the founder's hometown is an often repeated theme with technology-based firms. William (Bill) Gates and Paul Allen jointly founded software firm Microsoft in 1975 in Albuquerque, New Mexico, but moved it to their hometown of Seattle, Washington. Seattle in 2012 is the twenty-first city in USA by population and now a centre of the software, internet and multimedia industry.

Audretsch and Feldman (1996b) note that talented young professionals are attracted to Seattle by its 'right-brain side' its renowned music scene, acclaimed theatre and a surprising array of creative talent. The live music scene in Austin (Austin, 2013) and its diversity are attractive to the young scientists and engineers in its technology industries (Florida, 2002).

The U.S. Establishment and Longitudinal Microdata of the Small Business Administration developed from Dun and Bradstreet data shows that entrepreneurs in a range of industries in the USA only consider their current city as a possible site for a new small business, confirming a finding by Schmenner (1982). Almost all founders (89 per cent) of MIT alumni companies started their business in the general location in which they were living at the time (Roberts and Eesley, 2011). This home-town location preference is also researched in personal interviews with founders and managers of more than 200 HTEI firms located in five Australian cities which is discussed in Chapter 4. Location decisions are also based on economic logic. Amazon founder Jeff Bezos left a highly paid finance industry position in New York in 1994 to move to Seattle to establish Amazon.com because of its number of Internet and computer literate staff and its proximity to the Ingram Book Group, the initial supplier of books to Amazon (Robinson, 2010).

Spin-outs and start-ups are relatively common in HTEI clusters and the location of key resource requirements of trained and experienced technical people and business support with 'quality of life' are overarching factors (Mayer, 2011:118). These resources will include those that can be purchased and those that can be accessed through networking. A previous association with co-workers or school, undergraduate or graduate classmates is noted as a major factor in the collaborative networking of individuals and firms (Klepper, 2001; 2009c; Atherton, 2003). Professional relationships and trust are highly regarded cluster attributes (Bruneel et al, 2007; Lorenzen, 2002).

However, clusters of HTEI firms are widely dispersed across nations, these clusters are separated by great distances and the number of places where dense clusters have emerged is small compared with the number of broadly similar places having the required resources.

The literature reports clusters of HTEI in relatively small, isolated regions in nations which are not included in this research; Norway (Onsager et al, 2007); Denmark (Dalum, 1995); Sweden (Parker, 2006; Gausdal, 2006); Germany (Hassink and Wood, 1998; Parker and Tamaschke, 2005) and Canada (Parker, 2001). Horten, with population 26,000 is located 75 km south of Oslo and its high-tech cluster has 220 firms and 2,400 staff, with 1,700 employed in the electronics industry (Isaksen, 2003; Onsager et al, 2007; Gausdal, 2008).

Regions are important centres for innovation (OECD, 2011). The German cities of Dresden, population 523,000 and Jena, 105,000 (CityPopulation, 2010) are relatively small regions compared to the total national population and relatively remote from major populations.

Both of these small cities have dense clusters of electronics firms. The cluster in Jena specialises in optoelectronic systems (Hassink and Wood, 1998). The Dresden cluster which has a focus on semiconductor design and fabrication is also compared, in one of very few publications with the ICT cluster in Adelaide (Parker and Tamaschke, 2005). This comparison is discussed in Chapter 4.

Canada's Technology Triangle (CTT, hereafter) links four cities in Ontario; Waterloo, Kitchener, Cambridge and Guelph which have a combined population of about 500,000 centred around the University of Waterloo. The centre of the CTT is about 80 kilometres from the provincial capital Toronto with its population 5.4 million. The development of the CTT electronics cluster is described as an example of a 'bottom-up' or endogenous cluster development and is another example of a self-organised cluster of HTEI firms in a small community remotely located from major national populations (Parker, 2001).

In each of these five nations, Germany, Norway, Denmark, Sweden and Canada a cluster of HTEI firms developed endogenously in a small region which is relatively isolated from their major national populations. These five examples further demonstrate that clusters develop in 'small and isolated' places in other nations and that the phenomenon extends beyond the cities selected for the case studies in Chapter 4.

A further example of the location of a dense cluster of HTEI firms with a high proportion of its nation's HTEI is the small and isolated city of Christchurch, New Zealand. This city of about 350,000 people or 8 per cent of the national population is located on the sparsely populated and relatively remote South Island. It is noted that this cluster emerged endogenously in Christchurch and not on the more densely populated North Island which has 76 per cent of the nation's population and the great majority of the nation's industry.

While both Wellington, the national capital with 450,000 population and the nation's largest city, Auckland with 1.3 million people host many electronics firms, it is claimed that 50 per cent of all of New Zealand's electronics industry employment is located in the small, South Island, second tier city of Christchurch (Saunders and Dalziel, 2003; Tantrum, 2003).

The decision to locate HTEI firms in Christchurch was *"... overwhelmingly based on the family origins of the firm's principal"* (Brown and McNaughton, 2003a:115). The emergence and development of this isolated HTEI cluster is discussed in Chapter 4 and informed by data obtained through face-to-face interviews with HTEI firms and civic and government organisations.

The foregoing discussion provides an overview of the origin and development of dense HTEI clusters in particular places and their location factors can be summarised in four general groups as follows:

- The availability of trained and experienced staff and network colleagues
- The hometown of the founders of the early member firms of the cluster
- A Logical business decision
- A chance event or serendipity

Employment density in HTEI clusters is measured in the five principal case study regions and discussed in Chapter 4. These regional clusters have a high proportion of their national HTEI employment, expressed as Location Quotient (LQ, hereafter) using the formula of Haig (1927) which is discussed in Section 3.11

2.5.8 Endogenous Clusters in Other Industries

Established examples of endogenous clusters in other industries are reported in film making in Hollywood (Storper, 2008), software in Bangalore (Saxenian, 2002), finance in London (Nachum and Keeble, 2003) and automotive in Detroit (Klepper, 2010). These clusters have developed endogenously and matured over a wide range of time periods.

Brenner, (2004:107) states that the manufacturing industries in which clustering is now emerging are *"synthetic textiles, hot-rolling mills, textile machinery, washing machines, electronics, steel furniture, wool twisting, cotton spinning and weaving, linen processing, sugar, and tobacco"*, showing that clustering occurs naturally in a wide range of unrelated industries. However, some other industries appear to lag behind in their development of clusters, Casper (2007) notes that few successful clusters exist in the biotechnology industry. This may be explained by the relatively young age of this industry. While microbiological organisms in yeasts have been used in bread and beer making for millennia the modern biotechnology industry which uses related processes in making products for therapeutic applications only commenced in 1980. The first patent granted for a *produced* bacterium in USA was confirmed by the USA Supreme Court (Diamond v. Chakrabarty, 1980). Since the most successful endogenous clusters have taken from fifty and up to more than one hundred years to develop (Enright, 2003) the biotechnology industry has not yet reached that age (Feldman, 1994a). Biotechnology clusters are however reported in Boston and Washington, USA and Cambridge, UK.

Two of the four principal cluster examples in Porter (1990); ceramic tiles and printing machines are not overtly electronic. However, electronic systems provide the control and monitoring functions, and without these functions these industries could not operate efficiently. One of the four principal cluster examples in Porter (1990b), the USA cardiac monitoring equipment industry is a classic electronics design and manufacturing industry. The fourth cluster, the Japanese robotics industry uses electronics as a core 'enabling' technology along with electrical and mechanical systems.

The de-industrialisation of many regions in the second half of the twentieth century including Detroit and New England, USA and Birmingham, UK coincided with the growth of electronics and related technologies in Santa Clara (Silicon) Valley, Boston, Massachusetts and Cambridge, UK which Hall (1985) posits may herald 'a fifth Kondratieff' (Kondratieff, 1926).

The upswing of knowledge-age developments from the mid twentieth century across a broad front included aerospace, electronics, biotechnology, information technology, nanotechnology and telecommunications also brought the endogenous development of industry clusters in these fields, in regions which had limited prior industrial history including Cambridge, Silicon Valley and Austin.

These knowledge-age industries also flourished in the second half of the twentieth century in places that had a prior industrial history including New Hampshire and Massachusetts. Both of these States had a long industrial tradition dating from the eighteenth century with the development of textile industry clusters and later with the building of textile machines. The skills developed in these industries led to the later development of precision machine tools that enabled the mass production of complex mechanical consumer goods.

In the section headed Boston, in Chapter 4 the prior industrial history will be seen as an influence on the development of the region's electronics industry and a very different industry structure to that in Cambridge, UK (Segal Quince, 1985) and Silicon Valley with their limited prior industrial activity (Saxenian, 1994).

2.5.9 Created Clusters

The widely cited work of Michael Porter (1990b) has attracted the attention of economic development agencies, governments and industry organisations to the economic development value of the geographic concentration and collaboration of manufacturers, their suppliers, service providers and research institutions in *"...geographically proximate clusters."* The reported success of endogenously established clusters (Porter, 1990b; Storper (1993) has focused attention on the expected benefits of clusters as an economic development strategy (Storey and Tether, 1998; Perry, 2005).

A growing literature has emerged on the process of the 'creation' of clusters, based on the analyses of the successful performance of established, clusters (Fromhold-Eisebith and Eisebith, 2005).

However, it is noted that all of the clusters studied by Porter (1990b) had emerged endogenously, and were established at least for several decades to more than one hundred years and all emerged endogenously and developed through self-organisation, and notably without government planning or programs.

The created cluster process is also known as a 'top-down' process (Lyon and Atherton, 2000) which is typically planned, funded and often managed by government agencies (Fromhold-Eisebith and Eisebith, 2005). The motivation for the implementation of the 'top-down' cluster process is typically the desire to emulate the success of the widely referenced *'bottom-up'* endogenous clusters with Silicon Valley widely proposed as a desirable model (Martin and Sunley, 2003; Krugman, 1991; Castells and Hall, 1994; Montgomery, 2007). However, Mayer (2011:4) cautions that the Silicon Valley *model "... may represent the exception and not the norm."* Porter's work on clusters has also formed the basis of cluster development strategies in many European countries and the emergence of a growing global cluster advisory industry.

The results of the creation of clusters as a regional development strategy have been mixed with some government agencies reporting difficulties in implementing the ideas in practice (Atherton and Johnston, 2008).

While the central focus of this thesis is endogenous, self-organised HTEI clusters, for comparison a discussion is included, in Chapter 4 on the origin, development and the variation in the performance of endogenous clusters and clusters that were assisted, supported or created by government agencies in the Republics of Ireland and Singapore (Kuan, 2008; MTI, 2010). In both countries HTEI clusters have developed in large part through the attraction of foreign direct investment (FDI, hereafter), government MNC attraction and finance programs (Birkinshaw, 2000; Green, 2000; MTI, 2010).

In other regions including Northern Ireland and Scotland, clusters were developed through programs of the regional authorities. Scottish Enterprise (1998) reported that in 1997-98 electronics was Scotland's major growth industry, based largely on foreign direct investment (Botham and Downes, 1999; Lagendijk and Cornford, 2000). However, the investments of MNC's are also described as *"footloose capital"* (Commendatore et al, 2007).

The Research Triangle Park near Durham, North Carolina is an example of a successful science park with significant clustering reported (Link and Scott, 2003). The Park was developed near five universities, including The University of North Carolina at Chapel Hill, and North Carolina State University. The facility hosts more than 39,000 people in more than 170 companies, including MNC's IBM, Cisco, DuPont, GlaxoSmithKline, BASF and Bayer that were attracted by development programs.

While it may seem attractive to economic development authorities to bring companies and related research, marketing, finance and other entities together through a *'top-down'* process and despite good intentions, development workshops, and tax incentives and policies to attract foreign MNC's many of these plans fail in the long-term (Huggins, 2000).

2.5.10 Cluster Failure

Since the reporting of the concept of clusters by Porter (1990b) national, regional and local economic development authorities in many nations have attempted to *create* clusters to emulate the success of the clusters identified in many regions in the growing literature. While some 'created' clusters have survived, many have failed. Various modes of failure of 'cluster policies' devised and implemented by economic development organisations have been reported (Glavan, 2008). Examples include *"countless communities around the United States tried to clone Silicon Valley to accelerate their own growth rates, but these programs consistently failed"* (Bee, 2003:115). During the 1990s many regions attempted to create technology-based clusters, but the *'dot com crash'* in 2000 crippled many of these developments (Wallsten, 2004; Suire and Vicente, 2009).

Feldman et al (2005) quoting Wallsten (2004), show that the Texas Research Park at San Antonio was a '*notable failure'* and typical of many such attempts. This facility was constructed in the mid 1980s with an expectation of 50,000 employees and another 100,000 spin-off jobs over 30 years. In 1991 researchers were offered generous inducements to move to the facility (Culliton, 1992), but in 2003 it had only 300 employees (Wallsten, 2004).

Another example of cluster failure was a 'Defence Contractor Network' with 20 member firms, with 1,100 staff formed in 1995 in regional UK including British Aerospace, GEC Marconi and McDonnell Douglas and the Ministry of Defence. A network broker was appointed as its manager and paid from membership fees of the firms to pursue contract business for the members. It was later found that the target market did not exist and trust between its members was diminished, not developed (Huggins, 2000).

Despite large EU cluster development programs the results of a study of 43 European clusters indicate that most government policies have no significant impact on the growth of industry clusters. The clusters in that study operate on a wide range of industries including Optoelectronics, ICT, Pharmaceuticals and Biotechnology (McDonald et al, 2006).

Some highly promoted attempts also failed. In the 1960s New Jersey, Dallas, Texas and South Korea were targeted to establish a *'Silicon Valley'* style cluster and assisted by Professor Frederick Terman the *'Farther of Silicon Valley'* and David Packard, co-founder of Hewlett Packard.

Higher education institutions that resembled Stanford University were proposed, the objective was a replica model of Silicon Valley (Kargon and Leslie, 1996).

These well-resourced attempts to transplant the Silicon Valley model failed. The chosen sites lacked the networks and cooperation and the long period of parallel development and collaboration of the industry and University (Leslie, 2001).

Endogenous clusters can also fail. An example of the failure of a long-established endogenous cluster was the shipbuilding and the associated heavy engineering industry in Glasgow, Scotland. Checkland provides an example: "*The upas tree of heavy engineering killed anything that sought to grow beneath its branches"* (Checkland, 1976:12). This example shows that without the monitoring and understanding of regional authorities and their timely action that mature clusters can decline and fail (Menzel and Fornahl, 2010; Mayer, 2011; Ter Wal and Boschma, 2011). Glasgow had "*drawn to itself too little of the new industries, especially automobiles and electronics"* (Checkland, 1976:48).

It is prophetic that electronics was seen as early as the 1970s as a growth industry and one which could contribute to the sustainability of the economy of Glasgow. Electronics and particularly opto-electronics is now firmly established in Glasgow, but the clustering of local HTEI firms in Glasgow is not yet significant (Hendry and Brown, 2006).

Mayer (2011:28) notes that clusters move through four stages of development, the last of which is *"stagnation and decline"* and that all clusters - including successful clusters - must consider their own future and plan and work towards their own sustainability.

The cluster of minicomputer firms in the Boston region emerged around MIT in the 1960s and included Control Data, Prime, Data General, Wang and the highly regarded Digital Equipment Corporation (DEC, hereafter). None of these companies survived into the twenty-first century and in Chapter 4 the adoption of the *vertically integrated* structure of the prior industrial era in the New England region is discussed as a suggested reason for the failure of the minicomputer industry and its cluster (Bresnahan and Greenstein, 1999; Hamilton, 1996) and contrasted with the more successful open networking structure of Silicon Valley (Saxenian, 1994).

While the failure of some created clusters and the subsequent partial devaluation of the cluster concept, it is noted that the five clusters selected in the principal case study in this research are endogenous in their origin, self-managed and have developed over a period of a minimum of 50 to more than 100 years. The three in USA and UK are widely reported to be successful. The relatively unknown Adelaide and Christchurch HTEI clusters will be surveyed to quantify their performance in their small and isolated antipodean regions.

2.6 The Transition from Industrial-Age to Knowledge-Age Manufacturing

Through the nineteenth and twentieth centuries manufacturing in developed countries grew steadily, then fell during the great depression and surged again after the Second World War (Wyn, 1991). From the mid twentieth century a major focus of manufacturing was on consumer durables as developed economies evolved into *consumer societies*, fuelled by post war demand including homes, home appliances and vehicles (Szirmai, 2012). The goal was volume production, productivity and unit cost reduction. At that time the major influences on a manufacturing location were labour cost and unionism, followed in descending order of importance by taxes, proximity to customers; proximity to materials with labour availability the least important factor (Mueller and Morgan, 1962).

By the end of the twentieth century the manufacturing landscape had been substantially altered, as predicted by Bell, (1974) and many industrial-age plants in developed countries were uncompetitive and reducing their output or closing. Knowledge-work and the knowledge-age had arrived (Bereiter, 2002). While much of the focus of the twentieth century had been on mass production and mass consumption, Piore and Sabel (1984) show that advanced technologies and particularly, computer systems made *'flexible specialisation'* possible (Steinle and Schiele, 2002). Flexibility could not be accommodated by highly structured mass production systems; however, customisation and low-volume production are characteristics of the flexible specialisation which is the norm in the HTEI. While Mueller and Morgan (1962) found that labour supply the least important factor in the location choice of industrial-age manufacturers; in the twenty-first century HTEI the availability of skilled staff is the highest priority of HTEI firms (Hadlock, et al, 1991).

Manufacturing in advanced economies is now in transition from a reliance on industrial-age industry to knowledge-age industry and governments are encouraging industry to move away from low skill, low value-added products and practices (MacBryde et al, 2011). Since the mid twentieth century this transition has progressed through three waves of economic thinking (Kures and Wise, 2008): industrial recruiting and financial incentives; cost competition and scale economies to regional competitiveness innovation and clusters. Table 2.2 below illustrates the contrast in selected locational factors over time.

Table 2.2: Selected Locational Factors: Industrial-Age and Knowledge-Age

Industrial-Age Manufacturing (1)	**Knowledge-Age Manufacturing** (2)
• Labour cost (and unionism)	• Quality of life for staff and management
• Taxes	• Innovative people, ideas and technology
• Proximity to customers	• Availability-professional/managerial
• Land availability and cost	• Availability of appropriate premises
• Industrial climate	• Access to international airport
• Labour supply	• Access to local business services

(1) The order of importance of location factors to firms considering relocation (Mueller and Morgan, 1962)
(2) Survey of region-specific advantages to 140 high-tech firms in Portland, Oregon (Mayer, 2011:118)

Companies in the UK were encouraged by their government to move to high skilled, knowledge-intensive manufacturing (Porter and Ketels, 2003), while the *value chain* concept (Porter, 1985) is well understood there is no universal definition of '*high value manufacturing'* (MacBryde et al, 2011). However, the *high value* in this context is not a high selling price; the focus is on high '*value-added'* in the design and manufacturing process. In this context the design and manufacture of HTEI products adds significantly to the value of the inputs of labour, materials and overheads by the embedded IP in the product and the IP employed in the design and manufacturing processes. The selling price of a typical HTEI hardware product, with its embedded software is a significant mark-up on the input costs. This high margin is typically achieved through the ownership or control of the IP by the HTEI firms.

The BankBoston Report (BankBoston, 1997) discussed in Chapter 1 shows that the 4,000 MIT related firms produced sales revenue of US$232 billion, approximately equal to a gross domestic product of US$116 billion, or 50 per cent of the value of sales; an extraordinary high margin, by industrial-age standards.

In contrast the ex-factory price of a typical passenger motor vehicle produced in Adelaide returned approximately 1.5 per cent on the considerable investment in its research, development and design (Rankine, 1979). A characteristic of knowledge-age manufacturing is the substantially higher gross margins produced by low-volume, flexible specialisation in HTEI products compared to low return from high volume industrial-age manufacturing. The explanation is that the widely available knowledge of the technologies used in the design and manufacture of passenger vehicles forces their manufacturers to compete on price, based on volume, but increasingly, vehicle assembly is moving to low wage countries. The typically small volumes of HTEI products, their customisation, flexible manufacturing processes and their embedded IP provide higher margins and, importantly, with IP security a sustainability advantage for HTEI firms in high wage countries. Small volumes of highly complex products are less attractive to copyists than larger volumes of simpler products.

Productivity is measured as the monetary value of the output for each unit of time worked and in all knowledge-age industries, including the HTEI productivity is significantly higher than in industrial-age manufacturing and the gap is growing steadily. Between 1986 and 1992, the top 200 electronics companies worldwide improved productivity at a compound rate of 10 per cent per year, so that it doubled in those 7 years, as sales rose by 6 per cent per year (McKinsey, 1994a). In contrast the USA automotive industry productivity increased by 4 per cent per year from 1989 to 1994, so that it rose 30 per cent in those 7 years (Baudin, 1996). Freeman (1988) argues that the electronics industry has the highest growth rates in labour productivity and especially in the computer and the electronic components sectors. It was also found that structural change generally works in favour of industries with increasing productivity (Kruger, 2008). This effect is strong in the years since 1990, in the HTEI and *"… the impact of the computer revolution can be clearly identified"* (Kruger, 2008:407).

In a study of 24 industries in 39 countries Fagerberg (2000) found that while structural change has not increased productivity generally, in nations that have increased productivity that this was led by their electronics industry. "*Only in countries with an increasing share of the electronics industry was productivity growth noticeably higher"* (Kruger, 2008: 420).

The influence of electronics technology has also been positive on increasing productivity across many other industries where electronics is an '*enabling technology'*.

An important factor in the transition from the industrial-age to the knowledge-age was the invention of the transistor followed by the integrated circuit, microelectronics, microprocessors and solid-state memory. The development of these solid-state electronic components revolutionised the electronics industry and is a key to its productivity increases. Riordan and Hoddeson (1997) claim that the transistor is the most important artefact of the twentieth century. These developments have revolutionised electronics and the HTEI beyond the planning horizon of most governments since the mid twentieth century.

A major gap has opened up between industrial-age and knowledge-age production costs. The selling price of electronic products, such as computers has reduced steadily while the price of industrial-age products such as vehicles has risen steadily over time. This highlights a major difference between industrial-age and knowledge-age products and processes.

While the design cost of both computers and vehicles is high, the production cost of vehicles rises with wages, materials, transport and energy and other costs. Engine and transmission systems for vehicles are machined typically from cast or forged metals and economies of scale are essentially maximised and final vehicle assembly is relatively labour intensive.

The cost of *reproduction* of the major electronic components; microprocessor and memory chips is less influenced by material input costs and is reduced by the continuous increase in the volume of production and high levels of production automation. Microprocessors and memory chips are reproduced by imaging processes and as their design scale continues to increase, so their unit production cost continues to fall.

Gordon Moore a co-founder of Intel noted that the number of transistor devices on a single chip doubles approximately each two years (Moore and Davis, 2001; Hellman, 2003). Known informally as 'Moore's Law' this design advantage has kept the price of major electronic components, on a downward trajectory since 1970 and explains how the performance of computers continues to increase while their price continues to reduce.

Pavitt (1990) noted that since 1973 electronics firms have invested more in R&D than in plant and equipment. Electronics, together with aerospace, biotechnology, information technology, nanotechnology and telecommunications are industries of the *knowledge-age*.

This new era reached a milestone in 1991 when for the first time investment in USA in *knowledge-age* capital goods including computers, software and telecommunications equipment exceeded investment in *industrial-age* capital goods, such as electrical, industrial, mining, agricultural and construction equipment. Trilling and Hood (1999:7) quote Negroponte (1995) that investment in equipment that *"makes, manipulates, manages and moves bits and bytes of information has exceeded investment on equipment that performs similar operations on the atoms and molecules of the physical world"*.

However the rapid development of technologies has created a major problem for the HTEI and other knowledge-age industries and also for governments in classifying, measuring and legislating for their development, regulation and sustainability. This global problem is highlighted by Fagerberg (2000) and the difficulty caused by an inadequate system of classification and measurement of the performance of the electronics industry and other knowledge-age industries is discussed in Chapter 4. Industrial-age decisions were based on the need to gain *'comparative advantage'* through natural endowment factors including materials, rivers and ports (Smith, 1776; Ricardo, 1821). In the late twentieth century a new concept was introduced; *'competitive advantage'* (Porter, 1985) based on factors which are *created* by firms through their development and implementation of strategies. This concept aligns with knowledge-age industry objectives of creating new markets and employing IP as a created advantage across their operations.

Porter identifies one of the *created* factors in competitive advantage, the '*experience curve'* (1979; 1980; 1985) as a barrier to entry by potential competitors. Williams (1998) promotes '*renewable advantage'*. While 'comparative' advantage is essentially static and the result of external factors which are not readily controlled by the firm and also available to competitors, 'competitive' advantage is dynamic, controllable by the firm and can be managed by *continuous improvement* or *'kaizen'* as it is described in the Japanese management literature, with its particular emphasis on quality (Imai, 1986, 1997). While *"... a theory of location for high technology industry does not exist"* (Markusen et al, 1986:132), high technology industries are typically drawn to areas with good natural amenities that will appeal to their staff; and in particular, a pleasant climate, attractive housing at reasonable prices with good educational opportunities, specialized cultural and recreational opportunities and low levels of pollution (Markusen et al, 1986: 134-5). R&D activities tend to concentrate in only a few locations marked by significant agglomeration economies (Nijkamp, 1987; Glasmeier, 1988). In the knowledge-age the intellectual capital of the firm is its most valuable asset of HTEI firms, exceeding its physical capital value.

2.7 Electronics and the Automotive Industry

The transition from industrial-age manufacturing to knowledge-age manufacturing is illustrated by the important and growing relationship between the automotive and electronics industries. These two industries emerged independently at the end of the nineteenth century and grew independently until the latter part of the twentieth century when the first electronic systems were integrated into the purely mechanical and electrical automotive systems which had prevailed.

Electronic ignition and electronic fuel injection systems have provided the internal combustion engines with its largest improvement in fuel economy. These systems were followed by electronic emission control systems. Major automotive safety improvements have been achieved by electronic systems including anti-lock brake systems, electronic stability control systems and electronic actuation of airbags. Electronic collision avoidance systems which are now being introduced will further increase passenger and pedestrian safety while electronic battery management and control systems for electric and hybrid vehicles will further increase the use of electronics in the automotive industry.

In 2012 the global electronics industry supplied over 7 per cent of its annual output to the automotive industry (Custer, 2013) Electronic components and systems now comprise 20 to 30 per cent of total costs for all car categories, and this figure is forecast to reach 40 per cent by 2015 (Electro to Auto Forum, 2011). The automotive industry produced 74.1 million vehicles in 2010 worth approximately US$1.5 trillion (Custer, 2011) while the sales revenue of the global electronics industry was US$1.847 trillion in 2010 (Custer, 2011) and US$ 1,890 trillion in 2011 (OICA (2011) the future of these two industries is now inexorably linked.

2.8 Regions and Cities

A 'region' is defined as: *'an area, especially part of a country having definable characteristics but not always fixed boundaries'* (Oxford, 2008). Without an established boundary the population and number of employees in the HTEI cluster in a region cannot be determined so the region is not a precise unit of measurement.

A 'city' is a municipal area *'created by charter'* or *'incorporated by regional or national government'* (Oxford, 2008), within defined boundaries, so its population and employment can be measured. However, the *region* is important as the locus of the extensive 'regional innovation' literature which provides important insights (Storper and Scott, 1995).

The regional literature includes many concepts that are also applicable at the city level:

- The region was proposed, in the early 1980s as the basis of economic and social life "*after mass production"* (Storper, 1997b:3).
- For centuries, the fortunes of regions and nations have depended on new ideas and products to facilitate their economic growth (Feldman and Florida, 1994).
- The region is now the locus of untraded interdependencies (Storper, 1995).
- Polarization reversal: when regional spatial trends overtake the previously dominant national inertia (Richardson, 1980).
- Theoretical predictions that globalization will overtake economies of proximity have been exaggerated (Storper, 1995).
- Despite continued predictions of the *'end of geography'* regions are now important nodes of economic and technological organization (Florida, 1995:528).
- Since the early 1980s social scientists have increasingly focused on the significance of the region to the organization of economic life (Storper, 1995).
- A region must not have a determinate size (McCall, 2009).
- In the past twenty years economic geography has refocussed planning attention on the location of manufacturing in cities and regions (Krugman, 2010).

The finance and fashion industries thrive in large cities and *"Large urban areas and capital city regions dominate the creative and cultural industries."* (Power and Nielsen, 2010) and *"Creative industries tend to concentrate mainly around large and medium cities"* (Lazzeretti et al, 2009). The focus of this research, however, is the HTEI in selected second tier cities and Chapter 4 provides new data and analysis of selected parameters of the HTEI performance to measure clustering of the industry across selected small and larger cities.

In 'The Competitive Advantage of Nations' Porter acknowledges that *"While the book is set at the level of the nation, the same framework can and has been readily applied to the regional, state and city level"* (1990b: xi). The expansion of the title from 'nation' to the region, state and city is relevant to HTEI clusters which are typically located within cities. Porter also notes *"Geographic proximity of rivals raises interesting questions about whether a city or region instead of the nation is the proper unit of analysis"* (1990b: 156, Note 22). This clarification is important since the referenced work is titled: *'The Competitive Advantage of Nations'* however, a major finding of the study is that competitive advantage is primarily in the *"geographic proximity*" of regions and cities, rather than across nations. Pavitt (1984) describes a 'science-based' taxonomy, while Mayer (2011:8) analyses economic performance, talent, innovation and entrepreneurship providing five distinct types:

1. High-tech centres
2. High-tech challenger regions
3. High-tech hidden gem regions
4. Old economy regions in transition
5. Regions with no significant high-tech activity

The five clusters selected for the principal case studies will be examined to determine their placement within this typology. Austin, Cambridge and Silicon Valley may qualify for inclusion as *'high-tech centres'* on the basis of their reported performance, employment, innovation and entrepreneurship.

Both Adelaide and Christchurch may fit the typology of *'high-tech hidden gem regions'*. These two cities are the leading economic performer and leading employer in the HTEI, both having their country's highest proportion of HTEI employment. However, the economic and social value of the electronics industry in these two second tier cities is relatively unknown to their communities, which contrasts with Austin, Cambridge and Silicon Valley where the literature records a high level of recognition by governments and communities in each of these communities of the economic and social value of their HTEI.

A report on Tait Electronics Ltd., the largest HTEI firm in Christchurch shows its strong performance in employment, revenue and exports, but its HTEI is relatively unrecognised *"high-tech and competitive industries like electronics have not really been accepted"* (McCarthy, 2000:2). The HTEI in Adelaide is relatively unknown to its community and most press reports on business topics in Adelaide promote the mining, defence industries.

Speaking in Adelaide Professor Roy Green, a member of the Australian Prime Minister's Manufacturing Taskforce said *"...South Australia's capacity to make high-end products in defence, food production and electronics manufacturing would have more economic benefit for the State than the mining boom"* (Milnes, 2012). The 'Adelaide Advertiser' daily newspaper reported this statement under the headline "*Adelaide-An Electronics Hot Spot to Rival Mining"* (Advertiser, 2012). These reports suggest the applicability of *'hidden gem'* status to the HTEI in Adelaide and Christchurch.

2.9 Second Tier Cities

As introduced in Section 1.1, second tier cities are "*... those cities outside the capital city whose economic and social performance is sufficiently important to affect the potential performance of the national economy."* (ESPON, 2012a:2). This definition from the EU Research Report *'Why Do Second Tier Cities Matter'* is adopted for this thesis. A major element in this definition is the value of a second tier city to its national economy and this is demonstrated in all five of the clusters included in the principal case study in Chapter 4. This EU Report adds that second tier cities are "*not less important than capital cities"* and emphasises that they are *"not second class"* and not necessarily the second city in the country (ESPON, 2012b:1). Markusen and DiGiovanna (1999:3) describe second tier cities as: "*… spatially distinct areas of economic activity where a specialized set of trade oriented industries takes root and flourishes, establishing employment and population growth trajectories that are the envy of many other places."* They add that second tier cities are "*… entire metropolitan areas, spatially separated from primate cities"* (1999:10).

Mayer (2011) adopts this *second tier* description in her recent book which analyses the endogenous emergence and development of clusters of high technology firms in three USA second tier cities. Mayer confirms that endogenous development of technology clusters in second tier cities is a phenomenon that is not limited to the clusters analysed in this thesis. Markusen discusses the growth and status of second tier cities and asks why some can grow and "*successfully challenge primate cities"* while others do not (1999a: 21).

Mayer (2011: 29) analyses three USA high technology clusters in second tier cities and posits that "*Second tier high tech regions may represent a unique model of cluster emergence."* High technology sectors depend on knowledge spillovers (Audretsch and Feldman, 1996a, 2004) and geographic proximity is important in generating innovation (Danson, 2009). These factors are measured and reported in Chapter 4.

Sweeney (2004) agrees that the description of Markusen (1999) captures the characteristics of spatial distinction and activity specialisation and adds that this definition does not restrict second tier cities by size, but it *"does capture the notion that [they] are spatially distinct."* Sweeney posits that second tier cities possess a specialized set of activities "*paralleling the cluster concept in economic development"* and trade-oriented industries and wealth generation, both of which take root "*through attraction and growth"* in these communities (2004:1). Sweeney also observes that second tier cities have comparatively strong growth characteristics in terms of both population and employment and *"are characterized by the attraction of mobile capital and labor"* (2004:1).

The concept of '*mobile labor'* is illustrated by Richard Florida (2002), who reported that Austin Texas, in 1999 had 38 per cent of its private-sector workforce employed in high technology industries and a high proportion of these relatively young professionals had moved to Austin from other USA cities. Florida also relates the story of the young Carnegie Mellon IT graduate who moved from Pittsburgh to Austin to join a software firm because *"it's in Austin"* and "*I can have a life in Austin"* and not merely a job (Florida, 2002:217).

Overman and Ioannides (2001:543) note that "*Second-tier cities show more mobility than top-tier cities*" which aligns with Florida (2002) that the young, scientists and engineers are among the most mobile and will move to where the challenging and rewarding jobs are, if that place also offers the lifestyle they also seek (Florida, 2000). Major cities attract people in many fields, including fashion and finance, but second tier cities attract knowledge workers (Florida, 2000). The mobility of young engineers and scientists contrasts with the preference of many start-up entrepreneurs to locate their new business in their home town.

A relevant contribution to the topic refers directly to the question of *how* clusters in second tier cities develop: *"Second tier high-tech regions evolve and grow primarily through spin-off processes*" (Mayer, 2011:5) and importantly, that *"Little attention has been paid to so-called second tier high-tech regions."* (Mayer, 2013:1392).

During the latter part of the twentieth century investment and trade patterns and in some regions, government policies encouraged decentralisation in national economies disrupting the previous patterns of urban and regional growth (European Union, 2012). Many smaller or 'second tier' cities developed as spatially distinct places of economic activity where specialised, often technology-based industries have taken root and flourished *"… establishing employment and population-growth trajectories that are the envy of many other places"* (Markusen and DiGiovanna, 1999: 3). Examples of technology-based and growing second tier USA clusters include, Austin, Santa Clara/San Jose (Silicon Valley), Seattle and Albuquerque. In the UK this phenomenon is evident in Cambridge, Edinburgh, Glasgow and Belfast.

These characteristics were found in two second tier cities, Adelaide and Dresden (Parker and Tamaschke, 2005). Christchurch was also included in this group (Saunders and Dalziel, 2003; Tantrum, 2003). Growth in the electronics industry in second tier cities including Kyoto, Japan, population 1.45 million (Ibata-Arens, 2008) and Kumi, Korea, population 13,000 is outpacing growth in their national capitals (Markusen and DiGiovanna, 1999).

Malmberg and Maskell (1997) stress that regional economic advantage is derived from the existence of factors that prevent external competitors from imitating unique regional capabilities that underpin economic success. The four principal case studies in Porter (1990b) are focussed on cities where important clusters of manufacturing firms emerged endogenously over many decades. None of these cities is a major city in its host nation. This reinforces the concept that dense and successful clusters do form in second tier cities.

Second tier regions are distinct from '*non-core'* regions, a concept derived from the *core and non-core* nation concept in *World Systems Analysis* (Barfield, 1997) and *World Systems Theory* (Wallerstein, 2004). The non-core regions literature provides a range of descriptions of the concept but a universal definition of a 'non-core region' is elusive. Contributors to the non-core region literature include Arnoud Lagendijk (1999a), who defines non-core regions as *"regions outside the core urban agglomerations"* or, in terms of the OECD '*Regions Matter'* (2009) "*the 'runners-up' and peripheral areas"* (Lagendijk, 2011).

A summary of the two literatures places non-core regions at the margin of and dependent on larger cities while second tier cities are discrete, socially, physically and economically separate. The second tier city descriptor applies to the five principal case study regions selected for this research, Adelaide; Austin, Cambridge, Christchurch and Silicon Valley.

2.10 Electronics Industry Clusters in Second Tier Cities

The focus now narrows to HTEI clusters those small and economically independent places defined as *second tier cities* by ESPON (2012a:2), discussed by Markusen (1999a) and described by Mayer (2011) as '*second tier regions'.* Strong growth is reported in clusters of knowledge-age industries in second tier cities (Markusen and DiGiovanna, 1999:3). These small communities gain wealth and employment from knowledge-age manufacturing and *"generate, attract and anchor productive activity while others do not"* (Markusen, 1999a:21). *"Specialisation is common among second-tier cities in the USA and elsewhere"* (Markusen, 1999a:21). While clustering of knowledge-age industry is not confined to second tier regions, HTEI clusters have become economically significant in a sufficient number of second tier cities to justify their inclusion as a research category.

Case studies conducted by Mayer (2011) on three high technology clusters in second tier USA cities; Portland, Oregon; Boise, Idaho and Kansas City, Kansas found that all three small cities have dense technology clusters which emerged endogenously and developed strongly with positive measures in terms of entrepreneurship and economic development. Contrary to the established understanding of the reported role of university and industry relationships in cluster development (Berlin, 2005; Saxenian, 1994; Sturgeon, 2000) , Mayer finds that: "*a research university is not necessary to spur high technology industry and that the lessons Silicon Valley appears to provide us may be misleading"* (Mayer, 2011: 5). In the three case studies (Mayer, 2011) finds that *'large and dominant industry players'* were the major factors in the development of the regional high technology clusters.

Boise with a population of 206,000 specialises in computer peripherals and semiconductors and hosts a large Hewlett Packard branch plant, established in 1973 and Micron Technology *"the only company that still manufactures semiconductors in the US"* (Mayer, 2011:129). Less directly relevant to this research is the cluster in Kansas City which specialises in pharmaceutical manufacturing and contract research and animal health sciences (Mayer, 2011:178). Mayer's case study supports Markusen (1999a) in her study of the successful clustering of the high technology manufacturing industry, in a second tier city,

Further support for the value of the development of HTEI clusters in second tier cities comes from patenting activity. *"Portland and Boise are about as inventive as Boston, as measured by rates of patenting activity"* (Mayer, 2009:2). The case study in Mayer (2011), on the HTEI cluster in Portland, is highly relevant to this thesis. Portland is the location of branch plants of Xerox and Hewlett Packard and Intel and importantly, the head office of Tektronix Inc. (Mayer, 2011).

Tektronix is an electronic test and measuring instrument design and manufacturing company with an international reputation, particularly for its range of oscilloscopes which revolutionised waveform measurement.[5] Oscilloscopes available before the first Tektronix instruments had relatively less stable and uncalibrated time interval and amplitude displays and were used primarily for waveform *observation*. Tektronix introduced instruments in the 1950s with stable and accurately calibrated time interval and amplitude measuring capability which elevated the oscilloscope from the function of an *observation* device to that of a stable and accurate *measuring instrument*. Tektronix instruments have contributed significantly to the development of computers, and communications equipment and to the advancement of the high-technology electronics industry for over sixty years. In the 1980s Tektronix employed 24,000 staff and with about ten per cent of the city workforce dominated the high technology industry sector in Portland. Tektronix was the major contributor to the growth of Portland as a high technology electronics cluster.

Tektronix was founded in 1946 by two engineers from Portland who returned to the city after service in the Second World War (Porter, 1990b: 296; Mayer, 2011: 81). The technology capability and reputation of Portland surged when internationally known Intel opened its manufacturing plant in 1976.

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[5] While resident in Sydney, then later in Brisbane, and Adelaide this author was associated with Tektronix Inc. during the rapid growth in the company in the 1950s and 1960s.

Portland is a classic second tier, high technology city with 585,000 population and 58,000 high technology staff and an electronics industry LQ of 1.35 (Mayer, 2011:3).

A set of four important characteristics (Mayer, 2011:28) provide key insights into the emergence of clusters in second tier regions:

1. Triggered by chance (Porter, 1990b:124-126), including '*home town'* start-ups.
2. Entrepreneurship drives cluster growth - and the importance of '*the entrepreneurial spark'* (Feldman and Braunerhjelm, 2006:3).
3. Institutions and social structures ensure that the effects of the *'chance'* event and spin-off processes do not dissipate.
4. Clusters evolve through 4 distinct processes: emergence, development, maturation and specialisation, stagnation and decline.

The world metros of New York, London and Paris excel in arts, entertainment, media, fashion, business and finance, community and social services and government and administrative support. But, among computer professionals and mathematicians, and engineers and life, physical and social scientists, these cities are outclassed by the group of second-tier metros. *"These occupations form the heart of the 'high-tech' phenomenon"* (Markusen and Schrock, 2003: 9).

The concentration of these technical people in second-tier cities provides evidence that these cities *"are winning in a competition for high-tech activity against the world metros"* (Markusen and Schrock, 2006: 1308).

Scientists, engineers and technologists appear to shun the larger cities and concentrate in the 'second tier' cities, typically between 0.8 and 1.4 million, (Markusen and Schrock, 2006:1302) who describe these computer professionals, mathematicians, engineers, life and physical scientists as: *"... the heart of the so-called 'high tech' occupations"*. They add that *"... some urban economies are finding specialisations that enable them to thrive, while others are floundering"* (Markusen and Schrock, 2006:1301).

While high technology clusters, particular HTEI clusters including those selected for this research have prospered in a small number of second tier cities, some of these clusters have remained almost unnoticed for decades. However, the literature on the origin and development of the HTEI clusters in Silicon Valley, Cambridge and Austin is extensive and these clusters are included with Christchurch and Adelaide in the principal case study in Chapter 4.

The endogenous cluster development process has attracted the attention of a number of scholars of economic geography and regional development (Oakey, 1985, 1991, 1995; Porter, 1990b; Krugman, 1991 [USA]; Shefer, 1993 [Israel]; Lagendijk, 1999b [Europe]; Markusen et al, 1999 [USA]; Druilhe and Garnsey, 2000 [Cambridge and Grenoble]; Parker and Tamaschke, 2005 [Adelaide and Dresden]; Parker.2006 [Adelaide and Karlskrona], 2008 [Adelaide and Limerick].

The endogenous emergence of local industrial clusters in different places at different times and in industries with different characteristics *"are not isolated cases but general phenomenon of industrial organisation"* (Brenner, 2004:3). While it may be counter-intuitive, high technology electronics industry clusters have emerged in a limited number of second tier cities across nations and across time and this pattern can be described as a *phenomenon*.

2.11 Innovation

The term *innovation* is now widely used and the standard dictionary definition is: *'to make changes in something established, especially by introducing new methods, ideas, or products*' (Oxford, 2008). While this is an adequate definition of *incremental* innovation it does not deal with radical or "*disruptive innovation"* (Christensen, 1997) or the more extreme *'creative destruction'* the term used by Schumpeter (1942) and adapted by him from Marx (1867).

An example from consumer electronics of radical or disruptive innovation, which has led to creative destruction in the marketplace, was the introduction of the Compact [tape] Cassette developed by Philips in the early 1960s. This innovation was not incremental, but disruptive as it replaced the Bakelite or vinyl disc record as a medium for music reproduction. The disc record had replaced the first recording process, the cylinder and the Cassette was overtaken by another disruptive innovation, the compact disc (CD), which is now being overtaken by disk based and flash memory based devices.

Each of these developments was incompatible with its predecessor and disruptive, requiring new equipment. The foregoing discussion is consistent with the 'applied' concept of innovation *"Innovation, either product, process or organizational is the novel application of economically valuable knowledge"* (Feldman, 2000:373). Utterback and Abernathy define *'product innovation'* as: "*a new technology or combination of technologies introduced commercially to meet a user or a market need or a market"* (, 1975: 642).

As discussed in Chapter 1, *Innovation* is distinguished from *invention.* The distinction is that while the inventive step is the creation [the concept, discovery or theory], innovation is the implementation of that invention in a new or improved product, process or service. Many innovative electronic products and systems are not based on fundamentally new science, but on existing scientific knowledge or combinations of known technologies or concepts or the use of existing concepts in different ways to create new products and services.

New products and processes are more important to some national economies. The *consumer economy* of the USA relies significantly on the ongoing replacement of household, office and personal electronic devices and other relatively durable items, with new or higher performance products. The rate of new developments is increasing: "*Each generation now confidently expects to enjoy a higher standard of living than its predecessors"* (Deane, 1979:1). This observation on the Industrial Revolution it is equally applicable today.

Economics teaches that an emerging demand for a product or service will be satisfied in a free market by the supply of a new or modified product to meet that demand, however, Marshall quotes an early observation of the concept of the *creation* of a market from Roscher: "*a characteristic task of the modern manufacturer*,[is] *that of creating new wants by showing people something which they had never thought of having before; but which they will want to have as soon as the notion is suggested to them"* Marshall (1890: 280).

The electronics industry frequently offers products that have not been demanded by consumers. Successful examples of products for which there was no specific demand at the time of their introduction include the Sony Walkman personal music player introduced in 1979 and the Palm Pilot, personal data assistant in 1997 and the Apple iPod in 2001. These products were quickly taken up by technology devotees; the 'early adopters' and later by mainstream consumers. While these products were highly successful many other products have failed the '*market validation'* test (Adams, 2010).

The process of offering a product that has not been requested by a *demanding customer* is common in the electronics industry and in all knowledge-age industries and these products are based on a *latent* demand perceived or measured by the entrepreneur. This process is less common with industrial-age products. The earlier example of the transition from cylinder to disk, tape, CD and digital storage of music illustrates a progression through five stages of evolution, each of which was not demanded by consumers, but for which a latent demand was sensed by an entrepreneur or designer.

An empirical study found that innovation is unusually dependent on an area's technological infrastructure and proposed four measurable indicators: 1) number of firms in related industries; 2) university R&D; 3) industrial R&D; and 4) business service firms. (Feldman and Florida, 1994).

While it is said that *invention* is driven by necessity, this concept is challenged by Diamond (1997:242) who shows that many or possibly most major inventions were developed by people "*driven by curiosity or by the love of tinkering"* in the absence of any initial demand for the product they had in mind. Diamond supports this contention with examples. Inventions in search of a use include most of the major technological breakthroughs of modern times "*ranging from the airplane and automobile, through the internal combustion engine and the electric light bulb to the phonograph and the transistor"* (1997:242).

The laser could be added to that list, as it was initially theorised by Max Planck in 1900, the theory was confirmed by Albert Einstein in 1917 and first demonstrated in 1960 (Taylor, 2000:137). *"When the laser came in 1960 no one, except for a small group of physicists knew anything about its application."* Laser technology was a solution *"looking for its problem"* (Nobel, 2002). Innovation is the life-blood of all industry and a critically important factor in the sustainability of the electronics industry.

2.12 National Innovation Systems

The concept of a nationwide *system* of innovation and the term '*National Innovation System'* (NIS, hereafter), is credited by Lundvall (2007) to Freeman, whose 1982 OECD discussion paper was later published (Freeman, 2004). Freeman analyses how technological infrastructure differs between countries and how these differences are reflected in international competitiveness. Freeman and Lundvall attribute the NIS origin to the concept of '*mental capital'* of List (1841).

The NIS concept was described by Nelson as *"a set of institutions whose interactions determine the innovative performance…of national firms"* (Nelson, 1993:4) and defined more recently as "*all economic, political and other social institutions affecting learning, searching and exploring activities"* (Roos et al, 2005:2). NIS theory is well researched across a number of major economies (Freeman, 1974, 1982, 1987, 1995, 2004; Lundvall, 1992, 2007; Lundvall et al, 2011; Nelson, 1993, 2000a; Nelson and Rosenberg, 1993; OECD, 1997; Roos at al, 2005). The NIS in small economies, including Australia and New Zealand is analysed as an SME (Davenport and Bibby, 1999).

The application of NIS theory was further developed by Freeman (1987) through his analysis of the rise of Japanese industry, and particularly, the manufacture of semiconductors. At the time of the introduction of the NIS theory by Freeman in 1982 the electronics industry was producing stunning new developments.

The semiconductor, introduced some thirty years earlier and commoditised in USA had replaced the electron tube in most electronic applications and created new products and systems that were only possible with semiconductors, including microprocessors and solid-state memory. These developments were, examples of *'creative destruction*' (Schumpeter, 1942); the tendency to devise "*new and better ways of doing things"* and to put these into practice is an inherently human characteristic (Fagerberg, 2004:2) and practiced widely in the electronics industry.

In 1978 Dr Robert Noyce, a co-founder of Intel warned that Japanese semiconductor manufacturers were out-competing American manufacturers as they had done in the manufacture of portable radios, television receivers and in the steel industry (Berlin, 2005).

The Japanese electronics industry supported by its powerful Ministry of International Trade and Industry (MITI, hereafter), [Ministry of Economy, Trade and Industry (METI) since 2001] produced and successfully incorporated semiconductor devices in consumer and HTEI products including transistorised radio receivers since the 1960s.

European nations invest significant levels of research and development funds and now fill seven of the top ten places in global research and development investment, with Sweden and Finland in the top two places, based on investment as a proportion of GDP. The only non-European nations in the global top ten are Japan (number 3), Korea (number 4) with USA (number 6), Australia (number 11), (ABS 8112.0, 2010).

2.13 Regional Innovation Systems

There has been a focus on the study of national innovation systems since the introduction of the concept (Freeman, 1982), however it was not until 1992 that the term *Regional Innovation System* (RIS, hereafter) was introduced (Cooke, 1992, 2008).

The introduction of the concept of *'regional innovation systems'* was a response to the challenges facing economic growth in Europe, because of globalization and the decreased importance of the national state (Gausdal, 2006).

At the time of the introduction of the RIS concept other important developments were also seen in regions (Isaksen, 2001). The revival of the cluster concept (Porter, 1990a) and subsequent research addressed the importance of the region as the focus of science, technology and knowledge-age business (Andersson and Karlsson, 2004). The regional focus highlighted the importance of more localised cultural factors, including trust, cooperation, and social network relationships, which flourish in geographic proximity. A typology of regional innovation systems is now formulated, drawing on regional science and innovation studies (Cooke et al, 1998). Size and scale have relevance in the RIS context and Cambridgeshire and Oxfordshire are compared (Lawton Smith and Waters, 2005, 2011).

The HTEI in Cambridge is discussed in Chapter 4. Asheim and Isaksen (2002) examine how firms in the electronics industry in regions of Norway, previously dominated by shipbuilding and mechanical engineering now exploit both place-specific local resources as well as external, world-class knowledge to strengthen their competitiveness. Asheim and Isaksen (2002) find that external contacts, beyond the local industrial milieu, are crucial in innovation processes in many SMEs where place-specific and often non-economic factors apply in creating competitive advantage (Asheim, 2001). This aligns with Porter's argument that enduring competitive advantage in the global economy is in local knowledge, relationships and motivation *"that cannot be matched by distant rivals"* (Porter, 1998a: 78).

Time-to-market for new products in Australia was less for small, agile and interconnected regional firms than larger firms and in China research and development is moving towards the private sector in township/village enterprises from large state-owned laboratories, capitalising on regional specialisation (Turpin and Garrett-Jones, 1997).

2.14 Local Innovation Systems

While the evolution of the regional innovation systems concept from the national innovation systems concept is well developed in the literature (Cooke, 1992), the evolution of the next derivative stage, the *local innovation system* (LIS, hereafter) is less studied. However the linear relationship of the regional innovation system and the local innovation system has been established (Gregory, 1993). The relationship between 'industrial districts' and LIS's is also established by Muscio, (2006:776) "*... in some cases, industrial districts may be considered as local innovation systems with independent innovation patterns."* Martin and Simmie (2008) discuss path dependence and local innovation systems in city-regions and focus on the development of the technology industry in small cities. In Cambridge they note its unique university and business culture where no prior major industry or entrenched business or industrial cultures had existed. This development in Cambridge is further discussed in Chapter 4. Bathelt et al, describe the "*local buzz and global pipelines"* (2004:42) to illustrate the advantages of localised operation and globalised relationships.

A further illustration of the concept of *local base and global reach* is provided by McKinsey (1994b) in *Lead Local, Compete Global,* identifying high value-adding manufacturing in Adelaide which is the location of many HTEI firms and showing that employment growth rates in some smaller Australian cities are four to five times faster than those of Sydney (4.63 million) and Melbourne (4.14 million) (ABS 3218.0:2011).

Another view suggests that: "*Over time the interrelationships between local economic structure and innovation determine the path dependent economic trajectories of city economies relative to one another."* (Martin and Simmie, 2008:183). The vigour and dynamism of local economies depends on the ability of local firms to adapt to changing markets within their local innovation system (Storper and Scott, 1999).

A study in twenty-two locations in six countries identifies the role of universities in local industry development (Lester, 2005). This study, which is highly relevant to this research found that the most important contribution of universities to local communities is the provision of education followed by the informal role of universities as *'a public space for ongoing conversations, involving local industry practitioners, about the future direction of technologies, markets and local industrial development'.* Leslie (2001) adds that the '*public space'* role of universities which is frequently underestimated is likely to be more important than their direct contributions to local industry problem solving. However, in a contrary view the role of the research university in the development of local technology-based firms and clusters is found to be overstated in a study of three innovative USA regions (Mayer, 2011). Confirmation of the *'local'* factor is provided by Krugman "... *the most striking feature of the geography of economic activity… is surely concentration*" (1991:5).

2.15 The National Innovation System in Australia

In Australia, the Federal and State governments share constitutional responsibility for science and innovation policy (Garrett-Jones, 2004). The distinctive characteristics of the Australian national innovation system are a modest overall level of science and technology expenditure, a high level of government involvement in financing and undertaking research and an exceptionally high dependence on foreign technology. A structural feature of this system, during the twentieth century is that Australia's small population and high wages led to a tradition of small scale manufacturing.

As a result of high costs, manufacturers of industrial-age products found it difficult to export and to compete against imports. The manufacturing sector was directed almost exclusively to the small home market, large segments were protected by tariffs. As a result of these factors, until recently, there was a low level of private sector innovation (Gregory, 1993: Marceau and Manley, 2001). These observations were made at that time primarily on industrial-age R&D and products, and a recent study indicates that while the large economies such as the USA, Japan and Germany are among the global leaders, the most advanced innovation systems are now found in smaller countries (in terms of population) such as Australia, Sweden, Denmark and Norway (Fagerberg and Srholec, 2008).

At the end of the 1980s, about 80 per cent of Australian exports were primary products, approximately half from the rural and half from the mineral sector.

GDP per capita was still relatively high, although in the 1980s was about 10 to 15 per cent less than the USA. The manufacturing sector was small scale, accounting nationally for 16 per cent of GDP, and less than 10 per cent of its output was exported. Manufacturing was protected by an average tariff rate of 19 per cent in the early 1990s and now the effective rate is minimal and Australia continues to import most technology. The Australian government "*remains important and dominates tertiary education, R&D expenditure"* (Gregory, 1993: 325).

Exports of Australian HTEI products increased steadily from the 1980s to the late 2000s, but have been slowed by the rising value of the Australian currency from around 50 cents to the US dollar in 2001 to 70 cents by 2009 to parity and above in 2012. Government policy and incentives on innovation have not overcome the downward pressure on exports caused by the steady rise in the Australian currency.

Import tariffs influence innovation and tariff rates have varied greatly since the federation of the six Australian States into the Commonwealth of Australia in 1901. Tariffs were set initially at an average of 30 per cent, and rose to over 60 per cent in the early 1930s and were still over 30 per cent in the early 1980s, but had fallen to an average below 10 per cent by 2000 (Lloyd, 2007).

The downward movements in import tariffs since the 1980s has exposed Australian manufacturers to increased foreign competition resulting in some business failures, increased innovation intensity and improved product design and manufacturing processes, particularly in the electronics industry.

Table 2.3 (below) shows that private business investment in R&D in Australia by 2009 reached 62 per cent of the national total, whereas it was below 50 per cent until 2003. Although Australia has improved its innovation capacity and intensity over time, it has not done so as fast as key international competitors (Gans and Stern, 2003).

Table 2.3: Australian Research and Development Investment, A$ millions (2008-09)

Australian Government	State/territory Governments	Higher Education	Private Business	Private Non-profit	All R & D Total
2,252	1,169	6,717	16,858	744	27,270

Source: ABS 8112.0, 2010: Research and Experimental Development, All Sectors, Australia, 2008-09

Australia's national industry development program is currently led by the Federal Government's A$9.4 billion (2011-12) *'Powering Ideas: An innovation agenda for the 21st century'.* The Australian Government invests in research, through national bodies including the Commonwealth Scientific and Industrial Research Organisation (CSIRO, 2003), (CSIRO, hereafter) and specialist bodies, including the nation's largest defence research facility DSTO, which beneficially for the Adelaide HTEI is located in that city.

Total R&D investment in Australia in 2009 was 2.21 per cent of GDP, which placed Australia 11th in global R&D investment, behind the leaders, Sweden with 3.75 per cent and USA at 2.77 per cent and ahead of France at 2.02 per cent and UK at 1.77 per cent (ABS, 8112.0: 2010). For the high technology industries in Australia to grow, increased expenditure will be required on R&D and technologically sophisticated machinery, as well as innovations in organizational structure, marketing and distribution (Nelson, 1993).

2.16 Regional Innovation Systems in Australia

The Australian (central) Government, with its vastly larger budget has tended to overshadow the States both in funding and research and innovation policy. But we may now be seeing the rebirth of regionalism at the State level, in government support for science, technology and knowledge-based industries, (Garrett-Jones, 2004).

The large size and small population of Australia provides governments with challenges. Australia is almost twice the land area of Western Europe, but sparsely populated with only 23 million people and compared with USA, which has about 20 per cent more land area and a 2013 population exceeding 310 million. The continent of Australia contains the largest desert region in the southern hemisphere and a high proportion (around 70 per cent) of the Australian continent is arid or semi-arid (ABS, 1301.0: 2006).

A total of 65 per cent of Australia's people is concentrated into five mainland coastal State capital cities. Adelaide the smallest of the mainland State capitals has 73 per cent of the South Australian State population, the most urbanized concentration in any Australian State (ABS 1345.4 (2011).

Australia's State capital cities are spaced a minimum of 700 km and up to 2,500 km apart. However this isolation has facilitated regional specialisation. Improved transport and communication has reduced the effects of isolation, but the distances and inter-state rivalries are a significant barrier to intercity collaboration and during the second half of the twentieth century the electronics industry in each of the State capitals and in the National capital, Canberra developed divergent specialisations.

Canberra and Adelaide have a significant focus on defence electronic systems, with Adelaide capitalizing on the location of the DSTO defence research facility and with the Defence Force headquarters in the national capital, Canberra. The HTEI in Melbourne with the head office of the national telecommunications carrier Telstra and previously its research laboratories has a focus on telecommunications, optoelectronics and photonics. Ford, General Motors and Toyota all have design and manufacturing facilities in Melbourne and automotive electronics has been a major industry focus. However in all three have announced closure plans. Sydney has HTEI firms specializing in telecommunications, wireless and medical applications, while Brisbane has expertise in microwave, power systems and monitoring. Perth on the west coast is the most isolated State capital, 3,300 km from Sydney and specialises in communications and mineral processing and control systems, responding to the demand of its large mining sector (AEEMA, 2005).

The pattern of growth of new industries and the decline of old industries is uneven across regions. *"Some regions gain jobs and some miss out or even lose employment"* (Beer et al, 2003:108). Examples of new industries developing in unexpected places include Silicon Valley "*which grew out of an agricultural region"* (Beer et al, 2003:128), who ask *"Could something similar happen in Australia."* Importantly for this thesis, these authors note: *"There are very few studies that examine the location of these [new high-technology] industries."* (Beer et al, 2003:130). The phenomenon of the HTEI cluster in Adelaide may not have been evident ten years ago but, Chapter 4 will show that this cluster although still relatively unrecognised is now firmly established and developing steadily and with recognition and supportive government policy this cluster could be a sustainable and valuable contributor to the economy of Adelaide and Australia.

2.17 The Role of Government in HTEI Cluster Development

The principal focus on cluster development in this thesis is on clusters which emerged through the *'bottom-up'* or endogenous processes. Section 2.5.5 introduced the role of government in the *'top-down'* process of the *creation* of industry clusters (Fromhold-Eisebith and Eisebith, 2005). The government role of HTEI cluster development will be discussed in relation to Ireland, Northern Ireland, Scotland and Singapore in Chapter 4.

Governments have an important role in the *development* of endogenous clusters that emerged through the '*bottom-up'* process. Development in this context refers to the stage beyond *emergence* and applies to the ongoing or *growth* stage as described in the four distinct phases of cluster development; *emergence, growth, maturation and specialisation and stagnation and decline* (Mayer, 2011: 28). A major role of government is to promote and to regulate finance, industry and trade. Both the level and the form of government involvement vary across nations. The governments of Ireland and Singapore have been proactively involved in the development of their HTEI, typically through MNC attraction.

The UK with EU membership has applied regional development programs to the HTEI in Scotland, Northern Ireland and Wales for decades. The New Zealand Government followed a more interventionist policy in the past and is now less involved at the national level and many industry development functions now operate in regions. Chapter 4 will discuss the effect of these policies on the development of the HTEI in Christchurch. The USA government has a limited national influence on the HTEI and some industry organisations are active in States and regions. Australia has national policies and programs and State-based industry development programs and few active industry associations.

A major role of Governments in Australia, Ireland, New Zealand, Singapore, UK, USA and across Europe is the collection, analysis and dissemination of statistical data on all industry and including manufacturing industry. It important for this research that these data are collected at national and regional level and in some cases, at city and local level, however, collection methods, availability and the value of data vary across nations and regions.

Classification systems vary across nations. The USA uses the 'North American Industry Classification System' (NAICS, hereafter); the UK uses the 'Standard Industrial Classification' (SIC, hereafter) and Australia and New Zealand use the 'Australian and New Zealand Standard Industrial Classification' (ANZSIC, hereafter) (ABS 1292.0, 2006) All of these systems have a major challenge: knowledge-age industries evolve faster than the statistical systems can create new classifications (Porter, 1996).

While industry classification systems vary across nations, three categories are broadly comparable across UK, USA, Australia and New Zealand. These classifications describe and differentiate these groups of electronic equipment under the ANZSIC system:

2419: Professional and Scientific Equipment Manufacturing
2421: Computers and Business Machines Manufacturing
2422: Telecommunications, Transmitting and Receiving Equipment Manufacturing

However, all other manufactured electronic systems, products and components that are not included in the above three classifications are treated rather differently by the national classification systems, with the greatest contrast between the NAICS and ANZSIC systems.

The six digit NAICS system publishes a comprehensive range of separate classifications which includes more than 60 sub-classifications for all other types of electronic equipment and components, not included in the above classifications, with separate numbered categories which include, inter alia: *amplifiers, capacitors, printed circuit boards, inductors, semiconductors.*

In contrast ANZSIC records all of the above and more than 50 other categories of manufactured electronic equipment and components that are not included in the three above classes are published in one category '*Class 2429: Other Electronic Equipment Manufacturing'.* With only one code number for the public reporting of such a wide range of manufactured electronic products and components the government and industry can have only a limited understanding of the capability and capacity of the Australian HTEI.

It is estimated that more than half of the output of the Adelaide HTEI is classified under ANZSIC 2429 as *'other electronic equipment manufacturing'* which provides no data on specific products, just a single figure for what is disaggregated and published online in great detail under the USA NAICS system (EDD, 2012). With such a coarse-grain system the many, small-size creative enterprises are *"well off the economic developer's data-driven radar screen and omitted from standard industry databases, and therefore unnoticed"* (Rosenfeld, 2004: 893).

Talented, trained and experienced people are a major requirement of HTEI cluster firms and where regions are known by governments and communities as "*High-tech regions"* (Mayer, 2011:8), the economic value and employment opportunities are also generally well known to the community and importantly, to students who will be the industry's future employees.

Regions including Austin, Cambridge and Silicon Valley that are included in the *'High- tech regions'* (Mayer, 2011:8) category have a generally high level of government and community recognition of the industry, so the information on careers in the industry is continuous and effective and the value of the industry is frequently promored in the media. However, the situation appears to be very different in regions where there is a low level of industry recognition, including Adelaide and Christchurch. These two regions are included in the principal case study which will determine the level of government engagement in their respective HTEI and to identify opportunities for government to engage in the further development of the HTEI in these regions for the benefit of their communities.

Adelaide and Christchurch appea to fit the "*High-tech hidden gem region"* typology (Mayer, 2011:8) and the lower levels of community recognition of the HTEI in these two cities requires government promotion of the economic, social and employment value of the industry. This promotion does not require paid media advertising and the value of HTEI can be promoted to the community through government's existing industry strategic planning and development processess at minimal or at no additional cost.

Regional governments in some cities which have successful endogenous industry clusters do not yet understand the present and future value of these new industries. Montgomery (2007: 29) argued that the past fifteen years have been crucial in shaping the economic urban geography of the next fifty years, and that the next two to three years will also be crucial: *"…if your city hasn't made its move yet, it's almost too late to start."* Montgomery quotes Jane Jacobs (1969) who noted that within cities a conflict exists between people whose interests and understanding are with established economic activities and those whose interests are with the emergence of new economic activities. It is this latter group where local and regional government can assist and where a significant benefit could be created at little cost. Where established interests predominate, to the detriment of the new, *"then only stagnation can follow*" (Montgomery, 2007: 29) who lists cities including Adelaide, Chicago, Glasgow and Pittsberg in this category. In cities where new activities predominate, economic growth will result and Montgomery (2007: 29) lists cities including Austin, Dublin and Seattle in this category.[6] Mayer notes that Boise, Idaho has been transformed into a knowledge-based regional economy through the development of its HTEI industry: "*but its local and state policy makers are reluctant to embrace this new type of economy"* (2011:11). The lack of community and government recognition is a common problem for the HTEI in many second tier cities, including Adelaide and Christchurch.

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[6] John Montgomery was appointed Adelaide *'Thinker in Residence'* in 2002.

2.18 The Role of Major Organisations in HTEI Cluster Development

Three of the regions selected for the principal case study are widely reported as successful HTEI cluster regions. The literature shows that a major local intuition has been a central factor in the emergence and development process. In these three regions the major local organisation is a research intensive university. The role of Stanford University in the development of Silicon Valley is widely reported (Morgan, 1967; Saxenian, 1994; Sturgeon, 2000; Lecuyer, 2007). The relationship of the University of Cambridge and the Cambridge HTEI cluster is also well documented (Segal and Quince, 1985; Cattermole and Wolfe, 1987; Keeble, 1989; Heffernan and Garnsey, 2002; Athreye, 2004). The role of the University of Texas at Austin is also well documented (Kleiner, 1983; Smilor et al, 1989; Oden, 1997; Henton et al, 1997; Engelking, 1999b). In Austin, the development of its HTEI was also greatly assisted by the establishment of two national research institutions and by the *'civic entrepreneurship'* of its Chamber of Commerce (Henton et al, 1997).

However, in two of the case study regions the major influencing organisation was not a university. In Christchurch the major influence was a large privately owned electronics company (Green, 2005) and in Adelaide the major influence was the large Federal Government funded defence research establishment (Morton, 1989). The nature of the influence of these major organisations in HTEI cluster origin and development of each of these five cities is discussed in Chapter 4.

2.19 The Role of Individuals in HTEI Cluster Development

The literature shows the critical role of a small number of individuals in the emergence of electronics clusters in a number of global cities. Stanford Professor Frederick Emmons Terman is highly regarded world-wide by a generation of students of electronic engineering or *radio engineering* as it was known until the 1950s - for his textbook *'Radio Engineering'* (Terman, 1932). His involvement in the early events that led to the development of Silicon Valley was unknown to the community at the time. Terman's role is widely reported (Morgan, 1967; Saxenian, 1994; Tajnai, 1996; Sturgeon, 2000; Malone, 2002). Horace Darwin and the role of his Cambridge Scientific Instrument Company in the establishment of the HTEI cluster in Cambridge is well researched (Segal Quince, 1985; Cattermole and Wolfe, 1987).

The role of Angus Tait, who was knighted in 1990, is well researched and his founding of Tait Electronics is credited with the key role in the emergence of the HTEI cluster in Christchurch (Green, 2005).

The origin of the HTEI cluster in Austin is generally attributed to the founding of Tracor Inc. and its development to individuals and particularly Dr George Kozmetsky and Mayor of Austin, C. Lee Cooke and their roles in the attraction of two national research and development facilities to Austin.

These events are discussed in Chapter 4 in separate accounts of the emergence and development of each of these five principal clusters. No one individual or firm is credited with the origin of the Adelaide HTEI cluster, however, the establishment of the DSTO in 1947 is suggested as a catalyst in its origin and development.

Individuals and small enterprises provide much of the creative content and the competitive advantage not only in their own field, but also to more conventional cluster firms, "*including electronic products manufacturers"* (Rosenfeld, 2004: 893). Florida (2002) argues for a new way of define the growing number of people associated with the knowledge-based economy.

2.20 Path Dependence

Arthur (1983a; 1983b) identified the seemingly small historical events that can determine the path of the adoption of technologies and advanced the concept of 'path dependence'. A path-dependent process can influence economic outcomes "*by chance rather than systematic forces"* (David 1985: 332). Economies are irreversible historical processes in which future outcomes depend on past events and outcomes (Martin and Simmie, 2008).

The tendency for past practices and technologies to gather and retain users regardless of potentially superior alternatives is demonstrated in the virtual standardisation of the QWERTY keyboard (David, 1985), the VHS video system (Liebowitz and Margolis, 1995) and widely used business software. Krugman (1998:16) notes *"the persistent effects of historical accident via 'path dependence …'"*

The development of new technologies in a region can influence the divergence of a regional economy from the national pattern. The sectoral development of city economies evolves over many decades in a path dependent manner and *"as a consequence influence the scope and scale of future development"* (Martin and Simmie, 2008:183).

The evolution of a local economy rests on the interaction between irreversible local economic history and the capacities of local firms, organisations and institutions to absorb and adapt new technologies and, *"for cities that are forging ahead, like Cambridge in the UK, these relationships are largely positive."* (Martin and Simmie, 2008:192).

Based on Arthur (1989) and David (1994), Martin and Simmie (2008) identify four phases of path dependent evolution of an industrial sector in an urban or regional economy:

1. a pre-formation stage
2. a path creation phase
3. a path lock-in phase, and
4. a path dissolution phase

These four phases have important similarities with the four stages of cluster development observed by Menzel and Fornahl (2010) and Mayer (2011) and discussed in Section 2.5.2.

The economic trajectories of the cities included in case studies in Chapter 4 depart from those of other cities in their nations and show higher returns and employment growth rates in their HTEI. Divergence from the national norm in these regions is traceable to individual events which will be discussed and their value to these communities will be measured and evaluated in Chapter 4. As Page (2006:87) notes *"history matters"*.

2.21 Triple Helix: Industry, Research and Government

The *triple helix* concept was named after the structure of DNA to illustrate the intertwined nature of the relationship of industry, research and government (Leydesdorff, 1995; Leydesdorff and Etzkowitz, 1996).

The core of the triple helix concept is the relationship where universities perform a hybrid role that overlaps with the traditional roles of industry and government. The role of Stanford University in the origin and growth of Silicon Valley is widely reported (Saxenian, 1994; Berlin, 2006). In both Austin, Texas (Williams and Gibson, 1990), and Cambridge, UK (Segal Quince, 1985) the universities collaborated with local firms, from the early development years of their clusters, and before the regional governments became engaged in the triple-helix relationship.

From various places around the globe there is a movement towards a new model for the management of knowledge and technology (Etzkowitz and Leydesdorff, 1997). Universities in increasingly knowledge-based societies can assume an active role in innovation and in regions lacking effective or interested governmental structures, universities can bring together entrepreneurs, businesses and government through their '*public space'* role (Leslie, 2001) into customised local versions of the triple helix concept to fashion innovation strategies and foster new projects (Etzkowitz, 2002).

2.22 Untraded Interdependencies

The history of this concept is discussed by Storper (1995) and the *region* is identified as the locus of '*untraded interdependencies.'* Storper (1997b) attributes the formal origin of the term to Dosi in 1984 and Lundvall in the 1980s. The unintended circulation of trade information was reported by Adam Smith (1776:59). Tacit knowledge circulates informally within clusters (Tallman et al, 2004) and is described as one of the reasons for the success of Silicon Valley (Saxenian, 12994).

The movement of employees between companies (Saxenian, 1994), or '*job-hopping'* in Silicon Valley increases the likelihood that *"knowledge acquired in one firm is employed in another"* (Fallick et al, 2006). Henry et al (1996) illustrate the flow of untraded interdependencies in the circulation of codified and tacit knowledge - much of which concerns electronics systems - in the motorsport cluster in Northamptonshire, UK. Informal discussions by engineers and scientists at the office or after-hours is a noted method of exchange of knowledge in electronics clusters (Saxenian, 1994).

Japanese firms view formal, codified knowledge as merely the tip of the iceberg; knowledge is felt to be primarily tacit, and tacit knowledge is highly personal and hard to formalise, making it difficult to control (Nonaka and Takeuchi, 1991).

The tacit nature of relations lie at the heart of specialised urban agglomerations (Storper, 1995), and *what* is done and *how* it is done creates "*geographical differentiation"* of wealth and growth of regions (Storper, 1997b:5).

2.23 Proximity and Isolation

Proximity is a major topic in the regional development, cluster and economic geography literature (Lagendijk and Lorentzen, 2007). Geographers emphasise the importance of spatial proximity to innovation (Hall et al, 1985; Nelson, 1986; Markusen et al, 1986; Malmberg and Maskell, 2002). Presutti et al (2011) emphasise the social and cognitive dimensions of proximity on high technology start-ups.

Varga (1998, 2000) shows the significant proximate association between university research and high technology innovation in USA States and metropolitan areas and Gertler (1995) and Boschma (2005) report the level of university research to be positively and significantly related to the R&D intensity of an industry.

Recurrent themes in the literature include the role of proximity in relation to entrepreneurship (Sternberg, 2007), clusters (Torre, and Rallet, 2005), trust (Bruneel et al 2007), technology transfer (Gibson et al, 1994) and the value of face-to-face contact in innovation (Jonsson, 2002). Storper and Venables (2003:1) offer four features of face-to-face contact as key industry development factors:

1. It is an efficient communication technology
2. It can help solve incentive problems
3. It can facilitate socialization and learning
4. It provides psychological motivation

Storper and Venables (2003:1) also state "*... existing models of urban concentrations are incomplete unless grounded in the fundamental aspect of proximity; face-to-face contact.*"

Isolation in the economic geography was introduced by Thunen (1826) and in the related literature is commonly joined with the topic of *peripherality.* Peripherality (Harrison and Hart, 1990; Lagendijk, 2000) and non-core regions (Lawson, 1999; World Bank, 2011) are also two commonly related themes in this literature. Non-core regions are defined as "*the 'runners-up' and peripheral areas*" (Lagendijk, 2011:1). Redding and Venables examined the "*economic implications of isolation and remoteness*" and its negative effects (2002:93).

However, is noted here that *'non-core'* regions are not *'second tier'* regions. Section 2.10 above shows that second tier regions are *"not 'second class"* (ESPON, 2012a:2), furthermore, second tier regions are the location of the most successful global HTEI clusters that are surveyed as described in Chapter 3 and discussed in Chapter 4

Considered separately *proximity* and *isolation* have divergent meanings. The definition of proximity includes *nearness* and the definition of isolation includes *separation* (Oxford, 2008). However, *proximity* and *isolation* can be seen in a dyadic relationship to interpret the factors that positively influence the development of HTEI clusters in relatively small and remotely located second tier cities.

Because of their small size and their *isolation* from major populations and because of their comparative shortage of resources, HTEI firms clustered in second tier cities typically turn to the firms, organisations and colleagues in their *proximity* for technical and business support and collaboration on industry and other issues of common interest.

While HTEI cluster firms in second tier cities are isolated from the wider resource opportunities available their remote peers in major cities, cluster firms in smaller communities are typically more closely connected to and more mutually reliant on fellow cluster members and generally proactive and protective of their relationships with the relatively limited number of available collaborators. *Isolation* from major populations can drive beneficial clustering and collaboration with firms in their *proximity.* In practice "*... distance, proximity, isolation and connection materially shape a political economy of creative industry production"* Gibson et al, (2010: 25).

The limited literature on this topic includes the observation that the balance between physical proximity and isolation in human economic relationships is not yet understood (National Research Council, 1994).

An important observation on collaboration states*; "Human interaction when people are physically proximate has a characteristic quality of interactive information transfer that is intrinsically difficult to duplicate via telecommunications"* (Niles, 1998:132).

A focus on the physical isolation, of an island community approaches the concept by linking isolation and innovation: *"**Isolation**, as the history of so many island cultures shows, breeds **innovation**. When you are out of the mainstream and dependent on your own skills for growth, **innovation** is fundamental"* [author's emphasis retained] (Mercury, 2004).

Knowledge developed in a cluster flows more easily within it "*but more slowly outside and across its borders"* (Dahl and Pedersen, 2004:1673), who also find that engineers do share even quite valuable knowledge with informal contacts, showing that these contacts represent an important channel of knowledge diffusion. Short distances facilitate knowledge and information sharing (Camagni, 1991). A practical example of this finding is that shorter commute distances and lower traffic densities in second tier cities can facilitate the increased frequency and length of face-to-face meetings which typically assists collaboration and the development of trust.

Industry meetings attract proportionally larger numbers of company owners and managers in Silicon Valley, but high attendances were not found in the larger cities, Los Angeles or Boston, "*where companies are widely scattered"* (Bylinsky, 1976:67).

More productive networking is suggested in the HTEI clusters in the five small and isolated second tier cities surveyed in the principal case study than in the larger cities of Boston, Melbourne and Sydney in the second case study; the findings are discussed in Chapter 4.

Feldman and Florida argue that in geographic proximity that face-to-face interactions enhance effective technology transfer and spillovers "*that lower the costs and reduce the risks associated with innovation*" (1994:214).

Gertler (1995) discusses the importance of geographic closeness between collaborating parties for the successful development and adoption of new technologies. Trust is an important element in collaborative relationships (Malecki, 2000). Closeness is used both in the literal sense, as in allowing more frequent, effective, often unplanned interaction, and more broadly to encompass common language, modes of communication, customs, conventions, and social norms (Gardiner et al, 2006). The Mott Committee of the University of Cambridge (Mott, 1969), reported a five mile limit to the effectiveness of inter-personal communication.

This thesis also analyses the two-directional view of cluster firms, organisations and individuals; while the primary focus of cluster firms is on in-house business, customers and proximate cluster firms and organisations a constant peripheral surveillance is maintained on opportunities for knowledge acquisition, export business and for external threats. This two-directional view is inherent in *'Lead Local Compete Global'* (McKinsey, 1994b). Cortright and Mayer (2001) illustrate (Table 3) the success of the HTEI in relatively small second tier regions showing the 1997 LQ in NAICS 334 for Austin at 4.9, San Jose (including Silicon Valley) at 13.1 compared with Boston at 2.2. These regions and their HTEI clusters are further examined in the case studies discussed in Chapter 4.

2.24 Discovery, Invention, Diffusion, Innovation, Innovators and the HTEI

Nonaka and Takeuchi (1991) describe knowledge as the fuel for innovation and advocate a view of knowledge as renewable and changing. They promote knowledge workers as the agents for that change. The importance of the technology sector is that it is most influenced by constant change and provides high value returns on innovation (Peck, 2005). As discussed in Chapter 1, electronics technology is the result of the accumulation of knowledge through the process of theorising, discovery and demonstration by many scientists and experimenters and the innovative development of electronics technology over more than a century. From the discovery of electromagnetism by Oersted in 1820 and the discovery of the electron by Thomson in 1897, the development of the vacuum triode by De Forest in 1906, the transistor in 1947, the microprocessor in 1971 shows that the initial discoveries and inventions were followed by innovative further developments and diffusion of the technologies, usually by others and often after an interval of time (Rogers, 1983).

The sequential interplay between invention or discovery - the *research* step in the R&D conjunction - and the subsequent innovative or practical application - the *development* step - are prerequisites for the emergence and development of an industry. In all of these sequential activities an element of entrepreneurship is a factor, and particularly, in the innovative process of finding or creating an application or a market for newly discovered technologies.

The importance of the technology sector is that it is most influenced by constant change and provides high value returns on innovation (Peck, 2005).

2.25 Entrepreneurs, Entrepreneurship and the HTEI

From the above section it follows that entrepreneurs and entrepreneurship are fundamental to the development of electronics technologies and the electronics industry. Entrepreneurs are also fundamental to the origin and development of HTEI clusters (Mayer, 2011). Entrepreneurs establish and develop firms and these people and their firms join together forming clusters.

As discussed in Chapter 1 the dictionary definition of 'entrepreneur' (Oxford, 2008) "*a person who sets up a business or businesses, taking on financial risks in the hope of profit"* is appropriate for the traditional business entrepreneur, but does not address the 'technical risk' issue that is at the heart of all HTEI and NTB start-ups; nor does it address the non-financial motivation of many entrepreneurs or civic entrepreneurship, all three of which are important in HTEI clusters.

These motivations are measured and the data are reported and their influence on HTEI clusters is discussed in Chapter 4. Five perspectives on the meaning of entrepreneurship in the ICT sector are provided by McQuaid (2002):

1. A function in the economy
2. A new business start-up
3. An owner-manager of a small business
4. A set of personal characteristics
5. A form of behaviour.

These five perspectives include the non-financial motivations and are, therefore, a more appropriate description of *technology* entrepreneurship.

A dimension of entrepreneurship that is not widely reported is *'civic entrepreneurship'* the origin of which is credited by Leadbeater and Goss, (1998) to Douglas Henton, John Melville and Kimberley Walesh, partners at Collaborative Economics in Mountain View, California and published in their book *Grassroots Leaders* (1997). The concept combines two important traditions: entrepreneurship - the spirit of enterprise, together with civic virtue - the spirit of community (Henton et al, 1997).

Jolted by the economic downturn in the early 1990s Silicon Valley leaders implemented *Joint Venture Silicon Valley* (JVSV, hereafter) a program of *civic entrepreneurship* in 1993 and developed by Collaborative Economics. Civic entrepreneurship programs have since been developed in many cities, regions and nations.

Elements of the JVSV program were incorporated in the early planning of the highly innovative, but failed project to build the Multifunction Polis in Adelaide, Australia (Stilwell, 1990; Inkster, 1991; Castells and Hall, 1994; Burns and Garrett-Jones, 2002; Roberts and Enright, 2004).

The pursuit of opportunities unseen or ignored by employers is a common factor in a proportion of new start-up of firms by former employees (Christensen and Raynor, 2003), and particularly in the rigid [hard] computer disk manufacturing industry (Christensen, 1993, 1997), This characteristic is observed in Christchurch and is discussed in Chapter 4.

Xerox Corporation has been a source for many HTEI entrepreneurs who have started or expanded businesses using technology developed at its XEROX PARC, Palo Alto Research Centre (Chesbrough and Rosenbloom, 2002; Chesbrough, 2003; Seeley-Brown, 2000).

Many semiconductor start-up firms have been established by former employees of other semiconductor manufacturers (Klepper, 2001) including Fairchild and Intel (Berlin, 2005). By adding the technology dimension to the entrepreneurship process the venture risk is increased and the number of available entrepreneur candidates is reduced and the range of skills required by the entrepreneur is widened.

Entrepreneurship in the HTEI typically requires knowledge of a new technology and its application, or a new or latent application for an available technology plus the skill to validate a market (Adams, 2010), to marshal and implement the required resources and to create and implement a sustainable business plan (Cooper and Bruno, 1977).

The *technology entrepreneur* is not necessarily as motivated by the *'hope of a profit'* which is inherent in the standard definition. The technology entrepreneur is often more influenced by the desire to prove the merit or usefulness of the technology-based concept and less influenced by the prospect of wealth (Berlin, 2005). This factor is measured in data obtained by a survey conducted for this research and discussed in Chapter 4.

While the common image of an entrepreneur is of an irrational, over-optimistic risk-taker, successful entrepreneurs are more likely to conform to models of rational behaviour than the population at large; along several dimensions (Bhide, 2000) and tend to rely heavily on their experience and intuition in making decisions (Podoynitsyna et al, 2012).

The typical scientist or engineer who establishes a new technology-based business is trained and experienced in balancing risk and reward (Matthews, 2007) and the Risk Management Standard (ISO 31000, 2009) and evaluation tools are available to quantify and manage technology risk (Wilhite and Lord, 2006; Ordoobadi, 2007).

The environment in which technology-based businesses including NTB and HTEI businesses are started is influenced by the growth, importance and the opportunities of this sector. By 2010 half of all jobs were forecast to be in industries that are either major producers or intensive users of information technology products and services (CEC, 2000).

The process of entrepreneurship is described as one of identifying an opportunity, creating a team, marshalling resources, and starting and managing the venture (Timmons, 1999). As discussed in Chapter 1, entrepreneurship is one integral part of a linear process of: invention, innovation, entrepreneurship and commercialisation.

2.26 Chapter Summary

The extensive literature analyses the growth of technology-based firms, their attributes and the interactive aggregation of individuals, firms and related organisations in HTEI clusters in the second tier regions of Silicon Valley, Cambridge and Austin. Start-ups, spin-outs and entrepreneurship are reported as essential cluster emergence factors.

The evolution of manufacturing and its transition from the industrial-age to the knowledge-age and the influence of innovation and entrepreneurship and of national, regional and local innovation systems is discussed. The influence on the HTEI by institutions, government and universities, path dependency and entrepreneurship is reviewed.

Limited success and cluster failure, particularly of clusters created by government programs is noted. The absence of a generally accepted theory of the origin of clusters contrasts with the extensive literature on cluster development and characteristics of growth, structure and economic value. The limited literature on the dual effect of proximity and isolation on the development HTEI clusters in relatively small and remote regions is discussed.

While the ongoing growth and development of clusters in general and of HTEI clusters in particular, is well-researched the lack of understanding of their actual origin is acknowledged in the literature. The structure, size, scope and value of HTEI clusters in USA, UK and EU regions are well-reported, and the motivation of the regional entrepreneurs, their location preferences, physical and intellectual resources and external influences are widely understood.

However, dense HTEI clusters in Australian and New Zealand regions are less-researched. Additional data and knowledge on the emergence of these antipodean clusters is required to develop our understanding of the relationships and interactions among the factors that may contribute to the emergence and development of endogenous clusters in these regions.

The following chapter discusses the development of an interview process from the three research questions discussed above and in Chapter 1. This interview process, informed by the knowledge obtained through the literature review and the identification of knowledge gaps will obtain new data and information that will assist in providing a response to these research questions.

Chapter 3: Methodology

3.1 Introduction

This chapter explains, and where necessary justifies, the choice of research methods. It deals mostly with the practical aspects of gathering data for analysis, through a number of structured interviews with carefully selected people in a variety of settings. There is nothing especially controversial about the research design. It was built around commonsense ideas about how data was to be collected and processed over a long period of fieldwork time. However, in choosing a largely interpretive approach some explanation is required as it is distinctly different in the assumptions made about the nature of systematically acquired knowledge through formal research than the positivist paradigm. This chapter briefly explains that. Starting with the theoretical underpinning of the research design, the spirit was decidedly based upon the interpretive knowledge paradigm. Expressed simply, at the conception stage of the research it was obvious that to better understand the process of industry cluster formation and subsequent development over a long time period it was essential to talk to many people about what they knew and their subjective interpretations of personal experiences as leading *insider* players in the industry. Altogether 293 people were interviewed in order to obtain their personal accounts of industry clustering as a process.

In identifying the research as being mostly within the interpretive research knowledge domain some explanation is necessary about important assumptions. From the early stage of the research it was clear that reliance was going to be placed on what industry *insiders* knew and thought about clustering and related subjects of interest. Their observations were clearly based on subjective and learned experience and therefore the research grew from these insider accounts of *'what is going on'* (WIGO, hereafter). Unlike scientific research it was not necessary to test and measure everything, like hypotheses or propositions, but rather to measure those parameters that are measurable and to also collect a multitude of subjective observations and interpretations of WIGO derived from actual experience and then identify patterns and variations to form reasonable generalisations from a data-set.

It was recognised that the core assumption behind the research approach was that people were self-conscious and aware of life around them and therefore naturally constructed in their minds an interpretation of their experiences. The role of the researcher in this context is to get as close as possible to the source of the respondents lived experience by asking questions, that is to say, by encouraging them to accurately describe what they knew and thought about their industry clustering process and to venture some interpretation of WIGO.

In this context their perceptions cannot be objectively measured but taken at *face value* as an honest attempt to make sense of their long experience and considerable knowledge of an industry. This is clearly an act of faith but a reasonable one given that there was no reason to tell lies or distort their own interpretations. It was therefore assumed that the majority of the respondents to the many and lengthy interviews would have an interest in reporting their knowing and experiences accurately and had no cause to do otherwise. Expressed another way, if people describe and analyse their lived experiences as real and meaningful to them then it becomes a form of knowing and the basis of forming systematic (academic) knowledge of a phenomenon.

In sum, interpretive research as understood in this research is concerned with knowing about a phenomenon, in this case the formation of individual firms and their place in industry clusters. Individual and subjective perception is of upmost significance in the interpretation of this particular reality (industry clustering) from the *inside* by those who 'had been there and done that'. Given that a large number of industry insiders were interviewed in some depth there is likely to be a common structure of experience forming a pattern or at least clear variations around a number of themes, and therefore the basis of generalisation and even theory-building about the formation of industry clusters.

In more formal language, the interpretive approach adopted in this thesis, makes three main assumptions: that subjective meaning has validity in the interpretation of experience and events; human beings are self-conscious and like to reflect and interpret their own actions to form a knowing about WIGO; and that the researcher is part of that action, not a neutral and impassive recorder but maybe assisting in the sense-making process by asking carefully constructed research questions with a definite point and purpose behind them. Having briefly explained the interpretive research paradigm and its core assumptions about knowing and knowledge it is now necessary to explain the design in operational terms.

Three research streams were identified in Chapter 1 which informed the development of these restated research questions:

1. *Why* did HTEI firms cluster in 'second tier' regions?
2. *How* have endogenous HTEI clusters developed in these regions?
3. *What* variations exist between the HTEI clusters in regions that emerged endogenously and those created by government action?

The literature review in Chapter 2 shows, in relation to the first research question that leading scholars report a limited understanding of '*Why did HTEI firms cluster in 'second tier' regions?'* The literature notes a disregard of the question *"how spatial concentrations actually come into being"* (Menzel et al, 2010:1). Cluster origin is described by Mayer as *"understudied"* (2011:26) who also quotes Porter (2000a) that clusters simply "*bubble-up"* (2011:27) because of physical proximity to factors that benefit firm development. Porter adds that clusters "*often emerge and begin to grow naturally…"* (1990b: 655). Many scholars quote Nobel laureate Paul Krugman that the emergence of a cluster can be traced to *"… some seemingly trivial historical accident"* (1991: 35).

It is also noted that *"an emerging cluster is hard to detect and can sometimes only be described ex-post"* (Menzel and Fornahl, 2007:1) and attributed to Bresnahan et al. (2001). However, the literature acknowledges that once established, clusters are readily recognisable and: "*It often seems obvious in retrospect that a cluster would have developed in a particular region"* (Romanelli and Feldman, 2006:108). Chapter 2 summarises the extensive literature on the second research question; '*How have endogenous HTEI clusters developed in these regions?'* The literature is comprehensive on HTEI clusters in USA and UK. Extensive government and industry data is also available on USA and UK regions.

A substantial literature also analyses the regional HTEI clusters established or developed by government programs in the Republic of Ireland, Northern Ireland, Scotland and Singapore. Government and industry data is available on these regional HTEI clusters. This literature and industry data together with the endogenous HTEI cluster literature and data assist the understanding of the third research question: *'What variations exist between the HTEI clusters in regions that emerged endogenously and those created by government action?*

While the literature is comprehensive on HTEI firms and clusters in USA and UK, it is limited and inadequate for the study of the evolution of the antipodean HTEI clusters.

3.2 Data Requirements

To address the research questions identified in Chapter 1 and discussed above, additional data are required to augment the available data and to advance the level of knowledge on the origin and development of the less researched antipodean regions towards the comprehensive level of knowledge available on the well-researched HTEI firms and clusters in USA and UK regions.

In the empirical phase extensive interviews obtain data and information on a range of origin and development parameters of HTEI firms and clusters, particularly in selected antipodean regions. The empirical phase includes limited surveys of HTEI cluster organisations in the well-researched regions to confirm and to understand the context of the origin and development of the firms and clusters in these exemplar regions and thereby to assist the understanding of the evolution of HTEI clusters in the less studied antipodean regions.

Three separate case studies are included and while this structure is not common in this field, it is noted that each of the three case studies encompass a discreet subset of cluster organisations that have common characteristics within the subset that exclude other case study groups. This design provides three separate datasets for comparison within the related regions. When combined these three datasets provide information for cross case comparison and resources to address the three research questions. The principal case study contains the five exemplar HTEI cluster regions, each with their nation's highest employment density, a multi-decade development history and each located in a small and isolated second tier city.

The second case study includes five less successful clusters in cities with a range of population, lower cluster densities and topographies that limit face-to-face contact with peers. Together these two case studies represent the range of size, density, and success of endogenously developed HTEI clusters that will provide data to address the first two research questions on the *why* and *how* of endogenous cluster origin and development and provide for cross-case comparisons of endogenous clusters.

The third case study group comprises *'created'* clusters in a number of economies and provides data for inter-regional comparison and separate comparisons with the data from the first two case studies to address the third research question on the '*variations'* between endogenous and created cluster types.

Case study structure is influenced by Yin (1990) and the theory building observes the processes of Carlile and Christensen (2004), while the research framework is derived from Crotty (1998). Regional and national employment data for all selected clusters will allow LQ calculation and inter-regional cluster comparison. The following is a discussion on the selection of case study regions, survey design and survey participant selection and describes the processes employed in the three case studies. However, these development processes were often undertaken in parallel because of the interdependent relationship of the cluster region selection, survey design and participant selection.

3.3 Selection of Regions for the Principal Case Study

A regionally diverse and representative group of HTEI cluster regions was required for case studies - a sufficiently large number of regions to ensure robustness of the data - but a small enough number to be manageable.

Each region was selected on the basis of its 'national significance' and the high proportion of its national HTEI workforce employed in its regional cluster.

The selection criteria for principal case study are shown in descending order of importance:

1. Expectation of endogenous origin and self-organised cluster development
2. Highest proportion of the national workforce employed in the regional HTEI cluster
3. Small city population compared to total national population; a second tier city
4. Relatively remote from and independent of major national populations
5. Industry data and structure details available from the literature, government and industry
6. English speaking with comparable cluster and business culture, to ensure uniform understanding. This factor assists in the determination of which questions to ask and to know how to interpret answers and what to look for and how to interpret unscripted comments by interviewees and observations in the region.

Applying these criteria, five HTEI clusters which emerged endogenously in relatively small and remote, second tier regions were selected for inclusion in the principal case study:

Cambridge, Austin, Christchurch, Adelaide and Santa Clara (Silicon) Valley

The first four cities named above are small, archetypal 'second tier cities' that are also relatively removed from and independent of their major national populations. Each region is an exemplar with the highest proportion of their national HTEI workforce, so their selection in the principal case study group is uncontroversial. The inclusion of Silicon Valley in this group may not be so obvious. The topic of this research is the *'…emergence and development'* of HTEI firms and clusters in second tier regions and, at the time of its *emergence* and early *development* as a technology region in the early to mid-twentieth century the Santa Clara Valley - now known as Silicon Valley - was an isolated fruit and vegetable growing district and its only established secondary industry was food processing and canning (Saxenian, 1985). Silicon Valley is still today relatively isolated in terms of the interdependence, self-sufficiency and the unique culture of its HTEI firms. Santa Clara County - including Silicon Valley - has a population of 1.78 million, approximately half of one per cent of the population of the USA and is located relatively remotely from and independent of its nearest large city, San Francisco.

While Silicon Valley population is larger in absolute terms than the four other regions in the principal group, its share of national population is below that of Christchurch and Adelaide and above that of Austin and Cambridge as shown in Table 3.1 below

Table 3.1: Principal HTEI Case Study Regions Ranked by National Population Share (2012)

City/Region	City/Region Population	City Rank by Population	% National Population
Christchurch, New Zealand	350,000	3/15	8.0
Adelaide, South Australia	1.21 million	5/50	5.4
Silicon Valley CA, USA Including Santa Clara County and San Jose	1.78 million	5/275	0.57
Austin, Texas, USA Austin-Round Rock MSA	1.25 million	14/275	0.40
Cambridge, UK	113,400	57/175	0.18

Sources: US Census Bureau; UK Office of National Statistics: Australian Bureau of Statistics: Statistics New Zealand.

The five cities selected for the principal case study group are the exemplars of the phenomenon observed only in very few global places which have the conjunction of: a high density HTEI cluster, in a region with relatively small population, that is relatively remote from and independent of major national populations. Industry employment data used in the selection of these regions is from national and regional government, industry associations and regional economic development bodies.

3.4 Selection of Regions for the Second Case Study

Five regions with wide range of population sizes were required for the second case study. These regions should have cluster densities that are less than in the regions selected for the principal case study. The selection criteria for the second case study regions are shown below:

1. Expectation of endogenous origin and self-organised cluster development
1. A mix of population sizes and proportions of the national population
2. A significant proportion of its regional workforce employed in the HTEI
4, Industry data and structure details available from the literature, government and industry
5. English speaking with comparable cluster and business culture, to ensure uniform understanding. This factor assists in the determination of which questions to ask and to know how to interpret answers and what to look for and how to interpret unscripted comments by interviewees and observations in the region.

Applying the above criteria, five endogenous HTEI cluster regions were selected:

*Boston, Brisbane, Canberra, Melbourne and Sydne*y.

The regions selected in this second group are generally larger than the regions in the principal case study. Again, the number of regions included is sufficiently large to ensure robustness of the data, but a small enough number to be manageable.

These cities have a range of population from 360,000 to almost 5 million and the employment density of these HTEI clusters are lower than the regions selected in the principal case study. The dataset from this group will provide cross-case comparisons between these 'less-successful' HTEI clusters and the 'successful' clusters of the principal case study. Low levels of HTEI employment precluded Australian State capitals Hobart and Perth.

3.5 Selection of Regions for the Third Case Study

This case study examines clusters in regions where government policies have been applied to create or to assist the development of regional HTEI clusters. These regions have been described as "*Silicon Valley imitators"* Bresnahan et al (2001).

The selection criteria for the third case study are shown in descending order of importance:

1. HTEI firms attracted or developed by government policies and programs
2. A mix of population sizes and proportions of the national population
3. Significant proportion of regional workforce employed in the HTEI
4. Industry data and structure details available from government and industry
5. English speaking with comparable cluster and business culture, to ensure uniform understanding. This factor assists in the determination of which questions to ask and to know how to interpret answers and what to look for and how to interpret unscripted comments by interviewees and observations in the region.

Applying these criteria regions eight regions in four countries were selected for the third case study:

Belfast, Cork, Dublin, Edinburgh, Galway, Glasgow, Shannon/Limerick, and Singapore

Data from this third case study of *'created' or 'assisted'* clusters will be compared with and data from principal and second case study to address the third research question:

'*What variations exist between the HTEI clusters in regions that emerged endogenously and those created by government action?*

It is noted that this research does not include any analysis of HTEI clusters in continental Europe. However, Chapter 2 discusses the significant HTEI clusters established in many European cities across a number of nations. Chapter 2 also includes important references to Porter (1990b) on the endogenous printing machine cluster around Heidelberg, Germany and the endogenous ceramic tile cluster in Sassuolo, Italy.

The HTEI cluster in Dresden, Germany researched by Parker and Tamaschke (2005) was discussed in Chapter 2 as it contains one of very few references in the literature to the Adelaide HTEI in its comparison with the HTEI in Dresden. Parker (2006) also compares the HTEI in Adelaide to the HTEI cluster in Karlskrona, Sweden and Parker (2008) compares the HTEI in Adelaide to the HTEI cluster in Shannon/Limerick region of Ireland.

However, no city in continental Europe or Asia (apart from Singapore) was included in this research as this author has no knowledge of foreign languages, no established network of contacts in European or other Asian HTEI firms, universities or government and industry organisations and no specialist knowledge of the culture, or structure of European or other Asian HTEI regions (except Singapore). Japan with its large electronics industry was not included in this research as its HTEI clusters also lack comparability and a common language and culture with those of the HTEI clusters in USA, UK, Australia and New Zealand and Singapore. Conversely, with more than 30 years of start-up and management in the HTEI in Adelaide, and with network contacts in USA, UK, New Zealand, Ireland, Scotland and Singapore the decision was made to focus on regions with familiar HTEI structures, language, government, cluster culture and conventions.

While the phenomenon of the emergence of dense, endogenous HTEI clusters is found in a limited number of relatively small and isolated regions, it is noted that many other similarly small and isolated cities that have many - some have most or all - of the required endowments, but do not have dense HTEI clusters. The phenomenon of HTEI cluster development in second tier regions is comparatively rare compared to the number of regions possessing the required characteristics.

3.6 Survey Design

The value of the data obtained from HTEI cluster surveys and interviews is dependent on many factors including the representation by the selected sample of the whole of the population to be researched.

Other factors include the relevance and extent and depth of the topics, the comprehensiveness and the integrity of the responses and the skill and industry knowledge employed in the interpretation, particularly of open-ended responses.

Based on the industry experience of this author as a respondent to many mail and on-line business and government surveys during the busy work day it was concluded that a survey document sent by mail, email or on-line could be ignored if it contained more than a very small number of quickly answered questions.

Mail or online surveys also do not provide the same level of interactive, open-ended comment as face-to-face interviews. Since a comprehensive understanding of the industry and firm origin and development parameters in the selected regions was required, a mail, email or on-line survey was rejected and a face-to-face interview method was selected.

The large number of topics to be covered and the need for industry engagement and open-ended comment indicated that this data and information should be collected through face-to-face meetings.

Knowledge from the literature, the research questions and from industry experience informed the design of the surveys, and particularly the wording of the discussion topics.

From the three research questions discussed above and the identified gaps in the antipodean HTEI cluster literature, nine expanded research themes were developed to achieve a broader understanding of HTEI clusters, in particular:

Nine themes were developed to obtain the data and insights that would provide the desired level of improved understanding. These themes are:

1. *Start-Up Driver*: Motivation for the commencement of the business
2. *Location Factors*: Reasons for the choice of location
3. *Technology Source*: Own technology or if acquired, process and experience
4. *Intellectual Capital*: Internal and external, relationships, innovation, creativity
5. *Physical Capital*: Family, equity, venture capital, retained earnings
6. *Markets and Marketing*: Niche/mass markets, exports, market pull/technology push
7. *Management and Strategy*: Networks, clusters, barriers, risk and IP management
8. *Government*: Assistance, grants received or needed, regulations/delay/barriers
9. *Major Institution Influence*: Benefits/disadvantages from university/research institutes

Further development of the nine themes outlined above produced the more detailed description below:

1. *Start-up Driver:* Self-employment, financial gain, fame, social motivation or the attraction to the technology and a desire to develop its potential.

2. *Location Factors:* Selection of home town or location by analysis, access to equipment or facility or a relationship with a university of other institution as a factor. Current location advantages and disadvantages and motivation and propensity to relocate.

3. *Technology Source:* From within the firm, from an associated or non-associated entity or joint venture or from a university or public institution and associated technology transfer issues.

4. *Intellectual Capital Resources:* Innovation and entrepreneurship, staff recruitment, retention, training and the value of institutional relationships and creativity and the creative class.

5. *Physical Capital Resources:* Start-up funding, attraction of investors, venture capital, reinvested profits, and family assets in the business.

6. *Markets and Marketing:* Niche or mass markets, exports and years since commencement. Market-pull/technology-push, global surveillance of opportunities and threats, dependence on local, regional or national government customers.

7. *Management and Strategy:* Low cost producer, market led, market leader, market maker and evolving strategy. Product differentiation, corporate culture, stakeholder focus. Risk management, intellectual property management, value of networks and clusters and barriers to growth.

8. *Government Factors:* Assistance grants sought, received, refused or not sought. Unmet needs for government assistance, government interference, barriers and delay by government regulation.

9. *Major Institution Factor:* Advantages and disadvantages of major local entity or institution, services and assistance wanted, received or not received and past, current and future estimated value of major local body.

Limited data and information on aspects of each of these themes is available from the literature and from regional government and industry bodies, however, taken together with additional, localised data and information from the founders and managers of cluster firms in the selected regions, it was concluded that an improved understanding of the origin and development of firms and the endogenous emergence of the clusters could be developed.

Additional, localised data and information could provide a firm level view of the start-up motivation, location choices and technologies employed and such issues as technology transfer and government influences. New insights could also be gained on intellectual and physical capital resources and strategy, structure and performance of firms, together with an understanding of their markets, marketing and management and their relationships with governments and local institutions, including university and research institutions. Knowledge of these factors could inform the development of government policies and industry programs for the sustainable development of the industry.

Similar but complementary data and information would be obtained from firms and industry and government bodies in regions where government actions have led to the creation or development of regional HTEI clusters, so an understanding of the variations that exist between the two principal cluster origin and develop modes could further assist the development of policies and programs for the sustainability of both endogenous and created clusters.

3.7 Survey Document

The nine themes outlined above were further sub-divided into fifty *discussion topics* and a draft *Discussion Agenda* was developed to elicit the required, but previously unavailable data and information. The draft document was tested with a face-to-face pilot survey of a sample of fourteen Adelaide firms representing the total range of firms by employee size in the population of the Adelaide HTEI cluster.

After analysis of the pilot survey results modifications were made to the Discussion Agenda to ensure that all required data could be obtained in a form that would provide sound qualitative and quantitative data. In particular, more Likert scales were incorporated to add dimension to some responses that were previously open-ended or binary. Based on the results of the pilot survey, it was concluded that a period of one hour would be required for the satisfactory completion of the survey, allowing for open-ended responses and discussion. However, it was known from industry experience that to ask owners or managers of HTEI firms for an uninterrupted hour of their work day would require a careful approach. The final Discussion Agenda documents are shown in Appendix 2, 3 and 4.

Each of the fifty topics on the Discussion Agenda seeks one of the five following responses:

- An affirmative or negative (binary) response to a stated proposition
- A response selected from a list of two to six options
- A Likert scaled response on a scale of zero to five (5 = maximum)
- A numeric response
- An open ended response

Forty-five of the fifty topics on the Discussion Agenda elicit either a binary, multiple choice, or numeric response, or are Likert scaled with the choice of 6 options [0-5] to specifically avoid the error of central tendency. Five topics request an open-ended response. These are *'What are the best and worst factors about running your business in this city now?'; 'Would you move from this city? If yes, why would you move?'; 'Do you target niche or smaller markets- If so why?'; 'Is your strategy now the same or different to start-up strategy? Why?'; 'What services or assistance are wanted from a major local institution?'* These five topics were considered separately and commonalities and differences between Australian, New Zealand, USA and UK regions were ranked for discussion in Chapter 4.

A database was developed for the storage and analysis of responses and to facilitate the comparison of individual parameters or related groups of parameters across and between regions, nations and case study groups.

The data collected classifies and where possible measures the start-up motivation and location decisions of the firms, their technology sources, intellectual and physical capital resources, markets, management, strategy and the influence of government and regional factors including the influence of universities and government funded research institutions.

Survey documents were developed for three classifications of organisations; HTEI industry, research institutions, government and facilitator bodies including industry associations.

The source of the required data was to be the firms, regional agencies and research institutions and the method of selection of the individual firms and organisations in each region to be surveyed was based on the '*purposive sampling'* method in which interviewees are chosen as the most appropriate representatives of the industry population.

3.8 Selection of Firms and Organisations for Survey – Principal Case Study

The literature on the HTEI in Silicon Valley, Cambridge and Austin provides a comprehensive understanding of the current structure and scope and the longitudinal development of the regional HTEI clusters in each of these regions over many decades. The required government data on regional and national HTEI employment is also available for these three regions, confirming their selection in the principal group. These data and the comprehensive understanding obtained from the regional cluster literature are augmented by a limited number of interviews to obtain additional and confirmatory information in these three HTEI cluster regions provide the requirements for the principal case study.

With limited HTEI cluster literature available on the Christchurch region more extensive surveys were required to expand the published industry origin and development data and information on the firms and organisations in this regional HTEI cluster. The method of Ann Markusen (1994) of *"Studying Regions by Studying Firms"* is adopted. Interviewees were selected representing firms of all employment sizes and industry activities and a wide range of industry support organisations to provide the required data and industry structure information. The LQ for the HTEI in Christchurch was calculated from national and regional government employment data obtained from the New Zealand Government and found to be relatively high, confirming the legitimacy of the inclusion of this region.

As discussed in Chapter 2 the literature on the development and current structure and scope of the Adelaide HTEI cluster is sparse and is the least comprehensive of all of case study regions. Therefore a more comprehensive survey of firms and related cluster organisations was required to provide inputs to the planned case study.

A stratified '*purposeful sampling*' method was adopted (Given, 2008), consistent with the explanation of the process at the beginning of this chapter. An alternative descriptor for this method is '*paradigmatic case sampling'* (Palys, 2008).

The individuals selected for interview in each region are a knowledgeable and representative sample of the organisations of the HTEI cluster in that region. A stratified sample was adopted for the survey of the Adelaide HTEI. The sample of seventy HTEI firms was selected with ten firms placed in each of seven employee size bands as follows:

Employees per firm = one; 2-4; 5-10; 11- 20; 21-50; 51-100; 100+

Stratification by these size bands was adopted following this practice in previous HTEI surveys in Adelaide and it was known from previous surveys (EASA, 1994; EASA, 1996; SACES, 2000, 2004) that firm structure and management practices in HTEI firms in Adelaide can vary by size of the firm and the data was required from firms of all sizes in the industry to produce a representative sample.

Following the earlier practice each size band in the selected sample contained a representative proportion of all industry activities; design, manufacture and services in each size band so as to represent the total industry population through the selected sample firms. Stratification allows comparison with previously collected data (EASA, 1994; EASA, 1996).

A letter explaining and endorsing the survey was obtained from the Board of the Electronics Industry Association (EIA, hereafter) the leading industry association representing firms employing approximately 70 per cent of all staff in the Adelaide HTEI. A draft copy of the endorsement letter is reproduced in Appendix 1. This endorsement letter was important as the EIA was known to members and non-members of the HTEI to be active in the development of the industry in Adelaide, so the EIA endorsement provided important legitimacy to the survey.

A majority of the firms selected for the Adelaide survey were EIA members although it is noted that EIA membership was not included in the selection criteria for survey participants and approximately 30 per cent of selected respondents were not EIA members, again mirroring the total population of the Adelaide HTEI. It is estimated that the seventy firms included in the sample employ approximately two-thirds of all employees in the Adelaide HTEI. Adelaide's HTEI employment was reported as 11,700 (TIA, 2012).

The owner, manager or chief executive officer (CEO, hereafter) of each of the firms selected for interview was approached by mail or email which described the purpose and expected value of the knowledge to be obtained from the research with a request for a one-hour meeting and a copy of the EIA Board endorsement letter attached. Response to the interview requests was generally positive, while some potential interviewees required follow-up.

Ultimately 67 leaders of HTEI firms agreed to participate in the survey. Three firms declined to participate and three replacement firms were recruited from the same demographic to complete the balanced sample of 70 firms.

The largest regional survey was conducted in Adelaide with the 31 per cent of all survey responses obtained in this one region. With national industry employment data from EIAA and industry sources the employment LQ for the Adelaide HTEI was calculated and found to be high. The 146 interviews conducted for the principal case study was slightly less than 50 per cent of the total number of interviews across the three case studies.

3.9 Selection of Firms and Organisations for Survey – Second Case Study

All of the regions in the second case study emerged endogenously and have developed through self-organisation. The regions in this group have a lower proportion of their regional workforce employed in the HTEI than the regions in the principal case study providing an important contrast.

The literature on the HTEI clusters in the second case study group varies from comprehensive in Boston, to minimal on Brisbane, Canberra, Melbourne, and Sydney. The selection of firms for inclusion in the surveys in the second case study is also influenced by the availability of the literature and of government and industry data and information. Available contacts in the regions were augmented using the *'snowball'* process where one source of data provides contact with another (Markusen, 1994).

These five regions represent a wide range of populations from 350,000 in Canberra to almost 5 million in Boston. With the comprehensive literature available on the HTEI in Boston a small number of interviews was conducted to confirm the structure and scope of the industry.

Using published USA Government data the employment LQ for the Boston HTEI, in 2011 was found to be 2.54 (BLS, 2013). With limited literature and employment data on the HTEI in Australia, the number of interviews conducted has a mean of more than 30 in each of Brisbane, Canberra, Melbourne and Sydney.

From these interviews a comprehensive database was built allowing comparisons between the cities across the range of 50 parameters in the Discussion Agenda. The total number of interviews conducted for the second case study was 43 per cent of the 293 total interviews.

The data and information obtained from the 125 interviews undertaken for the second case study of endogenously formed clusters discussed above assists with the first two research questions on the *why* and the *how* of endogenous HTEI cluster origin and development in two disparate groups of cities.

The principal group of dense and highly successful HTEI clusters in the five small and isolated regions has a mean population of less than one million. This contrasts with the second case study group of five cities with a mean population of more than 3.25 million with less successful and lower density and less developed HTEI clusters.

It is noted that the five Australian HTEI clusters included in these case studies are located in the National Capital and in the Capital City of the four eastern and southern States that together contain 86 per cent of Australia's population.

3.10 Selection of Firms and Organisations for Survey – Third Case Study

The literature on this group of cluster regions includes extensive published research data and government information on the development policies and programs implemented by national and regional government to create or develop the electronics industry in the cities of Belfast, Cork, Dublin, Edinburgh, Galway, Glasgow, Shannon/Limerick and Singapore. A limited number of surveys and interviews conducted in these eight cities augmented the available data, information and background to the political, cultural and economic factors in the government development policies and programs implemented in these regions.

Together these data and published information assist with the third research question that seeks to understand the *variation* between these assisted or created clusters and the endogenous clusters in the ten cities included in the first two case studies discussed above.

3.11 Units of Measure

Since clusters by definition are spatially bounded systems the major unit of analysis is the cluster of firms and related organisations located within each of the selected case study cities. The next level includes the firms and the related industry organisations within the regional cluster. The third level includes the management and staff in the regional cluster.

It is noted that the number of HTEI employees in a region is the unit of measure that is widely used in the global cluster literature. These data are available from all HTEI regions included in this research and since national HTEI data and total workforce data both regionally and nationally are also available; these data are used to calculate the LQ of the HTEI in the selected regions. The LQ is the ratio of the share of regional employment in an industry to the share of national industry employment (Haig, 1927). LQ is an important measure; it allows comparison of clusters in places of widely varying population. Figure 3.1 shows the calculation basis for employment location quotient of a region.

Figure 3.1: Calculation of LQ of an Industry in a Region (after Chapin, 2004)

$$\text{Location Quotient} = (\text{LQ}) \quad \frac{\text{Regional employment in the industry}}{\text{Total Regional employment - same year}} \Big/ \frac{\text{National industry employment - same year}}{\text{Total National Employment - same year}}$$

A region with an LQ of 1.0 in an industry has the same proportion of employment in that industry as the state or a nation. A region with an LQ of greater or less than 1.0 has a respectively higher or lower workforce proportion in its industry, than the state or nation. However, the interpretation of the LQ for an industry in a region requires an understanding of the degree of concentration or dispersal of the industry across the subject nation.

3.12 Survey Participant Data

The number and qualification of interviewees selected in each regional cluster was determined by the extent and relevance of the available literature and of the available data on each region.

In regions where the extensive literature and quality data from government and industry sources were available, a smaller number of interviews was undertaken to confirm and extend knowledge based on what was already known.

Larger numbers of interviews were conducted where the literature and data were less complete. Figure 3.2 below shows the number of interviews conducted in each region for each of the three case studies and the total number of interviews conducted.

Table 3.2: Number of Interviews Conducted in Each Case Study Region

Case Study Region	Interviews
Cambridge	7
Silicon Valley	8
Austin	11
Christchurch	29
Adelaide	91
Principal Case Study Total	**146**
Boston	4
Brisbane	34
Canberra	26
Melbourne	38
Sydney	23
Second Case Study Total	**125**
Ireland	8
Northern Ireland	2
Scotland	8
Singapore	4
Third Case Study Total	**22**
Three Case Studies Total	**293**

In all regions individual interviewees were selected for the relevance of their firm or organisation, their position in the organisation, their knowledge and experience and their expected additional contribution to the current level and relevance of published data and information.

Table 3.2 records the number of interviews conducted in each region showing the strong reliance on the extant literature where it is available and the need for an extensive exploration of the HTEI by survey in the Australasian cities and particularly in Adelaide

3.13 Survey Deployment

Versions of the survey document that was appropriate for each region and for each respondent group were produced. Using the Discussion Agendas discussed above, face-to-face interviews of approximately one-hour duration were arranged with founders or managers of HTEI firms, initially in Adelaide. Appointments were confirmed with interviewees in all regions and an interview schedule established for each region. All interviews were voice recorded and multiple-choice and Likert scaled responses noted on a prepared response document for later transfer to the pre-prepared database.

3.14 Survey and Data Collection: Adelaide

The seventy Adelaide interviews were conducted with HTEI firm representatives over a ten month period and completed in early 2005. The respondents to all surveys were either the HTEI firm founder or manager.

Ten senior representatives of government, facilitator and industry associations engaged in regional economic development, in the *Government/Facilitator* sector were also interviewed in Adelaide using a separate Discussion Agenda, shown in Appendix 3.

Eleven additional interviews were conducted with the head of the electronic engineering department at all three universities and with directors or senior staff of HTEI research institutions in Adelaide engaged in HTEI research, the *Research/Higher Education* sector using the Discussion Agenda shown in Appendix 4

The largest number of interviews was conducted in Adelaide, one of the five regions included in the principal case study. This large sample was adopted to achieve a high level of understanding of the HTEI in the region which had:

a.) the least number of references in the literature to its HTEI cluster

b.) the lowest level of understanding of its HTEI by its community and government

c.) the highest proportion of its national HTEI employment and Australia's highest LQ

Surveys were conducted between 2006 and 2010 in the non-Australian case study regions; Austin, Cambridge, Christchurch and Silicon Valley, Boston, Belfast, Cork, Dublin, Edinburgh, Galway, Glasgow, Shannon/Limerick, and Singapore. Surveys for the second case study were conducted in Brisbane, Canberra, Melbourne and Sydney in 2009 and 2010.

3.15 Survey and Data Collection: Austin, Cambridge, Christchurch, Silicon Valley

The literature on Cambridge and Silicon Valley is the most comprehensive of the regions included in the principal case study group, so a small survey was conducted in these regions with a focus on the confirmation of specific factors identified in the literature, for comparison with the HTEI clusters in the principal case study. The literature on Austin is relatively extensive, so the survey in Austin also included a small number of respondents. Austin is a Sister City of Adelaide and has a comparable population and like Adelaide is isolated from its major populations on its east and west coasts. With a more complete literature and data availability than on Adelaide, the survey in Christchurch includes a larger number of respondents than Cambridge, Silicon Valley and Austin, but less than Adelaide.

3.16 Survey and Data Collection: Boston, Brisbane, Canberra, Melbourne, Sydney

Using the same Discussion Agendas as those used in Adelaide, 121 interviews were conducted in the Australian National capital, Canberra and three Australian State capitals: Brisbane, Melbourne and Sydney. Interviews were also included HTEI firm founders, or CEO's and *Government, Facilitator, Research/Higher Education* representatives.

The sample in each of these cities was smaller than for the Adelaide interviews, and the purpose of these additional Australian interviews was to identify and where possible to measure regional similarities and differences with the major HTEI cluster in Adelaide.
Data obtained from these four Australian regions are included in the second case study group.

A small number of interviews was also conducted in Boston for inclusion in the second case study with the four Australian cities with moderately successful HTEI clusters.

The HTEI in Boston is moderately dense, but less than one-fifth of the LQ of Silicon Valley and less than half of the LQ of Adelaide.

Boston was one of the first cities in USA where an endogenous cluster of HTEI firms developed, and the relationship of the HTEI in Boston, with MIT and the early development of the HTEI cluster in Silicon Valley (Saxenian, 1994) is relevant to this research.

The industrial heritage of Boston and its vertically integrated manufacturing processes, dating from the Industrial Revolution are contrasted in Chapter 4 with the more open and collaborative style of Silicon Valley and the observations of Saxenian (1994) of the differing HTEI industry and cluster performance are discussed.

3.17 Survey and Data Collection: Ireland, Northern Ireland, Scotland, Singapore

Discussion Agendas modified to accommodate regional, cultural and regulatory differences - but otherwise unaltered in their scope and purpose - were used to conduct interviews with HTEI firms and with *Government/Facilitator* and *Research/Higher Education* representatives in seven cities in Ireland, Northern Ireland, Scotland and in Singapore to provide input to the third case study.

These interviews were conducted with smaller proportions of the firms and organisations in these regions than in the Australian cities discussed above, the objective in these regions was to observe and confirm differences and similarities published in the extensive literature in these regions where significant government policies and programs have been implemented over the past 30 years to develop the HTEI industry in each the following regions: Belfast, Cork, Dublin, Edinburgh, Galway, Glasgow, Shannon/Limerick and Singapore.

Data and information obtained from the interviews in these eight regions and the data and information from the two other case studies assists in the understanding of the third research question on the variations between clusters that emerged endogenously and developed by self-organisation and those that were ‘created’ by government policies and programs.

3.18 Survey Data Analysis

The Discussion Agendas prepared for the industry interviews discussed above include a total of 50 discussion topics. On 22 of these topics a choice of between two and six pre-prepared responses was obtained. A further 23 topics are Likert scaled as discussed in Section 3.7. The remaining five topics invite an open-ended response. The numeric responses to the Likert scaled topics were entered into the database and each multiple choice answer was entered as a response in an appropriate database column for analysis.

All interviews were voice recorded. The voice records were not transcribed formally, but were re-run later to capture responses to the five open-ended questions and all unprompted comments, which proved to be of high value in understanding the cultural, political and regulatory context of the regions. Numeric totals were produced for the results from the 70 firms in the *industry* survey in Adelaide together with sub-totals for each employee size-band of ten firms.

Totals were also produced from the ten interviews in the *Research/Higher Education* sector and separate totals were produced for the ten interviews conducted with the *Government/Facilitator* sector representatives in Adelaide.

The smaller samples obtained from the four Australian regions, Brisbane, Canberra, Melbourne and Sydney, from the approximately 30 interviews per region, were also entered in separate databases and totals and comparisons produced.

Open-ended responses from participants in each of the three case study groups were also ranked and categorised for comparison, commonality or variations between and within regions.

Valuable information and insights were gained from open-ended responses during interviews and in some cases from interactive discussion after the completion of the topics on the Discussion Agenda. Industry and technology trends, government activity and regulation and university relationships with industry were commonly recurring unprompted topics. These informal discussions provided a rich source of additional insights for regional comparisons. Through these structured interviews and from publicly available data and from data obtained from the relevant national and regional authorities an analysis of the origin and development process has been developed and is discussed in Chapter Four. Each of the eighteen cities included in this research is reported separately and as a member of an appropriate group of comparable regions with an analysis of the relevant cluster characteristics of each city and each region. Each of the clusters in these eighteen cities has a particular and in some cases a unique origin process that can be traced to a particular event or person or action at an identifiable time and place, these are discussed in Chapter 4. The two disparate cluster origin processes, the endogenous process and the created or assisted processes and insights achieved through the interview process are discussed in Chapter 4.

The principal case study which was informed by the literature, government and industry data and by the surveys in Adelaide, Austin, Cambridge, Christchurch and Silicon Valley is discussed in Chapter 4. These case studies show that various combinations of factors have been critical to the emergence of the five endogenous clusters selected in the principal case study. However, these factors have been found to be less dominant in the emergence of the clusters in the second case study group where clusters have developed through a similar endogenous process, but have not developed to the same high density as the regions in the principal case study.

The data obtained from these surveys when added to the data and information from the literature has informed the principal case study and the second case study and has led to an understanding of the origin and development of the HTEI clusters in the selected regions and thereby assisted in the answering of the first two research questions on why and how intense HTEI clusters form and grow in the selected regions.

The regions in the third case study were selected from global regions that have developed through various government policies and programs. The study of the HTEI in these regions assists with the understanding of the third research question on the variation between the HTEI clusters in the regions that emerged endogenously and those created by government action.

3.19 Chapter Summary

Data requirements are discussed and in particular, the need for larger numbers of interviews in places not adequately represented in the literature. The principles and the process of the selection of regions to be included in the three case studies are discussed. The design of the survey and the selection of the organisations and individuals to be interviewed are described.

The design and implementation of the pilot survey and the evolution of the final survey design are presented. The deployment of the survey and the analysis of its results are described with an outline of the nature and the value of the data obtained and its analysis.

In the following chapter the data and information obtained through the structured interview processes described above are discussed on the 18 global regions selected for this study. Comparisons of the regions are discussed and a cross-case comparison is provided.

Chapter 4: Findings and Discussion

4.1 Introduction

This chapter presents case studies of regional HTEI clusters which are informed by data from structured interviews and augmented where available by the literature, to address the three research questions; *Why* did HTEI firms cluster in the selected 'second tier' cities? *How* have HTEI clusters developed in the selected regions? *What* variations exist between the HTEI clusters in the selected regions that emerged endogenously and those created by government action?

This chapter presents findings from 293 structured, face-to-face interviews conducted with founders and managers of firms and representatives of industry, research and government bodies in HTEI clusters in eighteen regions of seven countries.

Data from the structured interviews and the available literature are presented in three case studies, selected and grouped by common characteristics and which taken together represent a wide range of size, age and type of cluster, location, origin and development processes.

While many HTEI clusters - particularly in USA and UK - are extensively researched, dense endogenous HTEI clusters that employ high proportions of their national HTEI workforce in other developed countries have received less research attention. It is in the HTEI clusters, in Christchurch and Adelaide, the "*High-tech hidden gem regions"* (Mayer, 2011:8) that the larger number of interviews was conducted for the principal case study.

4.2 Three Case Studies

The findings from three separate case studies are presented with a discussion on the origin and development of HTEI clusters in selected regions in USA, UK, Asia, Australia and New Zealand. The five regions in the principal case study are the exemplars that share several important characteristics. These regions have strong and growing HTEI clusters that emerged endogenously in relatively small, second tier regions that are also remote from major national populations and have developed through self-organisation over a minimum of five decades and up to more than a century.

A second case study includes HTEI clusters that emerged endogenously and developed through self-organisation and this group includes a range of city sizes to provide contrast in the performance of the endogenous clusters.

Analysis of the data on the performance of the endogenous clusters in these two case studies will assist in answering the first two research questions; *why* did these clusters emerge and *how* did these clusters develop.

A third case study includes regions where limited endogenous cluster development has been augmented by assistance from national or regional governments. This case study will assist with the third research question; *what* variations of cluster types have developed.

4.3 Principal Case Study – *Cambridge, Silicon Valley, Austin, Christchurch, Adelaide*

The literature on the HTEI in Cambridge and Silicon Valley reports the initial start-up of scientific instrument businesses employing university technology and with senior university faculty involvement in the process. These clusters grew in the early twentieth century as new spin-outs from the pioneer firms and from the university and others collaborated and cooperated to increase the size strength of the fledgling clusters.

While a small electronics industry existed in Austin the development of its HTEI cluster was boosted in the mid twentieth century by a spin-out from their university that was based on university technology and with faculty members as the entrepreneurs.

HTEI clusters evolved in the mid twentieth century in Adelaide and Christchurch, however university technology and faculty assistance were not features of the start-up of the pioneer firms in either of these two HTEI clusters. The catalyst was a government defence research laboratory in Adelaide and a two-way radio manufacturing firm in Christchurch.

The name Silicon Valley has been translated into many languages and adapted for many locations. The Cambridge, UK cluster is also known as *Silicon Fen* [fen: low marshy land]; the Austin, Texas cluster is known as *Silicon Hills* and the Adelaide cluster has been named *Silicon Mallee*, after the *eucalyptus mallee* tree that is native to the region.

The principal case study includes a small number of interviews to obtain the contextual background and confirmation of the well-reported cluster development literature on Cambridge, Silicon Valley and Austin and to understand WIGO in these exemplar clusters as a source of patterns and processes that may also be found in the less-researched clusters in Adelaide and Christchurch.

The comprehensiveness of the literature on the origin and development of the HTEI clusters in these regions is varied. The literature on Cambridge and Silicon Valley is extensive and detailed and high quality government and industry data on employment is available.

The literature on the Austin HTEI is less detailed but extensive and, importantly, good employment data is available from government sources. The literature on the HTEI cluster in Christchurch is limited, but the government data shows that a dense electronics cluster has established over time. Adelaide is the least reported of the five regions, however, industry data indicates that a dense HTEI cluster has developed over several decades.

The limited number of interviews conducted in Cambridge, Silicon Valley and Austin confirm and extend the knowledge provided by the large volume of published cluster origin and development literature and government and industry data. A larger number of interviews conducted in Christchurch produced origin and development data on the cluster and the cluster firms and organisations that were not previously available.

However, the largest number of interviews was conducted in Adelaide, which is the least studied of the five cities in the principal case study. These interviews produced a substantial database of new firm formation and HTEI cluster development data on Australia's smallest mainland state capital city; the classic second tier city with the densest HTEI cluster in Australia and the least reported of the five regions in the principal case study. Numbers of interviews comparable with those in Christchurch were conducted in four Australian cities to provide firm and cluster origin and development data for the second case study.

An important characteristic of the HTEI clusters identified in the principal case study is that all emerged endogenously and have developed through a process of self-organisation, have developed over a period of more than fifty years to more than one hundred years and these clusters require no external control or management, are self-sustaining and over time have developed unique, tacitly agreed and usually unwritten behavioural norms.

It is noted that these regions were selected for the high density of employment in their electronics cluster, not for their small size or remoteness, but it will be argued that the small size and remoteness of the regions has been found to have a positive influence on the endogenous origin and ongoing development of these clusters. The emergence and development of each of these clusters resulted from a serendipitous event (Braunerhjelm and Feldman, 2006) or described as "c*hance"* (Porter, 1990b: 125) or an "*historical accident"* (Krugman, 1991:35). A central characteristic of these self-organised clusters is the collaboration of their participants; exchanging assistance and support within the group of contemporaries, competitors and institutions.

Each of these clusters has a unique origin and development narrative and an important '*trigger'* event has occurred in each of the five regions. These individual events which are outlined briefly below will be discussed more fully in the separate sections on each region.

The formation of a Cambridge firm in the late nineteenth century to build scientific instruments, initially for the University of Cambridge, was assisted by senior faculty. Later spin-outs from this firm and local start-ups were the foundation of the HTEI cluster in this small city (Segal Quince, 1985).

The origin of the HTEI cluster in Silicon Valley is variously attributed to the foundation of a radio equipment manufacturing firm in Palo Alto early in the twentieth century or the start-up of a scientific instrument company thirty years later, assisted by a distinguished Stanford Professor. Both of these firms had an intellectual and financial connection to Stanford University which was crucial to their origin and their role in the cluster (Sturgeon, 2000).

In the 1950s a company that manufactured scientific instruments and defence electronic systems was started in Austin by faculty members at the University of Texas and later spin-out firms and relocation of established electronics firms into Austin are reported to be the origin of the Austin HTEI cluster (TSHA, 2013a). The importance of *civic entrepreneurship* in the growth of the Austin cluster is also discussed (Henton, et al, 1997).

Using new knowledge gained during war service and training in UK, a New Zealand radio technician formed a company in Christchurch in the 1950s to build two-way radios for police and taxi operators. This company and its later spin-outs and assisted start-ups led to the formation of the HTEI cluster in Christchurch (Green, 2005).

A radio equipment firm started in the 1920s (SLSA, 2013) and a scientific instrument firm started in the 1930s (Pay, 2007) are identified as the pioneer electronics firms in Adelaide. Australia's major government defence research institution established in Adelaide (Morton, 1989) has provided research and development on military systems and technologies since 1947 and its training and spin-outs have greatly assisted the Adelaide HTEI cluster.

The origins of the clusters in each of these five regions are linked by the entrepreneurial actions of individuals who had acquired technical knowledge in the course of their previous work. The exact motivation of these pioneering technology entrepreneurs cannot be known, but it does not appear to have been overtly financial. The instrument company in Cambridge "*rarely charged realistic prices"* (Cattermole and Wolfe, 1987:3), designing and making precise and elegant instruments was the focus of the business.

This focus on the technology is found in many of the early start-ups and in all the case study regions and more than one hundred years after these earliest recorded instances, the same characteristic is found in technology entrepreneurs today; a deep connection with the technologies and products they have developed and less initial focus on the financial benefits of their work.

4.3.1 Cambridge

The Roman settlement at Cambridge was granted *town* status in the twelfth century and developed as a *market* town over more than one thousand years. Its famous university was founded in the thirteenth century and major developments in the physical sciences at the University of Cambridge include the theory of electromagnetic radiation - or radio waves - was proposed 1865 by James Clerk Maxwell, (Kim, 2002). It is highly relevant to the electronics industry that the existence of the electron was discovered in 1897 by Professor J. J. (later Sir Joseph) Thomson at the University of Cambridge.

It is arguable that Cambridge was the first of these five regions in the principal case study to have a *technology industry;* a manufacturing industry which applied the technology available at the time to build scientific instruments and an industry which adapted and developed available technologies for emerging applications and adopted new technologies, as they emerged.

The earliest development that could be classified as a *'foundation'* event for a technology cluster was the establishment of a scientific instrument business in Cambridge in the late nineteenth century. The establishment of this firm arose directly from the outstanding scientific developments taking place at the University of Cambridge (Segal Quince, 1985:15) and this firm and its spin-outs and others that emerged in the town were the foundation of the region's technology-based industry. The relationship between precision scientific instruments and university research is illustrated by the origin of the firm that was to become the leader in the evolution of the electronics industry cluster in Cambridge (Williams, 1994).

4.3.1.1 Cambridge Scientific Instrument Co.

The first Cambridge technology firm was started in 1878 by Robert Fulcher, then head mechanic in the laboratory of the first Cambridge Professor of Engineering, James Stuart. Fulcher made scientific instruments, using mechanical technologies in the workshop of Professor Stuart for the University and for sale to other users (Cattermole and Wolfe, 1987:14).

In 1879, Robert Fulcher and a new partner, Trinity College, Cambridge graduate Albert Dew-Smith moved the workshop to a converted hay loft in the town. The Fulcher and Dew-Smith partnership was dissolved in 1880 and a new partnership, The Cambridge Scientific Instrument Co. (CSI, hereafter) was formed by Dew-Smith and his friend from undergraduate days Horace, youngest surviving son of naturalist Charles Darwin.

Horace Darwin had returned to Cambridge after three years in Kent apprenticed to a firm of engineers after graduating in mathematics at Cambridge (Williams, 1994). The population of Cambridge was reported to be 36,400 in 1881 (Census, 2013).

The new firm built scientific measuring instruments and their early instruments were based on university designs (Cattermole and Wolfe, 1987). The CSI partnership became a company in 1895. The initial mechanical technologies were augmented later by optical, electrical, electro-mechanical and by electronic technologies as they became available.

This company is identified as the pioneer in the development of the electronics cluster in Cambridge. A discussion confirmed that the founding of the CSI firm was the origin of a scientific instrument cluster in Cambridge, which grew over time into the high technology cluster of today. "*Cambridge Scientific Instruments was indeed the first-ever high-tech spin-off company from Cambridge University"* (Keeble, 2012). Alan Barrell (2004:7) states: "*Darwin founded the first technology company in Cambridge."*

The firm was locally known as "*Horace Darwin's Shop"* (Cattermole and Wolfe, 1987:21). Instruments for newly emerging industrial applications were added to the CSI range in the early twentieth century and instruments for defence applications were produced during the First World War. By 1918 the company employed 488 people (Cattermole and Wolfe, 1987: 82) and through the twentieth century was well known for its scientific and industrial instruments and particularly for its electron microscopes (Cattermole and Wolfe, 1987:71).

In 1924 the firm became a public company, Cambridge Instrument Company Ltd. (CIC, hereafter). Ten subsidiaries or companies founded directly by CIC up to 1984 are shown in a chart (Segal Quince, 1985: 32). In 1968 CIC became part of Brown Boveri Kent Ltd. (Segal Quince, 1985) and is now part of Leica (Minshall and Gill, 2011:16). Spin-outs from incumbent firms in the same industry "can lead to clustering"(Klepper, 2010:15). This process, noted in Chapter 2 (Mayer, 2011; Benneworth, 2004) was involved in the second of the two important Cambridge firms.

4.3.1.2 W G Pye and Unicam

William George Pye who had been employed by the CSI as a boy and after experience in London managed the workshop at the Cavendish Laboratory of the Physics Department at the University of Cambridge. He established an instrument workshop in his stable in 1896. His father William T. Pye was employed from 1880 at CSI as foreman and later as Company Secretary and he left CSI in 1898 to join his son in the instrument making business, W G Pye & Co. (Cattermole and Wolfe, 1987:23).

W G Pye produced scientific instruments in Cambridge through the early twentieth century and later, valves and military radio equipment during both World Wars, while a new subsidiary Pye Radio Ltd. produced consumer products including radio, television and records, until taken over by Philips in 1976. W G Pye continued to make scientific instruments in Cambridge after the Philips takeover. Almost forty firms descended from W G Pye between 1896 and 1984 and are shown in a chart (Segal Quince, 1985:32).

By 1950 there were more than 20 technology companies in Cambridge, most of which were related through their technology or their personnel to the University. A decade later there were 30 technology firms in Cambridge and by 1975 there were 100 and more than 300 in 1985 and approaching 1,000 by the year 2000 (Keeble, 2001). Wicksteed (2000) shows 1,250 firms with 32,500 employees in 1999.

Table 4.1: High-Technology Firm Growth in the Cambridge Region, (1960 – 2000)

1960	1975	1985	1992	2000
30	100	347	785	920

Source: Keeble (2001) *University and Technology: Science and Technology Parks in the Cambridge Region*,
Note: The Cambridge Region is defined as Cambridge City, East and South Cambridgeshire

Another significant firm was formed in 1934 by Sydney Stubbens who left his position as a foreman at CIC and founded, Unicam Instruments. This firm merged with W G Pye in 1947 to form Pye-Unicam Ltd. (Cattermole and Wolfe, 1987:56), which is now part of Thermo Fisher Scientific in Cambridge (The Valve Page, 2010).[7]

Cambridge Scientific Instrument Co and W G Pye were early adopters of electronic technologies and together produced almost 50 spin-out or subsidiary companies in Cambridge in the following 100 years. These instrument firms of the late nineteenth century and many of those formed in Cambridge during more than 100 years can trace their origin to the University or to the two pioneer firms, Cambridge Instruments and W G Pye.

[7] This author was associated with W G Pye and Unicam in three Australian States and during these ten years noted the close relationship of the companies and the university.

Such a long history is rare, with some parallels in the electronics industry in and around Boston, Massachusetts discussed later in this chapter.

CIC and W G Pye have performed the role of a training institution, a *"surrogate university"* (Mayer, 2011: 89) for employees who later started their own spin-out businesses. CIC provided this training for many people including the founders of Everett & Co in 1890 (later Everett & Edgecoumbe), C E Foster in 1910 and Unicam Instruments in 1934. Many people in the industry knew each other and the instrument firms in Cambridge formed a natural collaborative cluster and by the first half of the twentieth century, these firms cooperated in many ways including the "*loan"* of men during a downturn at CIC to meet a shortfall at W G Pye in 1931 (Cattermole and Wolfe, 1987: 55).

Beginning about 1960 a period of rapid development started with a movement of people and industry from London and South East England to Cambridge (Segal Quince, 1985:12). Barrell posits that the Cambridge cluster began in 1960 when a spin-out from the University, Cambridge Consultants Ltd. which gave birth to a family of technology providers, largely through a "*bottom-up"* process, by building "*communities of common purpose."* (Barrell, 2004:2).

However, 19 firms that were directly related to Cambridge Instruments and W G Pye as spin-outs or subsidiaries are shown in existence in 1960 (Segal Quince, 1985:32). Table 4.1 (previous page) shows 30 technology firms established in 1960 (Keeble, 2001).

The collaborative behaviour - evidenced by the loan of men in 1931 - and the existence of CIC, spin-outs, W G Pye and subsidiaries is evidence that the Cambridge technology-based cluster had existed for decades before 1960. The loan of men is also evidence of the goodwill and collaboration that would have been evident to other firms in the cluster and the spin-outs from CIC and other independent firms would have noted this as an example of cooperative and collaborative behaviour of cluster firms.

4.3.1.3 The Cambridge Phenomenon

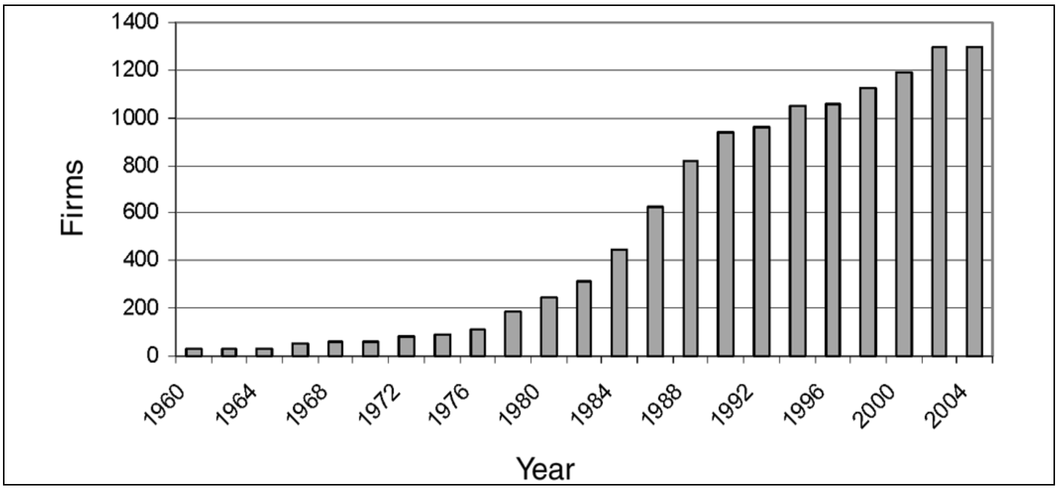
This evocative term was introduced in the financial press (Financial Times, 1980) and '*The Cambridge Phenomenon'* was adopted as the title of the first substantial report on the emergence of a new technology-based business paradigm in the region (Segal Quince, 1985). The rate of development, the economic value and the transformative value of the emergence and development of the technology-based cluster in and around Cambridge is indeed a genuine *phenomenon*.

In the five years 1979-1984 employment in the Cambridge high technology sector increased by 43 per cent or 4,100, at an average annual rate of 8 per cent per year and over 90 per cent of this growth was in firms established since 1974 (Segal Quince, 1985:29). Employment growth is reported at 80 per cent in the three decades 1971- 2001 compared to the UK employment growth rate of 16 per cent (Barrell, 2003).

By 1984 an unusually high proportion of over 42 per cent of all Cambridge high technology companies were located in one of the city's several technology or science parks (Segal Quince, 1985:30). This high proportion of co-located firms facilitated effective networking and strengthened the technology cluster (Garnsey, 1995; Heffernan and Garnsey, 2002).

In 1984 a total of 322 high technology firms were identified [and perhaps 25 more yet to be identified] in the Cambridge region and three quarters of these firms were identified as *'indigenous and independent.'* (Segal Quince, 1985:23).

Figure 4.1: Growth in High Technology Firms in Cambridgeshire, 1960–2004



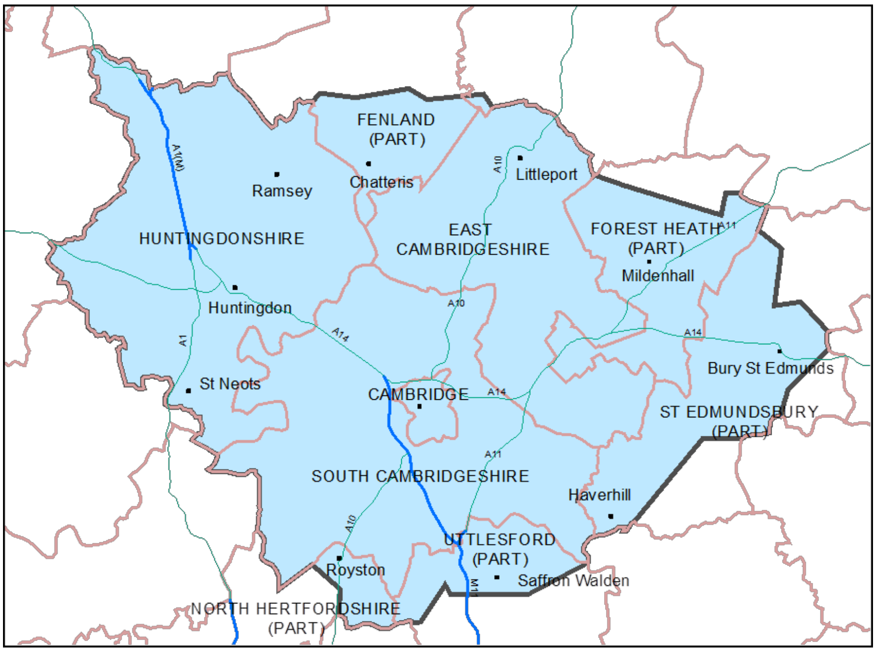
Source: Garnsey and Heffernan (2005: 1130)

In 1984 revenue and employment data was obtained from 261 of the identified technology firms, including 10 engaged in the chemical and biotechnology sector, 8 in electrical equipment, 60 in software, 26 in consulting and 157, or 60 per cent producing electronic equipment and computer hardware products (Segal Quince, 1985:29). A striking feature of the data is the high annual output per employee of the computer hardware sector of £230,000, compared with the whole Cambridge sample where the average was £65,000, [both in 1984 prices] and explained by outsourcing the production to non-Cambridge firms (Segal Quince, 1985:30). Outsourcing of routine activities is common in HTEI clusters particularly, product assembly while product design and marketing are core business.

The importance of employment in technology-based industry in general and particularly in electronics manufacturing in Cambridgeshire has been noted over time. Using the classification of Butchart (1987), Keeble (1989:156) shows that between 1981 and 1984 that high technology employment in East Anglia increased by more than 6,400, or 21 per cent.

In 1984, electronics, computer hardware and scientific instrument firms employed 61 per cent of the 13,700 employees in the high technology sector in the Cambridge region. These three sectors are included in the high technology electronics industry as it is considered here. Another 9 per cent were employed in chemicals and biotechnology, 8 per cent in computer software, and the remaining 22 per cent in the electrical, R&D and consulting sectors. (Segal Quince, 1985:29). Another report shows that by 1999 the Cambridge region had 1,000 high-tech firms with over 27,000 employees and *"Europe's highest concentration of high-tech industry"* quoted in Robinson (2002:8) and attributed to The Economist 23 February 1999.

Figure 4.2: Cambridge Technology Cluster: Radius of Approximately 25 Miles of Cambridge



Source: (Barrelll, 2003).

Barrell (2004:2) shows that the cluster grew to 350 technology companies by 1985 and 2,000 firms by the year 2000 and 3,500 firms by 2003, including consulting, manufacturing, research and supply and services firms. Herriot and Minshall (2006) report between 1,000 and 3,500 high technology ventures, depending on the definition used and 'high technology employment' at approximately 45,000 in the district population of 454,000. In 2008 the region had a working population of 365,000 of which 43,000, or approximately 12 per cent are employed in its 1,300 high technology firms, including electronics, telecommunications, instrumentation, software and biotechnology (Minshall and Gill, 2011).

The Cambridge high technology cluster or the *'Cambridge Technopole'* as it is also known (Castells and Hall,1994), is a geographic area of intense high technology innovation activity encompassing the City of Cambridge at its heart and the sub-regional Greater Cambridge hinterland of approximately 25 miles radius.

Cambridge is located in the wider region of the 'East of England', one of the fastest growing regions in the UK (Herriot and Minshall, 2006). Employment in the high technology industries of the region had grown to about 23,000 in 1992 at a compound annual growth rate of approximately 8 per cent (Garnsey and Cannon-Brooks, 1993: 179).

Data were obtained from Cambridgeshire County Council Research Group, based on ONS: SIC 2007 Division 26, for Cambridgeshire County, which includes Cambridge and surrounding communities, see Figure 4.2 above. SIC 2007 Division 26 includes computer, telecommunications, electronic component and equipment manufacturing and is generally comparable with NAICS (USA) 334 and ANZSIC 242.

In the 2009 year these data show that Cambridgeshire had the UK's highest proportion of its workforce employed in the high technology electronics industry. Employment in the HTEI in Cambridgeshire is 18,300 which represents 15.1 per cent of all HTEI employees in the UK, NOMIS Database (Roebuck, 2011) while the population of Cambridgeshire represents only 0.75 per cent of total in the UK.

These data from several sources show variations in rates of growth and industry definitions that prevent longitudinal comparison. It is clear that from a zero base in the late nineteenth century that the scientific instrument industry - which is an integral part of the HTEI - has grown from a one person firm to an internationally recognised cluster and with related industries; electronics, information technology, telecommunications, software and biotechnology forming a vast cluster of technology-based organisations and serial entrepreneurship (Myint et al, 2005) in and around Cambridge.

An official UK Government report has identified the *linkage* of two critically important factors in the emergence and development of the Cambridge cluster; *"... the emergence of the Phenomenon revolves around* ***Cambridge's short and limited industrial history and the town's relative remoteness and small size in a growing region."*** [bold emphasis is the original author's] (HMSO, 1988:17). The linkage of the factors; "*relative remoteness and small size"* in the evolution of the Cambridge HTEI cluster is highly relevant to this thesis.

These two linked factors identified in the HMSO report in relation to Cambridge and the conjunction of these two factors has also been critical to the emergence and development of the HTEI clusters in Silicon Valley, Austin, Christchurch and Adelaide.

The Mott Report (1969) to the Senate of the University of Cambridge proposed relaxation of city planning restrictions and the establishment of a science park. The Cambridge Science Park, the first in the UK was established by Trinity College in 1970 and several science, technology and research parks have since been opened. The role of Cambridge Science Park in the ongoing development of the Cambridge HTEI cluster is discussed by Segal Quince (1985:58, 5.51) noting that its relative underuse in the early years was reversed and this facility and the many new multi-use science and technology parks now report high occupancy. In the 1970s the many new indigenous and start-up firms in Cambridge created employment at a much faster rate than the national average (Gould and Keeble, 1984).

A convenient and readily comparable measure of the relative concentration of regional industry employment is provided by the calculation of the LQ as discussed in Chapter 3. The data show that HTEI employment in Cambridgeshire has an LQ of 1.66 using the formula shown in Chapter 3. The LQ figure for the HTEI in Cambridgeshire is the highest in the UK, but is lower than the LQ for the selected second tier cities in other nations in this principal case study group, a result of the wide dispersal of the HTEI across a number of regions in England and the significant clusters in Scotland, Northern Ireland and Wales.

4.3.1.4 The Influence of Chance on Cluster Origin

The emergence and development of the Cambridge cluster of HTEI firms and other technology firms and institutions during the twentieth century is linked directly by "*chance*" (Porter, 1990b:124) or by "*historical accident*" (Krugman, 1991:35) to the presence of the University of Cambridge and its output of new scientific and technical knowledge, in its small and relatively isolated location from major national populations during the nineteenth and early twentieth centuries; the period of the endogenous origin and self-organised development of the Cambridge technology cluster.

These are noted as major factors in the origin and development of the electronics and related industries in Cambridge (Segal Quince, 1985; HMSO, 1988). It is also noted that the high technology industry in and around Cambridge emerged and grew relatively slowly and essentially unnoticed by the Cambridgeshire community and by local, regional and national governments for a century, until a press report (Levi, 1980) noted the emergence of technology companies, many using technologies from the University of Cambridge.

The essential characteristics of the *Cambridge Phenomenon* (Segal Quince, 1985:50):

1. The presence in the region of a large number of high technology companies.
2. A very high proportion of young, small, independent and indigenous firms and a consequentially low number of large corporations that are headquartered elsewhere.
3. A long record of high technology business start-ups.
4. A focus on research, design and development of high value-added/low volume products, typically with the manufacturing process being outsourced.
5. Many direct and indirect links between firms, university and research institutions.

These characteristics and those listed in Section 2.5.2 (Markusen, 1999a:23) on page 36 are also observed in other regions selected in the principal case study group.

4.3.1.5 Why Cambridge?

Cambridge has long been regarded as a charming, historic, university town, relatively removed from London in a pleasant rural environment that "*historically has been far from the main centres of industrial development"* (HMSO, 1988:15). The factor of *isolation* from major centres of industry recurs in the narrative of all five of the cities included in the principal case study regions.

Local planning controls in and around Cambridge through the post-war years ensured that Cambridge remained predominantly a university community through "*tight control of development"* (Brindley et al, 1996:24). The Holford Report (1950) on the future development of Cambridge and the subsequent *'green belt'* regulations controlled development in the city and its surrounding villages (Segal Quince, 1985) and stabilised the population.

In the 1960s IBM was refused approval to establish its European Research and Development Laboratories and PA Technology, a University spin-out consulting firm was refused permission to expand in the city. The restrictions did help to keep the population of the city to near the desired level of 100,000 in 2001. Development in the historic city and surrounding villages is still tightly controlled. (Perry, 1999).

Technology-based firms emerged and developed in Cambridge in its isolated environment with no major industries, entrenched business or union cultures (Martin and Simmie, 2008). However, there was a fear that the traditional character of Cambridge with its university, its way of life and its architectural heritage would be threatened by industrial development.

The concerns that encouraged restrictions on industrialisation of Cambridge were based on the example of the vehicle industry at Cowley near Oxford having *"... a disharmonious impact of industry on a university town"* (Segal Quince, 1985:17) and local difficulties in Oxford *"arising out of the characteristics of local firms and institutions."* (Lawton Smith, 2000:72). However, Cambridge benefitted from "*... the reluctance of Oxford to encourage commercial science development ...*" (Hodgson, 1992:8). Garnsey and Lawton Smith (1998) compare the development paths of technology industry of the two cities and identify signs of convergence.

Cambridge started with a relatively "*clean sheet"* immediately after the Second World War and *"combined with an intellectual openness"* (Martin and Simmie, 2008:192) allowed Cambridge to take advantage of technology business opportunities to create new development pathways.

The small size and easy style of Cambridge have together made it much easier *"for a critical mass of high technology firms to be reached"* than it would in a large city and, importantly *"for the firms to be noticed"* (Segal Quince, 1985:159). This *scale* effect, based on the relatively small size of Cambridge, has also been important in the other four second tier regions in the principal case study and this effect is discussed later in this chapter. Small communities offer disproportionately large benefits for clustering of technology firms (Feldman, 2000).

The city of Cambridge has been transformed from a medieval seat of learning largely by the actions of Cambridge University "*… to a great educational centre and wealth-creating knowledge-based business centre"* (Barrell, 2004:2). Most of this growth of technology-based business has been accomplished in the past 50 years and is an example of the *'grassroots'* (Henton et al, 1997) or '*bottom-up'* process (Barrell and Littlewood, 2006). The self-organised building of communities of technology-based entrepreneurship and the matching of aspirations with achievements has developed endogenously, rather than through *"top down government policy, intervention or funding"* (Barrell, 2004:2) and the development of high technology industry in the Cambridge area was "*largely self-organising"* (Heffernan and Garnsey, 2002:3).

Two firms previously discussed, Cambridge Instruments and W G Pye are noted as examples of the many long and valuable relationships of technology companies with the University, *"... there is no doubt that a less liberal policy towards industrial links would have inhibited even if not actually prevented development of these relationships"* (Segal Quince, 1985:77).

Their many subsidiaries and spin-out firms have been an integral part of the *Cambridge Phenomenon*. The productive environment has been built through an endogenous and cumulative process with many direct and indirect spin-offs from the university (Keeble and Wilkinson, 2000).

Three important factors were noted from interviews in Cambridge and these are integral to the high technology development in Cambridge in the past 50 years. First, while the role of the University of Cambridge and its active involvement with industry is well understood in Cambridge it is not widely known beyond the region. David Probert of the Centre for Technology Management, Department of Engineering at University of Cambridge detailed the linkages between industry and university that were established decades earlier, not by industry, but primarily by the actions of the university. The discipline of *'Technology Management'* was created in the Engineering Faculty years before the Business School was established at the University of Cambridge in 1990 (Probert, 2006). The concept of the University being the initiator in industry-university relationships was unexpected; the belief that universities are more conservative than industry is widespread in other places.

Second, Dr Malcolm Grimshaw of Cambridge Enterprise explained that in addition to allowing academics to have significant control of the intellectual property arising from their research that a wide range of assistance was also provided, some at no cost to academic entrepreneurs to promote the development and commercialisation of promising technologies. This demonstrates that the University of Cambridge allows greater freedom to its academics to decide on the exploitation of technologies than in many other universities (Grimshaw, 2006). See Section 4.3.1.6 for details of University IP Policy. If substantial profits are made through commercialisation the University *"might seek to become involved in some way in order to acquire a proportion of that profit"* (Segal Quince, 1985:75), and the University does benefit from the generosity of many of its academics and alumni. This relaxed stance contrasts with the more rigid policies in most UK, USA and Australian universities where '*commercialisation offices'* are established to manage the intellectual property developed by their academics and research institutes. Some generous gifts have been made to the University of Cambridge by successful entrepreneurs and by supportive firms and families, and this practice is noted at many USA universities where the level of generosity is published regularly. In 2011, the recipient of the largest endowment was Harvard University and was followed in order by Yale University, the University of Texas and Stanford University. These latter two universities and their relationships with their local industry are discussed later in this chapter.

Third, the role of Matthew Bullock and his employer Barclays Bank is noted. Segal Quince (1985) and Levi (1980) reported that a meeting arranged by him in 1979 established the Cambridge Computer Group [now renamed Cambridge Technology Association]. This association brought together a number of scientists, engineers and entrepreneurs who had recently started electronics and computer related businesses, many using technologies developed at the University. The Association built on the informal relationships of members and provided a forum for face-to-face discussion by peers and for speakers on technical, business and finance topics. Bullock recognised the need for funding for these fledgling firms and encouraged Barclays to provide financial advice and initially small levels of funding to these businesses that were outside of Barclays' normal banking services to the farming, town-based businesses and the University. Walter Herriot, the manager at Barclays, in the 1980s developed this financial relationship and was manager of the St John's Innovation Centre in Cambridge from 1990 until his retirement in 2008.

Importantly, in 1984 Barclays Bank and others supported Cambridge-based consulting firm Segal Quince to research the origin and development of high technology industry in Cambridge. The '*The Cambridge Phenomenon'* is the widely quoted report of that research (Segal Quince, 1985).

Since the concentration of technology firms emerged endogenously and developed in Cambridge, the question arises: could this develop elsewhere in the UK? At the general level the combination of the capability and the involvement of the University and the *"relative remoteness and small size"* (HMSO, 1988:18) of the city have been major factors. While these factors may have been present in other places, few can match the success achieved in Cambridge and particularly over such a long time period, remembering that the first spin-out company from the University of Cambridge, CSI was started as a one man business in 1878. However, it is noted that although this first spin-out business began more than 130 years ago that the surge in development that is now evident began only a few decades ago.

The Cambridge Phenomenon was of its "*time and place"* (Herriot, 2007:4) and a combination of "*civic entrepreneurship"* (Henton et al, 1997: xi), cost effective business operations, "*entrepreneurship on a shoe string"* (Herriot, 2007:2), university technology and the assistance of organisations including Barclays Bank and St John's Innovation Centre. These factors are advanced by Professor William Herriot in a summary of the "*bottom-up"* origin and development of the cluster of high technology industry in Cambridge since the 1970s (Herriot, 2007:4) who also notes the value of government assistance, particularly since the mid 1990s through the East of England Development Agency.

Apart from the concentrations of firms in the science parks located around the city, the electronics design and manufacturing industry is not highly visible in the city of Cambridge. Peter Cowley, Managing Director, Camdata Ltd. explained at an interview in the village of Harston near Cambridge that due to development controls, many small HTEI firms are located in the villages and small towns in the surrounding Cambridgeshire countryside. His responses to Discussion Topics echoes many others, including a strong desire to be independent, but connected to other firms and the university through networks and a primary focus on the development of new technologies rather than their exploitation for profit (Cowley, 2006).

Infrastructure developments including the M11 motorway from north London to Cambridge which was completed in 1979 and improved train services have greatly reduced the time for the 80 kilometre journey.

These transport options and the benefits of high speed and ubiquitous electronic communication have lessened the need to be in the same city, but still those that have a proximate location can respond more quickly and effectively if the other party is a short walk away, a cycle ride or car drive away. The development of trusting, technologically and economically productive relationships still benefit from the proximity of the collaborators, and it is noted that cluster participants find it convenient, economic and comforting to continue to rely on trusted local business partners; those local firms with the advantages *"that distant rivals cannot match"* (Porter, 1998a:78).

4.3.1.6 University IP Policy

A major element in the success of Cambridge as a high technology centre was the traditional policy of its University which allowed its academics to own the IP and to file patents in their own name for their discoveries or developments, unless a contract specified otherwise (Segal Quince, 1985:62). From 2001, the university claimed IP created from externally funded research, with the exception of *'normal academic forms of publication.'* Changes in 2005 transferred control of patenting rights from individual researchers to the university itself but allowed academics to own all other forms of IP and publication rights (Cambridge Enterprise, 2005). A sliding scale of reimbursement for inventors has been introduced which awards 90 per cent of the first £100,000 in revenues to the *inventor* reducing to 34 per cent after £200,000. Despite these changes the university's IP regime is still considered more liberal than those of other UK institutions (Scientist, 2005). Conversely, the University of Oxford has a more rigid policy of *"...claiming Intellectual Property Rights generated by staff and students"* (Cooke and Huggins, 2003:58).

The University of Cambridge also allows faculty members to undertake outside work while relying on student and peer pressure to regulate the amount of time away from their academic duties. The University accepts no legal liability for the outside work of its academics, but does recognise that this is beneficial for their "*inside"* work (Segal Quince, 1985:76).

Another element in the success of Cambridge as a high technology region is the support of the University through Cambridge Enterprise, discussed above and the direct support of research by the University of Cambridge which is provided through the Research Services Division (Research Operations). Liam Garvey discussed the services including generous assistance with grant funding applications and research facilities and equipment and sponsor support which encourage the high level of research output (Garvey, 2006).

Further support is provided by The Cambridge Network, a membership organisation founded in 1998 to assist collaboration and the interchange of ideas within and, importantly, across disciplines. Cross-discipline or *crosscutting* research is important to the electronics industry for its access to biotechnology, medical, nanotechnology and engineering for which so many of its new applications are developed. Dr Peter Hewkin, Director of Cambridge Network discussed the services provided to members including programs to assist cross-disciplinary interchange through networking events held regularly to present local and visiting specialists from its global network of academic, business and government specialists. Other services include an annual salary survey for industry members and a recruitment service for short and long term engagements and training on topics including business start-up, technology and human relations topics, on a fee for service basis (Hewkin, 2006).

4.3.1.7 Cambridge and Oxford

The University of Cambridge and the University of Oxford are respectively about 80 kilometres north and north-west of London and approximately 110 kilometres from each other. Rivalry between these two regional cities and their universities goes back at least to early thirteenth century. Relative to population Cambridge and Oxford are ranked first and second in Europe's top 30 *'science centres',* measured as the output of scientific, medical and engineering publications (Keeble and Wilkinson, 2000). Cambridge and Oxford universities are ranked third and fourth respectively by reputation, after Harvard and Massachusetts Institute of Technology (MIT hereafter) in the Times Higher Education World Reputation Rankings (Times, 2013), while in the Times category of 'Engineering and Technology' Cambridge is ranked number 5 and Oxford is ranked number 11.

Cambridge's high standing assists the attraction of academics, business and funding from global sources. Cambridge has an *"arts : science"* ratio of 1:1 while Oxford has ratio of 2:1 (Segal Quince, 1985: 63). Despite this disadvantageous ratio Oxford has a number of technology-based firms and many have evolved out of a relationship with the University of Oxford. It was estimated that in 1984 there were about 50 high technology firms in the Oxford region (Segal Quince, 1985:63) and 261 such firms in Cambridge (Segal Quince, 1985:29). Estimates of 50 advanced manufacturing firms in Oxfordshire in 1979 and 182 firms in 1987 were made by Lawton Smith (1990), which contrasts with the 100 in Cambridge in 1975 and 347 in 1985 [Table 4.1, above]. In a survey of 100 SME firms sampled in the cities, 75 per cent of Oxford firms and 84 per cent of Cambridge high technology firms had *"extensive and wide-ranging links with public sector research"* (Lawton Smith et al, 2001).

The first recorded Oxford high technology spin-off firm, Penlon a medical equipment firm was established in1946. Oxford Instruments is the leading firm, established in 1959 as a spin-out firm from the university and has more than 1,800 employees and sales of US$502 million in 2012 (Oxford, 2012). Lawton Smith and Waters (2011) show that the technology industry in Oxfordshire has 12 per cent of County employment with 36,682 employees in 1,400 firms while Cambridgeshire has 13 per cent of County employment with 48,300 employees in 1,526 firms.

4.3.1.8 Cambridge as a Location

The factors in the choice of the location of new high technology firms were discussed in Chapter 2 and in Cambridge the *'hometown'* factor is evident. In a sample of 44 start-up firms 86 per cent chose Cambridge, the home town of the entrepreneur as the location for their new high-tech firm (Athreye, 2004). Segal and Quince (1985) reported 73 per cent of high-tech start-ups chose Cambridge because it was the founder's home town. Brenner, (2004) quotes Bramanti and Senn (1990) and shows that the home town was chosen by 56 per cent of start-ups and (Pleschak, 1995) shows 58 per cent of founders chose their location for personal reasons. The hometown factor was also found to apply strongly in Adelaide, Christchurch and other Australian cities in survey data from these HTEI clusters which is discussed later in this chapter.

The comparative isolation of Cambridge from major cities assisted the early development of technology clusters (HMSO, 1988:17). In this context *early* applies, particularly to the post-war period and to about the early 1980s, when the existence and early growth of the Cambridge technology cluster was becoming evident.

The joint effect of *proximity and isolation* discussed in Chapter 2 is evident in Cambridge during the post-war period. In a small community researchers and engineers can network with a higher proportion of colleagues than is possible in large populations and organisations such as Cambridge Network facilitates these connections.

Knowing that there are a limited number of people working in similar and possibly complementary or crosscutting fields in the confined region can highlight the benefits of collaborating with local firms or institutions. Knowledge-based firms emerge and grow around a new activity in an area and, *"Proximity aids the formation of centres of learning and research."* (Garnsey and Heffernan, 2005:1128).

Crosscutting relationships are important in the HTEI clusters in this study; electronic technologies are applied in many other disciplines, often as the *enabling* technology as in biotechnology through analytical and measuring instruments and process control systems and in the medical field with an expanding range of diagnostic and treatment systems and devices. Access to crosscutting relationships with potential collaborators in these *natural* sciences can be critically important for both parties in the development of new systems.

Industry experience through an association with W G Pye and Unicam of this author shows that crosscutting relationships with biochemistry researchers have produced instrumentation that has enabled major advances. This industrial experience extends to the development of analytical instruments for biotechnology research by Tracor Inc. in Austin Texas, which is discussed below in 4.3.3.

It is known that in such relatively small and isolated communities, such as Cambridge that a higher proportion of researchers, manufacturers and potential collaborators in business firms are known to each other through prior school, university, workplace, sporting or social relationships; these relationships deepen the clustering effect and produce tangible value for cluster members and communities.

Trust is more effectively developed through face-to-face meetings, and those meetings can be of longer duration and occur more frequently in smaller communities; the building of trust through face-to-face contact is fundamental (Storper and Venables, 2003). The enduring value of face-to-face contact in the development of trust in second tier cities is a recurring observation in all of the principal case study regions.

The role of the University in the development of the Cambridge HTEI cluster is established from the literature and from data obtained from interviews with industry, local government and research community representatives.

Several place specific characteristics are evident in Cambridge and four surveys, discussed above, from 1985 to 2004 show that the hometown was chosen as the location for a new business in 56 per cent to 86 per cent of new business entrepreneurs in Cambridge. The University is highly regarded for its teaching and research and its role as an anchor to the technology community is unsurpassed.

4.3.2 Silicon Valley

The largest and most widely studied global cluster of high technology electronics design and manufacturing industry is located in the Santa Clara Valley in Northern California, now known as Silicon Valley and described as *"…one of the great industrial wonders of the modern world"* (Klepper, 2011:142). The emergence and development of this cluster has focussed global attention of governments and communities, particularly on the value of the development of the electronics and related technology-based-industries. More broadly this focus is on the transition of manufacturing industry from a reliance on industrial-age processes and products to the new paradigm of knowledge-age industry which has created vast wealth and employment in Silicon Valley and in other regions selected for this research.

4.3.2.1 The Early Years in Silicon Valley

In the first half of the twentieth century the Santa Clara Valley was a rural community, the largest fruit production and processing region in the world and known as the *'Valley of Heart's Delight'* (Malone, 2002). At the time of the early growth of the electronics industry in 1950 Santa Clara County had a population of 290,000 (Mosier, 2001) and more than 30 food canneries, the last of which closed in 1997 as the fields and orchards were replaced by houses and factories. The population of Santa Clara County increased tenfold from 145,000 in 1930 to 1.46 million in 1990 (Dominguez, 1992) and in 2010 had reached 1.781 million (United States Census, 2013). However, it is important to note that during the emergence and early development of the HTEI, Santa Clara Valley was a small, remote and scattered, self-reliant agricultural community with its County Seat in the second tier city of San Jose.

The name *Silicon Valley* (Hoefler, 1971) is derived from the silicon substrate used in the manufacture of semiconductor devices, commonly known as *'microchips'*. Silicon Valley is not an official location for statistical purposes. Silicon Valley generally fits within the San Jose-Sunnyvale-Santa Clara Metropolitan Statistical Area (MSA, hereafter), which covers more than 3,300 square kilometres on the southern end of the San Francisco Peninsula. The Silicon Valley MSA does not include San Francisco which is more than 80 kilometres north of the Santa Clara County Seat, San Jose and 50 kilometres from Palo Alto at the north end of Silicon Valley. Palo Alto is also the location of Stanford University, the intellectual hub of Silicon Valley. Other major centres in Silicon Valley include the small cities of Cupertino, Milpitas, Mountain View and Sunnyvale. It is noted that Silicon Valley as a region is relatively self-contained with a high level of local interdependence, particularly between SME's and independent of the larger population of San Francisco (Lawson, 2006).

While the endogenous origin and unplanned development of the HTEI in Cambridge is defined as a *'phenomenon'* (Segal Quince, 1985) the emergence and development of the HTEI cluster in Silicon Valley is also an unplanned phenomenon. Its emergence was endogenous and its development, self-organised, as in the case of Cambridge, and over time Silicon Valley developed its own unique, tacitly agreed and unwritten behavioural norms.

While no plan or policy existed to create a technology industry in the area the literature records a number of events that are proffered as the '*origin*' of Silicon Valley. Three start-up firms and one farsighted individual are widely credited for their role in the origin and development of the Silicon Valley HTEI cluster. The foundation of a radio equipment manufacturing business, in Palo Alto in the early twentieth century was a pivotal event in the evolutionary development of the electronics manufacturing industry Silicon Valley.

Independently, and in the same year an experimental radio station commenced broadcasting at the southern end of the Valley in San Jose using the new *wireless* technology to provide information and entertainment (Schneider, 1996; Herrold, 2012), a service concept which quickly spread worldwide triggering a demand for radio broadcast receivers and also creating the *consumer electronics* industry. A major benefit to the HTEI sector of the electronics industry is the demand of consumer electronics sector for large volumes of components, many of which are also used in the HTEI providing lower cost and greater availability to both sectors.

4.3.2.2 Federal Telegraph Company

The radio transmitting equipment manufacturing business, the Poulsen Wireless Telephone and Telegraph Company was established in Palo Alto in 1909 by Australian born, Stanford graduate Cyril Elwell (Castells and Hall, 1994; Vance, 2007; Sturgeon, 2000). The company name was later changed to Federal Telegraph Company (FTC, hereafter). The founding shareholders included David Starr Jordan, President of Stanford University and C. D. Marx, its Head of Civil Engineering (Morgan, 1967).

This start-up business began a relationship between Stanford University and the electronics industry that was to become highly relevant (Vance, 2007). FTC developed quickly building high powered radio transmitters and receivers for military and merchant shipping operations and collaborated with the High Voltage Laboratory at Stanford University for equipment testing (Morgan, 1967; Sobel, 1982).

An early FTC staff member, Dr Lee de Forest, had been granted a patent in 1908 for the three element vacuum tube or triode valve which he named the Audion. In 1912 at FTC de Forest employed his vacuum triode valve in his development of the *amplifier* and in 1914 in the development of the *oscillator*, two of the most important developments in the history of electronics technology (Malone, 2007).

Only one year after its founding, FTC produced the first of several spin-outs (Morgan, 1967). Magnavox started in a garage by former FTC engineers and produced and patented the moving coil loudspeaker, which later boosted sales of domestic radio broadcast receivers. This early spin-out began the dynamic process of new firm formation that has become a major feature of the *"Silicon Valley model"* (Sturgeon, 2000:19). FTC was an early manufacturer of vacuum tubes and other electronic components and unintentionally incubated important start-ups included EIMAC and Litton, makers of microwave and radar tubes and components that were critically important in wartime and peacetime (Vance, 2007). Through mergers FTC became part of the world's largest communications company International Telephone and Telegraph in 1928, but the relationship of FTC and Stanford University marked the origin of the electronics industry in the region.

The employment by FTC of a twenty year-old Stanford chemistry graduate, Frederick Terman in 1920 and Terman's later academic career at Stanford was a "*chance"* event (Porter, 1990b:124) that was "*a starting point for agglomeration"* in Silicon Valley (Perry, 2005:110). It is notable that the early involvement of Stanford's administration and faculty in FTC "*... came a full 30 years before Frederick Terman would help Hewlett and Packard to start their company"* (Sturgeon, 2000:20).

4.3.2.3 Stanford University

The unlikely location of Stanford University in the Santa Clara Valley was the result of another *chance* event. An area of 650 acres of rural land was purchased in 1876 for a country home at El Palo Alto by Union Pacific railroad entrepreneur and former California Governor, Leland Stanford. He later added adjoining properties to bring his landholding to more than 8,000 acres. All of this land and a gift of US$5million provided for the foundation and early operation of Stanford University, which opened in 1891 with a student body of over 500 young men and women. Stanford University was conceived as a place where both the classics and science would be taught and researched and is today ranked in the top levels of world and USA institutions. Stanford University and the origin and development of the HTEI cluster in Silicon Valley are inextricably linked.

Stanford continues to support its creators of new technologies through its Office of Technology Licensing and Kirsten Leute discussed the unique assistance programs provided to Stanford staff and research students (Leute, 2006).

4.3.2.4 Frederick Emmons Terman

After his short period of employment at the FTC laboratories (Malone, 2007) Terman returned to Stanford to study electrical engineering (Morgan, 1967). At that time no degree in 'electronic engineering' was available and 'radio engineering' was yet to become a sub discipline of electrical engineering. In 1925 Terman returned to Stanford after receiving his doctorate at MIT and joined the electrical engineering faculty teaching, researching and managing the newly established 'radio laboratory' (Morgan, 1967). He also established the then new discipline of 'radio engineering' in the Electrical Engineering Department.

Professor Terman became concerned that his best students were moving to the East Coast to find employment with the established radio firms including RCA and Philco. Terman began his practice of regularly taking his students on 'field trips' to visit the small but growing number of electronics firms in the area around Palo Alto to introduce the students and the firms to each other and to encourage the students to understand the role of technology in the establishment of businesses. These visits may have been a *"pivotal act"* (Malone, 2007:41) in the development of the HTEI cluster. Another of Terman's inspirational acts was to encourage and assist two of his former students, William Hewlett and David Packard to create their own company in 1939 (Gillmor, 2004).

During the early 1940s, Terman was appointed to head a government defence research project at Harvard University developing radar countermeasures (Gillmor, 2004). The experience connected him with the mainstream of government electronics research. These government contacts helped him to later attract federal funding for electronics research at Stanford. In 1946 Terman returned to Stanford as Dean of the School of Engineering and successfully attracted increasing research support from both government and industry. Terman also attracted bright new faculty and students. In addition, he continued to encourage his graduates to start their own companies.

Faculty were also encouraged to engage in consulting, investing in and creating new technology-based companies. Terman instituted the Honours Cooperative Program in 1954 to integrate formal electronic engineering study at Stanford with part-time work, initially with four local firms, Sylvania, Hewlett Packard, SRI International and General Electric. This program was similar to one at MIT which Terman encountered as a student in 1922 (Gillmor, 2004).

Krugman, (1991:35) discusses "*historical accident*" as a factor in cluster origin and *"chance"* as a factor in cluster origin is discussed by Porter (1990b: 124). In Silicon Valley "*the chance event was Frederick Terman's presence in the Valley"* (Perry, 2005:110).

4.3.2.5 Stanford Industrial Park

While the university had over 8,000 acres of land, money was needed to finance the University's rapid post-war growth, but the Leland Stanford bequest prohibited the sale of University land. Terman proposed the creation of Stanford Industrial Park (now Stanford Research Park) which was achieved in 1951 by setting aside 209 acres of Stanford land for light industrial use. Dr Henry Lowood, Stanford Historian described the documented founding process of the Industrial Park in an interview at Stanford (Lowood, 2006). By leasing of the land to technology companies the Park provided a source of income and a place for the commercial development of Stanford University's technologies and a place to develop *"a community of technical scholars"* (Morgan, 1967: 148). The Park also served the master plan of Terman, who set out in the 1950s to develop Stanford University from a financially struggling regional university to an internationally recognized world-class research university (Sandelin, 2004). The location of the Industrial Park on the Stanford campus also facilitated the networking of faculty, industry and students, now a feature of technology-based industry clusters in all regions included in this study. In 1951 the first Stanford Industrial Park lease was signed with Varian Associates, a company founded by Stanford graduates, Russell and Sigurd Varian and William Hansen. Others soon followed including Eastman Kodak, General Electric, Lockheed and Hewlett-Packard.

4.3.2.6 Hewlett Packard

William Hewlett had developed a revolutionary design for a test instrument and with his friend David Packard and some money organised by Terman started the Hewlett-Packard Company in 1939 in the garage of Packard's home in Palo Alto (Tajnai, 1985). The instrument was a revolutionary audio oscillator - a signal generator - which had both high accuracy and stability and was simpler, less costly to produce and outperformed existing models.

However, "*The idea of having a business came before our invention of the audio oscillator*" (Hewlett Packard, 2012). The two partners had discussed their idea of a business together since their undergraduate days (Malone, 2007). More innovative test instrument designs followed and the company became the world leader in instrumentation. In the 1980s computer printers were added and in the 1990s computers and peripheral devices were added creating new products and companies and expanding by acquisition including Compaq. Hewlett Packard was the world's largest producer of computers for personal and corporate use (Gartner, 2012). The company employs more than 330,000 people worldwide (SEC, 2012) and is still headquartered in Palo Alto, adjacent to Stanford University.

4.3.2.7 Defence Electronics

Government economic development policies of the type used in Ireland and Singapore were not applied in Silicon Valley; "*Government policy had little to do with the beginning of Silicon Valley*" Porter (1990b:655). However, the USA Federal Government did play a major role in the development of Silicon Valley HTEI cluster, notably as a purchaser of electronic systems and components particularly during the two World Wars. During the First World War the government closed all amateur and most commercial radio activity and diverted production to military purposes. Military requirements for radio equipment and components such as vacuum tubes swamped the local manufacturers, who collaborated and learned to use new methods to make better products (Morgan, 1967). FTC built hundreds of shipboard radio transceiver systems for the USA Liberty Ships (Sturgeon, 2000). In the 1920s and 1930s many USA homes had a radio made from components with improved performance and at lower cost as a result of developments during the First World War.

Silicon Valley's owes much of its current strength and structure to the steep rise in USA Federal spending on defence research, electronics hardware and systems during the Second World War and the Cold War which followed (Markusen et al, 1991; Adams, 2005). During the Second World War Santa Clara County electronics firms almost exclusively produced military communications equipment. In 1943 Hewlett Packard produced more than one million dollars in sales of military electronic equipment (Morgan, 1967). The production of EIMAC high power transmitting tubes – a key military electronic component - was moved from Palo Alto to Salt Lake City away from the Pacific Coast and produced 4,000 radar tubes per day. The Klystron a high power microwave amplifier tube invented by Varian and Hansen at Stanford in 1937 was produced by the new company, Varian Associates in Palo Alto for wartime radar systems. Post-War homes had television receivers using improved components based on technologies developed during the Second World War.

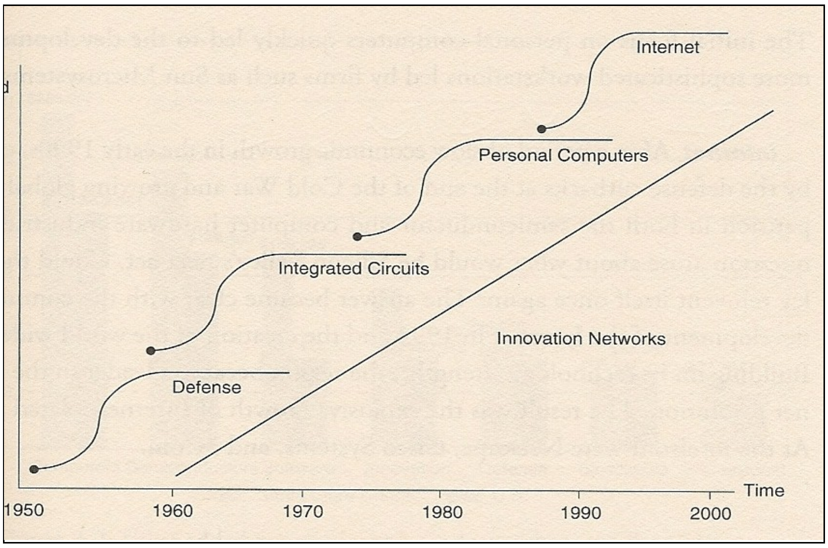
The electronics industry was boosted by the advance in technologies developed for the military that would be exploited for civilian purposes. And, "*… the rise of the commercial electronics industry after the Second World War led to the expansion of Silicon Valley"* (Mayer, 2011:28).

In the ten years following the Second World War the USA electronics industry grew sevenfold at a compound annual rate of more than 20 per cent, reaching US$11.5 billion sales in 1956 (Morgan, 1967). *"The impact of sustained public investment is seen as a spur that the Second World War and the Korean War gave to the build-up of the electronics industry in California, the accumulation of expertise in Frederick Terman's Electrical Engineering Department in Stanford University and the decision of various key companies to settle in the area before the semiconductor revolution took off."* (Perry, 2005: 174).

4.3.2.8 Waves of Development

The development of the Silicon Valley cluster has accelerated through distinct waves of development since the defence boom in the 1950s. This boom was followed by integrated circuits, personal computers and the internet, see figure 4.3 below.

Figure 4.3: Waves of Development of the Electronics Industry in Silicon Valley



Source: Henton et al (1997:47).

One current trend is security systems and the convergence of these technologies with telecommunications. In an interview in Palo Alto with an entrepreneur Russell Jones, founder of Sentinel Vision, Inc. details were discussed of the wide range of integration of security and telecommunications systems across the industry (Jones, 2006).

4.3.2.9 The Semiconductor industry

The semiconductor industry was established in the early 1950s and developed initially in New York, New Jersey and Massachusetts and was established in Northern California, less than 5 years after the invention of the transistor at Bell Laboratories in New Jersey in 1947. Dr William Shockley was a co-inventor of the transistor, for which he shared the 1956 Nobel Prize. In 1956 Frederick Terman encouraged Shockley to return to his native California and he established Shockley Transistor Laboratory in Mountain View near Stanford. (Braunerhjelm and Feldman, 2006; Lecuyer and Brock, 2006). However, due to instability in the firm eight of his bright young electronics specialists left in 1957 to establish Fairchild Semiconductor in Palo Alto (Riordan and Hoddeson, 1997). Fairchild alumni have spawned over 300 new companies, the largest of which is Intel Corporation which was established in 1968 by Fairchild alumni Robert Noyce and Gordon Moore (Berlin, 2005).

In an interview at Stanford, Dr Leslie Berlin, Noyce's biographer explained that Noyce was motivated to establish Intel by the belief that his new development, now known as the integrated circuit (IC, hereafter) could be the basis of the new company (Berlin, 2006). Noyce was also motivated by his dissatisfaction at Fairchild Semiconductor, which he had co-founded after leaving Shockley Semiconductor Laboratory. The '*push*' factor had impelled him to find a better workplace and later to create his own. The development of Intel lifted the growth rate of the semiconductor industry on which Silicon Valley is based.

Following Shockley nearly 100 semiconductor firms entered the industry in Silicon Valley, including five of the industry's top 10 firms. Spin-outs from existing firms emerged in increasing numbers and by 1970 Silicon Valley had developed into the centre of semiconductor manufacture with "*… the densest concentration of 'high technology' enterprises in the world"* (Saxenian, 1985:20). However, such extreme industry clusters are rare (Ellison and Glaeser, 1997) and elsewhere none have reached the absolute size or density of the HTEI cluster in Silicon Valley. In the early 1970s the Silicon Valley electronics cluster had a workforce of 58,000 (Lecuyer, 2007). During this period of rapid growth the movement of staff between semiconductor firms became a feature of Silicon Valley. In the 1970s the industry's average annual workforce turnover rate exceeded 36 per cent and in small firms was as high as 59 per cent (Saxenian, 1994: 34). This '*job-hopping'* behaviour and the management of the problem were discussed with Keith Halperin, international technology industry recruitment specialist in an interview in San Francisco (Halperin, 2006). A major effect of job mobility is the uncontrolled circulation of company confidential information, and as discussed in Chapter 2 Saxenian (1994), posits that such information flow is beneficial to the industry.

One means of obtaining another firm's technical secrets *"is to hire one of its key engineers."* However, there is a strong counter-strategy; the other firm may re-hire its original employee six months or a year later, *"…when he knows the competitor's technical secrets"* (Rogers, 1983:141). Silicon Valley firms combine a high level of turnover of scientists and engineers with extraordinary openness on technical information (Cooke and Huggins, 2003).

The example of the Wagon Wheel Bar in Mountain View (Saxenian, 1994:x) as observed by this author in the 1980's shows that the informal exchange of industry gossip and technological achievements at after-hours gatherings of technical people was by then an established process of information exchange.

The location of new start-up electronics and computer firms and particularly for those *'incubated'* while employed was usually in the same area and as high as 97.5 per cent of new firms in Palo Alto (Cooper, 1985). The pattern of spin-outs remaining in the area of prior employment, discussed earlier in Cambridge is observed in Silicon Valley (Klepper, 2011) each of the five HTEI clusters in this principal case study and this factor in cluster growth is discussed later in this chapter.

4.3.2.10 Joint Venture Silicon Valley

The electronics industry in Silicon Valley has surged and regressed in reaction to market forces, notably with the Japanese challenge to the global semiconductor market in the early 1980s. A new challenge in the early 1990s from defence cuts caused large reductions in employment in Silicon Valley. A survey in 1992 showed that confidence in the Valley's future *"was at an all-time low"* (Henton et al, 1997:47). A new organisation, Joint Venture Silicon Valley (JVSV, hereafter) was conceived in 1992 and launched in 1993 (Henton et al, 1997). The concept of *'civic entrepreneurship'* was implemented to harness the abundant goodwill and capability of the Valley community. The concept which is further discussed below in the development of the HTEI cluster in Austin is credited by Leadbeater and Goss (1998) to the firm of Collaborative Economics and its directors Douglas Henton, John Melville and Kimberly Walesh. In an interview in San Jose Kimberly Walesh explained the background to the origin and development of the concept and its rallying effect on the Valley community (Walesh, 2006). In the years since the launch of JVSV employment and company revenues have risen and continued to rise, despite the setbacks of the dot com downturn in 2000 and the global financial crisis of 2008. JVSV programs for the development of the Valley have been implemented in education at school, college and university levels and social programs including housing, health and arts (JVSV, 2013).

4.3.2.11 Silicon Valley Dimensions

Each region in USA is defined for statistical purposes and the San Jose-Sunnyvale-Santa Clara MSA contains most of the area known as Silicon Valley, see below Table 4.2.

The latest USA Government data available is for 2011 and shows employment in the electronics industry in the San Jose-Sunnyvale-Santa Clara MSA, total employment in all industries in the MSA and total regional and national employment in all sectors (BLS, 2013; Lang, 2013). Based on these data the regional LQ is calculated as discussed in Chapter 3.

Table 4.2 Silicon Valley Employment Data - National and Regional - NAICS 334

Employment Category and Location (2011)	Number
Employees in NAICS 334 in San Jose-Sunnyvale-Santa Clara MSA	108, 367
Total all employees in San Jose-Sunnyvale-Santa Clara MSA	795,117
Total National Employees in NAICS Category 334	1,103,588
Total National Employees - All Categories	108,184,795
Location Quotient for NAICS 334 in San Jose-Sunnyvale-Santa Clara MSA	13.36

Data Source: (BLS, 2013). Silicon Valley (San Jose-Sunnyvale-Santa Clara MSA) in NAICS 334.

The LQ figure of 13.36 shows that the proportion of electronics manufacturing industry employment in the Silicon Valley MSA region is 13.36 times the mean of employment in the HTEI sector across the nation.

Silicon Valley has the largest number of employees and also the highest concentration of electronics industry employment in the USA with 9.82 per cent of all electronics manufacturing industry employment in the USA located in the San Jose-Sunnyvale-Santa Clara MSA (BLS, 2013).

It is noted that the LQ for this region in NAICS 334 has increased from 11.38 in 2001 to 13.36 in 2011 which means that Silicon Valley has increased its share of the HTEI in the USA at the expense of other regions, including Austin.

Further analysis of the NAICS data, using the 6 digit code shows that the largest proportion, 38 per cent of all San Jose-Sunnyvale-Santa Clara MSA employment in NAICS 334 was in sub-category 334413: ‘Semiconductor and Related Device Manufacturing’ showing the continuing strength of semiconductor manufacturing in Silicon Valley.

4.3.2.12 Why Silicon Valley?

The literature strongly identifies the role of Stanford University and its farsighted Professor Frederick Terman in the origin and development of many of the early firms and later spin-outs and start-ups that now populate the Silicon Valley HTEI cluster.

It is difficult to imagine the shape and dimensions of the Silicon Valley HTEI cluster without the two major influencing factors of Terman and Stanford. The absolute size of its workforce - more than 108,000 in 2011- its strength, measured by its high LQ and its resilience in dealing with downturns and waves of new technologies is a testament to the success of the endogenous development of the '*Silicon Valley Way'*.

The ethos of Silicon Valley is unique and its economic development success has not been equalled by any other region. The region has reinvented itself at least four times since 1950 and is now recovering from its third recession. In one major respect the business environment is different to the established conventions in other countries. Many start-up firms are not typically expected to make a profit, pay tax and distribute regular annual dividends in future years to its owners. Instead, it is relatively common to develop the technology and the company to the stage that it is either ready for *'floating'* through an initial public offering (IPO, hereafter) or is attractive as a takeover target. Below is an illustration of this *'grow and sell'* philosophy:

At a meeting with this author in November, 1982 at Xicor Inc. in Milpitas, California, when asked when this relatively new and innovative semiconductor company expected to make a profit, CEO Raphael Klein replied that he and his fellow investors were not attracted to long-term profits, "*we are in this for the stock price."* (Klein, 1982). This remark highlights a significant and continuing difference between USA and Australian start-up motivations. Xicor was a typical Silicon Valley HTEI start-up, funded by VC, with a strategic focus on increasing the value of the company and its share price with the endgame objective of an IPO or a *trade sale* of the company to another company. Xicor Inc. was sold to a major competitor, Intersil Corp. The focus on stock price as opposed to ongoing annual profits highlights the difference in strategic management of Australian and USA companies and particularly, Silicon Valley technology companies at that time and indeed in the subsequent 30 years that focus on stock price rather than annual profit has not changed notably and is strongly influenced by the operating method of typical Silicon Valley VC firms. The objective of the typical Silicon Valley VC firms is to invest in a portfolio of companies with proven and protected technology at the point where the investee company is expected to produce strong growth in its share value over a short period of years and provide a profitable exit, either by IPO or trade sale. While an IPO focus using venture funding is evident in a small number of Australian HTEI companies, the more common plan is to develop the company to a size and at a rate of growth that are within the financial and management resources of its owners.

The success of Silicon Valley has focussed worldwide attention of industry and government observers on the emergence and extraordinary development of its technology industries and particularly its electronics industry. This agglomeration and its exceptional growth have been admired by many governments and several attempts have been made to emulate this success by economic development agencies, however, the replication of this unique, organic entity has proven to be highly problematic (Gillmor, 2004).

The literature shows that the earliest firms and their relationship with Stanford University started the gradual growth of the Silicon Valley HTEI cluster. Since the involvement of Stanford University in the start-up of FTC and Hewlett Packard, the continuing engagement of industry and university has produced many new firms based on university or government technology, including Cisco, Yahoo, Seagate, Google, Sun Microsystems and Cadence (Kenney and Patton, 2006:40). Industry focus on new or improved products, processes and services continues, the university continues to produce trained and talented graduates and technologies and the Silicon Valley model appears to be sustainable.

However, Mayer (2011:4) posits that the "*Silicon Valley model*" with its close links with Stanford University may be the exception and not the norm and details the origin and development of clusters in Portland, Boise and Kansas City, USA none of which have a significant research university. Both positions are correct within their respective contexts. Silicon Valley is unique and with its more than 100,000 HTEI employees and LQ of 13.36 it is an outstanding success.

The technology clusters in the three second tier cities researched in Portland, Boise and Kansas City have an LQ respectively of 1.35; 1.76; 1.14 (Mayer, 2011:3). Silicon Valley has succeeded with the assistance of Stanford University and other available resources, while Portland, Boise and Kansas City have succeeded without such assistance.

The common characteristic is that entrepreneurs in each region used available resources to their advantage. It will be shown below that Christchurch and Adelaide have also developed endogenous HTEI clusters, the densest clusters in each country, without significant influence or assistance of a university.

It was found from interviews in Silicon Valley, as in Cambridge that a significant number of the entrepreneurs knew each other from school, university, social contact or previous employment, so tacitly agreed behavioural norms evolved whereby individuals and firms collaborated and competed with knowledge of the capabilities and behavioural characteristics of many of their peers.

It is noted that this high proportion of interconnection between peers is a characteristic of second tier regions, and a noted success factor in Silicon Valley and in each of the other clusters in the principal case study. More formal gatherings such as those managed by the Cambridge Network are also productive sources of inspiration and information exchange.

4.3.3 Austin

Austin did not have Horace Darwin or Frederick Terman to pioneer the establishment of its technology industries, however, Austin has its prestigious University of Texas at Austin, an active Chamber of Commerce and the entrepreneurial spirit of its Texan citizens (Gibson et al, 1992). Electronics firms that have emerged in the city have been recorded since 1945 and the start-up rate has increased steadily (Smilor et al, 1989). Many of these local start-ups have grown into major national and international successes. Branches of established firms and new research institutions have expanded the technology capability of the region during more than six decades.

The economy of Austin has evolved through at least four phases: 1.) A government and university town; 2). Entry into high technology through product assembly; 3.) Influence of research and development on the economy; and 4.) Technology-based industry clusters creating a new economy (Smith, 2001).

Data on the start-up of technology firms in Austin from 1945 shows that less than 10 new companies were recorded each year to 1950 (Smilor et al, 1989). In 1950 the economy of Austin was substantially reliant as it had been for decades on its role as the Capital City of the State of Texas and as the principal campus of the University of Texas (UT, hereafter). These two large employers and their substantial budgets provided a stable base for the economy of Austin. The city's limited technology resources were boosted in the 1950s when Texas Instruments and Collins Radio (later Rockwell International) located manufacturing facilities in Austin. These and other firms were attracted to Austin by the pool of skilled labour, particularly engineers and it was noted that as the firms went through significant changes such as downsizing that some *"... employees left and started their own businesses"* (Mayer, 2011:23).

4.3.3.1 Tracor Incorporated

The first-mover in the endogenous start-up process and the growth exemplar in the Austin HTEI was Tracor Inc. established in Austin in 1955 as Associated Consultants and Engineers. The principals were UT faculty members, three physicists and an engineer.

Their initial specialisation mirrored their previous work at the university in acoustic systems that led to the development of sonar and antisubmarine warfare systems. The company merged with another local Austin technology firm Textran Corporation in 1962 and the new firm adopted the Tracor name (Kleiner, 1983).

Tracor commercialised many technologies from the University of Texas including analytical instruments for biochemical research based on knowledge of requirements from cross-faculty, off-campus discussions by colleagues. By 1969 Tracor operated in thirteen USA States and overseas (TSHA, 2013a). Products of the company also included aerospace systems, defence electronic systems, missile decoy systems and countermeasures systems. In 1976, Tracor became the first Austin based company to list on the New York Stock Exchange and in 1984 the first Fortune 500 Company headquartered in Austin (Smilor et al, 1989). In the 1980s Tracor employed 11,000 staff worldwide.

Tracor grew by acquiring other defence electronics companies and in 1998 Tracor was taken over by GEC which in 1999 was then taken over by BAE Systems. Tracor remains a major part of the defence business of BAE Systems. The story of Tracor and its origin as a spin-out from UT is well-known in Austin (Cooke, 2006) and the company is highly regarded as a prime example of a successful local spin-out from the university. A case study of Tracor parallels the growth of the city as the "*Austin Technopolis*" (Smilor et al, 1989).The company served as a "*center for start-up technology companies*" (TSHA, 2013a). With so many spin-outs from Tracor from the 1960s to the 1980s large numbers of founders and employees of these spin-outs had worked together that they evolved naturally into a cluster with a tacitly formed set of commercial norms, and this type of informal structure attracted other local firms to the emerging cluster.

4.3.3.2 Exceptional Growth

Two periods of exceptional growth in the number of indigenous technology start-ups and plant relocations are identified in Austin (Smilor et al, 1989). In 1957 the University of Texas, Bureau of Business Research conducted a study for the Austin Chamber of Commerce and recommended targeting of light manufacturing (Smith, 2001). During the first growth period, 1965 to 1969 Texas Instruments opened a new plant in Austin in 1967 to manufacture hand held calculators (Bennett and Giloth, 2007). Houston Instruments started in 1965 and IBM opened a new plant in 1967. Support networks were established to supply manufacturers with materials and components (Glasmeier, 1990).

Important plant openings and relocations continued in the 1970s including Control Data in 1970; Motorola in 1974; Tektronix in 1976 and Data General and AMD in 1978 (Smilor et al, 1989). The rate of new technology company start-ups increased to approximately 20 per year in 1960 and 30 per year by 1965 (Smilor et al, 1989). Between 1962 and 1988 at least 16 new companies spun-out of Tracor and all located in Austin. In 1985 these Tracor spin-outs employed more than 3,200 staff in Austin (Smilor et al, 1989).

During the second growth period, 1980-1984 several established electronics firms also located branches in Austin, including Lockheed, Schlumberger and 3M (Smilor et al, 1989). Through the 1980s Austin's HTEI gained a reputation for high technology development and entrepreneurial successes.

The benefit of research and development can be measured by patent activity in Austin. In the early 1980s few patents were filed, by 1990-92 the annual number was 403 and it rose to 704 in 1994-96 (Botham, 1999). The focus had moved steadily *"from assembly to innovation"* (Oden, 1997:14). In 1988 *Inc.* magazine named Austin the *'Number One Entrepreneurial City in the U.S.'* based on the number of new enterprises created (Smith, 2001). Recruiting of technology firms continued in the 1980s and 1990s *"by recruiting branches of firms from other places - IBM, Intel and Motorola"* (Florida, 2002: 298).

4.3.3.3 Civic Entrepreneurship

"In the early 1980's Austin was a sleepy college town and State capital, like many others. It was a quiet, low-cost place to live, study, work, or make policy. Within a decade a team of business, university and community leaders catapulted their branch-plant economy into an internationally renowned technology powerhouse." (Henton et al, 1997:4).

Civic Entrepreneurship is a concept introduced by (Henton et al, 1997). Many of the economic and social challenges facing Austin in the early 1980s have parallels to challenges in Silicon Valley in the 1990s. This is evident in the determined and collaborative quest for the establishment of two major national research laboratories in Austin. Tony Schum Director, Economic Development, Greater Austin Chamber of Commerce (GACC, hereafter) discussed the role of the Chamber and particularly the role of Lee Cooke, former Texas Instruments executive and later Mayor of Austin who led the bid process for these national facilities (Schum, 2006).

4.3.3.4 Microelectronics and Computer Technology Corporation

C. Lee Cooke, newly appointed President of the Austin Chamber recognised that *"the city was hostile to growth"* (Henton et al, 1997:43). Cooke and attorney, Pike Powers saw a major opportunity and led the quest to secure new research laboratory, the Microelectronics and Computer Technology Corporation (MCC, hereafter) for Austin (Henton et al, 1997). In an interview (Cooke, 2006) described how the University of Texas at Austin won the right to host the MCC laboratories of the new industry funded research body through a competitive bidding process against some better known USA universities, including Stanford (Ewing 1990; Henton et al, 1997). Cooke emphasised that they worked harder because Austin was the underdog in the competition and they wanted this facility more than the competitor regions.

The MCC was established in a new purpose-built building on land offered by the University of Texas on their North Austin Research Campus. Member companies of MCC were shareholders and could participate in any of four programs; software technology, semiconductor packaging, VLSI computer-aided design and parallel processing; human interfaces and artificial intelligence/knowledge-based systems (TSHA, 2013b).

MCC was jointly owned by twelve major computer and semiconductor manufacturers, including Digital, Harris, Control Data, Sperry-Univac, RCA, NCR, Honeywell, National Semiconductor, Advanced Micro Devices and Motorola, and all committed money and personnel to the MCC (TSHA, 2013b). It is noted that five of the twelve initial members were mainframe or mini computer firms and their products were soon to be challenged by the coming microcomputer revolution. The MCC commenced operations in 1984 conducting research on semiconductors and computer systems, with the object of competing with Japanese firms that had eaten away at USA leadership in these fields. It was known that the Japanese firms were assisted by large government research funding through MITI. The Japanese had formed consortia similar to MCC as early as 1956 (Gibson and Rogers, 1994:15). At its peak in the mid-1980s MCC employed almost 400 specialist engineers, scientists and technicians (THSA, 2013a).

The economy benefits from joint ventures and consortiums *"such as the Microelectronics and Computer Technology Corporation in Austin"* (Ewing, 1990:101). The MCC was based on an industry funding model and operated independently until its latter years when it undertook contract research for other leading universities and government agencies. Shareholding changed over time with Motorola one of few continuing owners.

In 1984, at the time of the establishment of the MCC, an unexpected plunge in oil prices occurred at the same time as a reduction in prices of beef and other farm products which caused a sharp regional recession. The State of Texas now faced unplanned deficits and "*The development of Austin as a technopolis began to lose momentum*" (Smilor et al, 1989:5). The recession continued until 1987 and caused cutbacks in higher education funding and a reduction in the previously positive mood of the community, foreclosures, company failures and a *"general loss of direction"* (Smilor et al, 1989:5).

The Greater Austin Chamber of Commerce reacted boldly to the recession and commissioned a report from the Stanford Research Institute (SRI, hereafter) in Palo Alto. SRI analysed the capability and capacity of the technology and business resources of the region and reported that Austin had *"all the elements needed to build an advanced information and knowledge economy that would provide opportunity for all residents within a uniquely liveable environment"* (SRI, 1985:9). The Chamber established task groups; to benchmark industry; to analyse the science and technology research base and to provide a perspective on technology-based industry in the 1990s. Implementation of the extensive SRI recommendations was reported by Gibson et al (1991).

4.3.3.5 Semiconductor Manufacturing Technology

Four years after the MCC was established Austin won the bid for another national research consortium of fourteen semiconductor manufacturers and thirty-one universities from fourteen USA States (TSHA, 2013c). The consortium name SEMATECH is derived from SEmiconductor MAnufacturing TECHnology. SEMATECH was established in Austin to conduct semiconductor manufacturing research jointly to assist its USA industry members to regain their leadership position, lost to Japan and in this endeavour this consortium was assisted with USA Government funding. The University of Texas at Austin was again a major participant in the negotiations and the Austin HTEI was a major beneficiary from the project. In the 1990s *"Austin manufactured more semiconductors than any city in the country"* (Bennett and Giloth, 2007: 85). Dr Randy Goodall discussed the strategic focus of SEMATECH and detailed the collaborative structure and relationships and particularly the role of UT and the positive flow-on benefits to the industry (Goodall, 2006).

With both MCC and SEMATECH in Austin, the university, the industry and the city benefitted from their exposure to the member companies of the consortia. A number of the people working at MCC and SEMATECH were seconded from the location of their employer company expecting to stay for a period of time, but many chose to remain after their projects ended (Smith, 2001).

This same reluctance to move was noted in Adelaide when mainly British engineers and scientists came to work in the government laboratories and on weapons field trials in the 1950s and many also remained in Adelaide and provided a collateral boost to the technology resources of the city.

Some of the specialists in Austin and in Adelaide left their employer and started their own enterprises and some SEMATECH member companies have established Austin-based operations (Smith, 2001).

Similarly, in Adelaide some British firms that came to Adelaide for the defence project later established permanent operations and these developments are discussed later in this chapter. The MCC and SEMATECH are identified as *trigger* events for a strong growth spurt in the previously small HTEI cluster in Austin (Gibson and Rogers, 1994; Smilor et al, 1989).

The MCC laboratories operated from 1984 until it was decided in 2000 that the industry and the technology had moved on and MCC was closed. SEMATECH operated in Austin from 1988 until moving to Albany New York in 2010. During the 25 years of the operation of MCC and SEMATECH in Austin the HTEI derived huge benefits and the current strength of the industry is a tribute to the bold planners and operators of these two world-class facilities in the relatively small city of Austin. The positive effect of these two organisations on the HTEI was far greater in Austin than it would have been on a larger city.

4.3.3.6 The Institute for Innovation, Creativity and Capital

The Institute for Innovation, Creativity and Capital (IC^2, hereafter) was founded in the University of Texas at Austin in 1977 by Dr George Kozmetsky, then Dean of the College of Business Administration and the Graduate School of Business. Dr Kozmetsky was respected as a co-founder in 1960 of Teledyne Inc., a US$1.6 billion technology corporation in 2012 with 8,800 employees (Teledyne, 2013). The IC^2 Institute was established to research technology innovation and entrepreneurship and to disseminate and apply the knowledge gained during the development of the '*Austin Technopolis*' on a global scale.

A Master of Science in Technology Commercialization degree (MSTC, hereafter) was developed by the IC^2 Institute to train graduates, typically in technology and business disciplines in the fields of innovation, entrepreneurship and commercialisation.

In an interview, Dr David Gibson, co-author of '*Creating the Technopolis'* recalled his 2001 visit to Adelaide - with a group of MSTC students, alumni and faculty from UT Austin - and his discovery of the export success of relatively young Adelaide technology firms; this important *'born global'* attribute (Gibson, 2006) is discussed in Section 4.8. MSTC Lecturer Meg Wilson explained that the course blends classes on innovation, entrepreneurship, technology transfer, business law, risk and intellectual property management with practical work on the building of companies around a business idea or a technology provided by the students (Wilson, 2006). The MSTC course has been provided by UT at Austin from 1996 and under licence at University of Adelaide from 2000.

Collaboration between the two faculties and interchanges of the two student bodies and faculty members provided an important part of the postgraduate education and the expansion of international networks of its graduates including this author.

4.3.3.7 The Austin Technology Incubator

The Austin Technology Incubator (ATI, hereafter) was created in 1989 by the IC^2 and is owned by the University of Texas. The ATI provides office and laboratory facilities and strategic and operational advice and support to technology-based start-ups during their critical early growth stages to help their transition into successful, high growth technology businesses.

The ATI was co-founded by its inaugural Director (1989-1996) English Chartered Accountant Laura Kilcrease who discussed the incorporation of her knowledge of the needs of growing companies in the founding of Triton Ventures in Austin to provide ongoing advice and financial assistance for these businesses.

By 2003 ATI graduate firms had created US$4.1 billion in revenues and some 3,000 jobs (Wiggins and Gibson, 2003). In an interview the current ATI Director Isaac Barchas described the current structure of ATI, its entry requirements and its facilities and services based on the now extensive and successful experience accumulated since 1989 and highly relevant to other cities (Barchas, 2006).

Since its foundation, ATI has worked with over 200 companies, helping them to secure over US$1 billion in investor capital and in the five years 2007 to 2012 ATI has worked with over 100 companies, assisting them to raise over US$250 million in investor capital. During that same 5-year period, ATI alumni companies realized approximately US$400 million in exit value (ATI, 2013).

4.3.3.8 The City of Austin

The University of Texas at Austin has played a pivotal role in the development of the *'Austin Technopolis'* by achieving scientific and technological pre-eminence; creating, developing, and providing new technologies for emerging industries; educating and training the required workforce and professionals for economic development through technology; attracting large technology companies; promoting the development of home-grown technologies; and contributing to improved quality of life and culture in the City of Austin (Smilor et al, 1989).

The Mayor of Austin, Will Wynne noted in an interview, quoting Richard Florida (2002) that the attraction of Austin is not just the technology companies, it is also Austin's live music scene and relaxed and tolerant lifestyle as well as the well paid technology jobs that are the strong attractors of young, mobile technology professionals to Austin (Wynne, 2006). This attraction is illustrated by the willingness of the young graduate - discussed in Chapter 2 (Florida, 2002: 217) to move thousands of kilometres across the USA from Pittsburgh to take up a job in Austin because "*it's in Austin!"* Austin is highly regarded as one of the best places to work in the technology industries (Henton et al, 1997; Florida, 2002; Mayer, 2011), it has the companies, the research facilities and the lifestyle and a large number of other similar age technology professionals and the confluence of these factors attracts more of these typically young specialists in this field. Importantly, Austin provides a large number and wide variety of technology employment so that an employee recruited from another community has alternate job options if the first situation is unsatisfactory.

Mayer (2011) considers the emergence and development of high technology regions that did not possess the attributes considered to be the keys to the success of the HTEI cluster leaders and instances Austin in this category. *"How can we theorise the process by which regions like Austin evolved as locations for high-tech activity"* (Mayer, 2011:26). The widely reported attributes include a world-class research university, large amounts of VC and a well-developed start-up culture (Mayer, 2011). Mayer poses this question in relation to Austin, which in the 1950s had a good university, but not the VC or high rates of start-up companies. Feldman posits that strong local networks, active research universities and abundant VC *"may be attributes of successful entrepreneurship in established clusters"* (2001:862). And, many of the conditions that the literature suggests should be in place to promote entrepreneurship *"appear to lag rather than lead its development"* (Feldman, 2001:863). Austin is described as a highly distinctive second tier city that has grown rapidly by nurturing its expertise (Markusen and Schrock, 2006:1318).

Austin did have and still has a very good university, a spirit of *'civic entrepreneurship'* and that strong desire to succeed that is found in those second tier cities that have generated above average growth.

4.3.3.9 The City, Community and University

The University of Texas at Austin enjoys close physical and cultural relationship with the City of Austin with more than 52,000 students in 2012 at its Austin city campus which is abutted side-by-side with the city. The presence of such a large number of students and faculty and their intercourse with the city has a positive influence on both city and campus life. In this case proximity matters. The relationship between the university and the high technology industry in Austin is both close and long-standing and it extends beyond the educational and commercial to the social and civic dimension.

Through the 1980s, Austin developed the critical mass of research and development necessary to produce sustained growth and the economy expanded through the diffusion of knowledge gained through the applied research conducted at the university, MCC and SEMATECH. Austin, where employment was previously dominated by the University of Texas and state government activities, by 1980 had also diversified into the arts and engineering fields (Markusen and Schrock, 2006). The rate of new company formation increased through the 1970s to reach 100 per year by 1980 and 120 in 198 (Smilor et al, 1989) and 161 in 1995/97 (Botham, 1999). State and local civic leaders in Austin had learned that research, development and commercialisation of technology would be critical to their future prosperity. "*In Austin, Texas the University of Texas has played an important role in promoting home-grown companies (some of them as university spin-offs) and in attracting large technology firms from outside."* (Mayer, 2011:18).

Author and lecturer in management at UT, Dr Rob Adams (Adams, 2002; 2010) described the training programs developed at AV Labs, a technology incubator during his period as its founder and Managing Director. These programs assisted the typically young technology entrepreneurs in Austin to ready themselves and their young firms for external funding and accelerated growth and are very relevant to the HTEI in Adelaide, which has no similar facility (Adams, 2006). These programs and their graduates add to the *'Technopolis'* culture in Austin. An important function of UT is the commercial development of IP developed by its staff and research students. The Office of Technology Commercialization was established in 1970. Its processes of licencing UT technology to firms and its assistance in developing the required commercialisation structures and its relevance to Adelaide and Christchurch was established by discussion with the Director, Dr Neil Iscoe, in Austin (Iscoe, 2006).

The success of the technological evolution of Austin can be measured by its population growth. The population of the USA has grown from 227 million in 1980 to 309 million in 2010, an increase of 1.36 times; and the population of Texas has grown from 14 million in 1980 to 25 million in 2010 an increase of 1.79 times and during the same 30 years the population of Austin has grown by 2.28 times from 345,900 to 790,400. Austin is now the 13th largest city in the USA (CityPopulation, 2011). By 2003 total employment in the Austin 'metropolitan area' was approximately 740,000 and of these 122,200 or 16.5 per cent work in the 'technology industries' which includes high technology manufacturing, health services, information, electronics, IT systems, engineering and research (Powers, 2004).

4.3.3.10 Employment and LQ in Austin

The most recent data available from USA Government, Bureau of Labor Statistics for 2011 shows that employment in *'electronic component and equipment manufacturing'* (NAICS Category 334) in the Austin-Round Rock MSA was 24,541 and in the nation it was 1,103,588, so 2.22 per cent of all USA employment in NAICS Category 334 is the Austin-Round Rock MSA (BLS, 2013). Total employment in all categories in the MSA was 615,065 and in the nation it was 108,184,795. From these data the LQ in 2011 for the Austin Round Rock MSA as 3.91 and the LQ for this MSA in 2002 was 4.83 (Kerr, 2013).

4.3.3.11 The Austin HTEI Cluster

Data and information had been obtained from a survey of 27 firms, 16 started by faculty, 6 by staff, 4 by graduate students and one by an undergraduate of University of Texas at Austin (Smilor et al, 1990). The sample includes 48 per cent of firms manufacturing electronic instruments, sensors and computer hardware while 43 per cent of the sample firms specialise on software and 9 per cent on pharmaceuticals. Using Likert scales the survey shows that *'pull'* factors including '*personal independence'* were important or very important to 80 per cent of firms and '*recognition of a market opportunity'* was reported by 93 per cent of firms and *'theory into practice'* was nominated as an important or very important factor to 94 per cent of respondents. A social objective, a desire to '*make the world better'* was recorded by 14 per cent of firms as a very important reason for their start-up. A total of 74 per cent of respondent firms used personal funds and 26 per cent used family funds while 22 per cent used funds from external investors and in 13 per cent of firms government grants were received. The survey found that 56 per cent of start-up firms considered that the university was *'important or very important'* in their company formation. The second most important positive influence was the Federal Government, as a supplier of grant funding.

Push factors such as downsizing and actual or potential unemployment were not significant influences on any of the surveyed firms; however 40 per cent reported *'frustration'* as an important factor in their start-up. This survey shows similar *'push'* and *'pull'* influences as those identified earlier in Cambridge and Silicon Valley and these same factors were identified and are discussed below in relation to Christchurch and Adelaide.

The role of a research university in the development of the HTEI cluster is demonstrated through the success of Tracor and exemplifies what Cooper (1985) calls an *'incubator organization'*. In 1999 Austin, Texas had 38 per cent of its private sector workforce employed in its high technology industries, (Florida, 2002:72) and more than 150,000 new jobs were created in the Austin region between 1990 and 1999 (Engelking,1999a).

A discussion with Dave Porter of GACC confirmed that the major increase in the population of Austin in the past 30 years was due to the increase in the technology cluster employment, principally in Austin's electronics industry (Porter, 2006). Jubal Smith at Austin City Council explained the City plan to continue the attraction of suitable businesses and particularly electronics manufacturing businesses (Smith, 2006). A new five year economic plan was launched in late 2012 (Hardy, 2012).

This targeted approach continues with National Instruments, a 1970s Austin start-up company announcing an US$80 million expansion of their Austin laboratory and industrial instrument design and manufacturing facility with 1,000 new jobs to be added (Statesman, 2013). The taxpayer cost for this expansion is considerable with a US$4.4 million State incentive and US$1.7 million City property tax concession and a possible US$1.3 million from the County would total US$74,000 per job.

4.3.3.12 Why Austin?

What makes Austin a special technology commercialisation place can be summarised:

- A good university (but, not as famous as Cambridge, Stanford or MIT)
- Collaborative relationships of university and industry sectors
- Civic pride and a high level of community understanding of technology/business
- Texan '*can do'* culture which has developed into *civic entrepreneurship*
- Austin's isolation from major populations encourages cluster self-organisation
- Industry development from the 1950s and continuing today: the HTEI cluster has endogenous elements that are hybridised with government funding and civic planning
- Success attracts new firms and people: e.g. Richard Florida's story of the young Carnegie-Mellon IT graduate's first job in Austin because "*it's in Austin"* (2002:217)

4.3.4 Christchurch

New Zealand was proclaimed a British Colony in 1840 and the first British settlers began farming the fertile Canterbury Plains and building the coastal settlement that became the city of Christchurch. With a population (2012) of approximately 350,000, or about 8 per cent of its national population, Christchurch is located on the east coast of the South Island. New Zealand is an isolated country; as far from Western Europe as is possible, with a time zone difference between New Zealand time and Greenwich Mean Time of 12 hours. Isolation has influenced the New Zealand culture of self-reliance and a wide ranging innovation capability. By the early twentieth century engineering firms produced agricultural and structural equipment and New Zealand became a major exporter of farm products to the UK. Exports were dominated by primary and resource based industry (Crocombe et al, 1991; Burnell and Sheppard, 1992), but when Britain joined the EU these New Zealand exports declined. New export industries have emerged including yachts, milking machinery and telecommunications equipment (Ffwocs-Williams, 1996).

The electronics industry in Christchurch began in the 'radio' era of the early twentieth century with imported radio receivers and a small number of locally built sets appearing in homes. In the 1930s a teenage boy in Oamaru, 250 kilometers south of Christchurch developed a lifelong interest in radio that would become the primary influence on the development of the HTEI cluster in Christchurch.

Angus Tait the farm boy left school at 17 to work in a radio shop learning about radio servicing; there was no formal training available to him. He joined the Royal New Zealand Air Force in 1940 and was posted to the Royal Air Force radio school in the UK and spent six years working with radar and became an instructor on radio and radar (McCarthy, 2000; Christchurch, 2013).

A M Tait was established in 1954 in Christchurch by Angus Tait who had returned to Christchurch after war service in the UK. This firm designed and built two-way radio systems for taxi fleets and later television receivers; the firm prospered initially and grew to 100 staff, but failed after several years of growth. A new company Tait Electronics Ltd. was launched in 1969 with many of his former staff returning to share in the passion of Angus Tait for two-way radio communications (Green, 2005). This company is the largest HTEI firm in Christchurch and in 2012 employed more than 800 staff in Christchurch. Tait exports more than 90 per cent of its output through offices in Europe, USA, Asia and Australia. The company spends 10 to 15 per cent of sales on research and development, compared to the national average of 1 per cent (McCarthy, 2000).

4.3.4.1 Christchurch Cluster Origin

"There is a nationally recognised concentration of high-tech firms in Canterbury." (Saunders and Dalziel, 2003: v). The origin of the cluster of electronics firms in Christchurch is credited to Angus Tait by three authors (Brown, 1999; Green, 2005). Quoting Peter Maire, founder of Navman; "*It's thanks to Sir Angus Tait that we have an electronics industry"* (Tantrum, 2003:2). The role of Angus Tait can be compared favourably with the role of Horace Darwin in Cambridge; both started technology businesses, but helped others where many may not have helped in fear of creating competition. The literature supports the endogenous origin of the Christchurch cluster; "*… most clusters including the Christchurch electronics cluster, form and develop not through the actions of any government, but by a random combination of locational factors or advantages"* (Brown and McNaughton, 2003b:120).

Angus Tait was widely respected for his vision and for his encouragement of senior engineers to start their own enterprises. These remarkable characteristics are seen in the careers of several of his senior people who built HTEI businesses in Christchurch and succeeded with the help of Angus Tait. These spin-out businesses were critical to the early years of the HTEI cluster development.

As with Cambridge, Silicon Valley and Austin, it was the spin-outs from the pioneer firm that fuelled early cluster growth in Christchurch. Since the founders of the new firms had worked together, collaboration between these non-competing start-ups in this remote location was natural and productive. The niche focus of SME firms in the HTEI is observed in many second tier cities including Adelaide; so many niche opportunities can be developed by start-ups that direct competition between local firms is rare (Kurgan, 1997).

Despite Tait's success in world markets and numerous awards, the message that New Zealand can succeed in high-tech and competitive industries like electronics *"has not really been accepted"* (McCarthy, 2000:2). This situation echoes the comment of Mayer in relation to Boise, Idaho where the local government has not embraced this new type of economy (Mayer, 2011).

4.3.4.2 Christchurch Spin-outs and Start-ups

John Croft was a talented and loyal electronic engineer who had worked at the first Tait business and rejoined the new Tait firm in 1969. Two of his colleagues at Tait had an idea for an aircraft beacon and approached him to join the part-time venture. They started Sea Air and Land Communications Ltd., known as Salcom and made the product after hours.

They told Angus Tait about the venture and he encouraged them and told them *"Go for it guys. Just don't sell your labour too cheap."* (Green, 2005:107). John Croft joined Salcom on a full-time basis in 1984 and another Tait engineer, Colin McKenzie then joined him at Salcom. This Tait spin-off company now produces a range of signalling and message handling systems for local and international markets (SALCOM, 2013).

Ben Rumble was Export Sales Manager at Tait for ten years and left to start his own communications firm, by giving notice one year in advance. He did not compete with Tait, but supplied markets not served by Tait. He was joined later by Gary Batley from the Tait Export Department.

Dennis Chapman was an innovative electronic engineer and while at Tait he built an electric car to overcome the Government one day per week ban on petroleum fuelled cars, during a fuel shortage. He designed the electronic switching system for his car and sold these to a small manufacturer of electric delivery vans.

While at Tait Chaoman also designed non-competing products for other start-up firms. Chapman offered some design ideas for products on a royalty basis to Angus Tait who declined, so he made the products for Ben Rumble (Green, 2005). Chapman then left Tait and founded Swichtec, now the second largest HTEI firm in Christchurch.

Phil Holliday migrated to Christchurch from the UK in 1990 and set up in business as a software engineer and was soon contracted to Tait and Swichtec and built up a team of talented engineers and a range of innovative products. Interviewed in Christchurch, Mr. Holliday emphasized the need focus on "*planning and pricing"*, a lesson he had learned when he had initially contracted his skills to Tait at low prices (Holliday, 2010). This characteristic is reminiscent of the low prices originally charged by Horace Darwin in the early days of CSI in Cambridge (Segal Quince, 1985).

Commtest, evolved from the research and development division of another company. In an interview, director Jack Henderson discussed the design, manufacture and test processes of their niche market data logger systems to monitor the operation of industrial machines and wind turbines (Henderson, 2010). The company spun-out in 1993 and has grown steadily and was acquired in 2011 by GE Energy New Zealand.

These firms and other spin-outs from Tait, including second and third generation spin-outs and independent start-ups have evolved into the relatively dense HTEI cluster in this small and relatively isolated city.

4.3.4.3 Christchurch Cluster Development

Since the first spin-out from Tait in the 1980s and the start-up of other independent firms the cluster has grown steadily, with Tait the largest firm in Christchurch, now twice the size of any other in the cluster.

It is difficult to estimate the influence by way of inspiration and assistance of potential entrepreneurs that has been due to Angus Tait. In the 29 interviews conducted in the Christchurch HTEI for this research the importance and influence on the cluster by Tait, was the most common, unprompted response from representatives of organisations of all sizes and the story is well known at the local level (Gallagher, 2010; Ridge, 2010; Thomas, 2010; Townsend, 2010; Walley, 2010).

A common characteristic found in endogenous HTEI clusters is observed by Saunders and Dalziel; *"A combination of historical accident and good local people has created a large critical mass of vibrant high-tech companies located in Christchurch"* (2003:42). Brown, McNaughton and Bell interviewed 23 electronics firms in Christchurch and state that in relation to Christchurch that for small-and-medium-sized firms *"location in a geographic cluster of networked firms is a source of competitive advantage."* (2010: 168).

Porter observed that *"An advantage in a single determinant often provides the initial impetus for an industry's formation in a nation, not infrequently around a single firm"* (1990b: 159). Porter's concept of the role of a single firm in the development of a cluster is well demonstrated by Tait Electronics in Christchurch (Green, 2005).

Under the heading of *'Developing a High-Tech Sector: Evidence from Overseas'* quoting OECD (2003) and its emphasis on networking, Saunders and Dalziel discuss the value of networking organisations illustrating by example two admired organisations: *The Cambridge Network,* Cambridge UK and the *Electronics Industry Association* in Adelaide, South Australia (2003:41). The former is discussed above and the latter is discussed below in section 4.3.5 Adelaide.

Tantrum also refers to: "… *the growing awareness of the importance of the electronics industry to Christchurch"* (2003:2). This recognition is still limited but growing and is critically important to the future development of the industry; recognition could be harnessed to promote careers in the industry. Moderate to high levels of community and government recognition of the HTEI are found in Cambridge, Silicon Valley and Austin, however, community and government recognition of the Christchurch HTEI is still relatively low.

In the Christchurch HTEI cluster *"A factor raised by almost all interviewees is the historically weak links between the high-tech sector and tertiary institutions."* (Saunders and Dalziel, 2003:26). The low level of collaboration between industry and research sectors is a barrier to the growth of the industry in Christchurch (House, 2010) and the low level of collaboration between these sectors in Adelaide is discussed in section 4.3.5.

The following quote supports the endogenous origin of the Christchurch HTEI: "*Little credit was given by firms or claimed by support agencies for the development of the cluster"* (Brown and McNaughton, 2003a: 120). This comment is not unexpected in Christchurch as the electronics industry is not well understood by New Zealand governments and consistent with the reluctance, discussed above of local and regional policy makers to embrace this new type of economy in small USA cities (Mayer, 2011:11).

4.3.4.4 Christchurch HTEI Structure and Cluster Dimensions

A study of the New Zealand economy in 1990 by Professor Michael Porter (Crocombe et al, 1991) found "*no more than a handful of industrial clusters"* in New Zealand, in yachting, forestry and agriculture industries and "*two more embryonic clusters"* in seafood and importantly, "*and in electronics centred on Christchurch"* (Ffwocs-Williams, 1996:218). This reference to the 1990 report by Porter may be the earliest international reference to the Christchurch electronics cluster.

A report from Lincoln University, Christchurch shows that the information and communications technology industries contribute an estimated 4.3 per cent to the gross domestic product of New Zealand. The report also shows that firms in the Christchurch HTEI contribute *"as much as half the total national electronics output"* (Saunders and Dalziel, 2003: v).

This report identified 98 firms in the electronics design and manufacturing industry in Christchurch, 6 large companies and 92 SME's. The project also identified 107 software firms in the region. The software firms are not included with the HTEI [electronics hardware] firms, but the two sectors together are referred to as the "*high technology industry"* (Saunders and Dalziel, 2003:5).

A report prepared for the Canterbury Development Corporation also shows that *"as much as 50 per cent of the total national electronics output"* is produced by the Christchurch HTEI cluster (Tantrum, 2003:2).

Further confirmation of the remarkably high density of the HTEI in the small city is provided by a report showing that "*More than 50 per cent of New Zealand's electronic engineers are based in Christchurch"* (BERL, 1998). Another report shows *"Christchurch is the hub of electrical and electronic engineering and manufacturing in New Zealand, employing 45 per cent of all people working in the industry"* (Careers, 2010).

Saunders and Dalziel quote Christchurch HTEI revenue at NZ$618 million with 2,801 employees (2003: Table 2.1, p.7). Productivity in the electronics firms was high, at NZ$221,000 per employee and, by comparison the output per employee of Christchurch software companies is lower at NZ$141,000. In the retail and wholesale sector productivity per person is shown as NZ$41,200 and NZ$60,750 respectively and in manufacturing the New Zealand average for all industries is NZ$61,280 per employee, quoting Statistics New Zealand, 2000 (Saunders and Dalziel, 2003:6).

A feature of the HTEI in Christchurch is the dominance of a small number of relatively large firms. The region's six largest electronics companies collectively employ more than 2,100 staff or 77 per cent of the industry total. (Saunders and Dalziel, 2003, Table 2.1, p.7). The 'Big Six' electronics companies are: *"Allied Telesyn International, Dynamic Controls, Invensys Energy Systems (NZ), Pulse Data International, Tait Electronics and Trimble Navigation (NZ)."* (Saunders and Dalziel, 2003:2). These firms formed a network organisation named the Canterbury Electronics Group. The Tantrum (2003) report quotes their adoption of the Australian *Electronics Industry Action Agenda* definition of the electronics manufacturing industry for their survey of the Christchurch cluster:

"... [a] group of companies which design, produce, service, install, and distribute products and systems made from electronic and photonic components and which may contain embedded or loaded software to provide an operational device or network. It also includes companies which provide services to support the production of electronic components and products." (EIAA, 2003:13).

The adoption of this definition allows the HTEI clusters in Christchurch and Australian cities to be directly compared. The NAICS 334 classification in USA and the SIC 26 in the UK are also broadly comparable with the EIAA (2003) definition and the ANZSIC (2006) 242 classification. The reports by Saunders and Dalziel (2003) and by Tantrum (2003) are valuable for their descriptions of the origin of the industry, its major firms and the structure of the industry. However, these reports are based on data collected ten years ago and later data is now available and the circumstances have changed significantly. Christchurch was badly damaged by a number of earthquakes, the worst in February 2011 which caused 185 deaths, widespread damage and a subsequent slowdown in the region's HTEI and its wider economy. HTEI data obtained from the New Zealand Government agency Statistics New Zealand in 2013, for the 2012 year are shown below in Table 4.3.

Table 4.3: Employment New Zealand: Electronics and all Industries, Regional and National

Year: 2012		
Area	Total New Zealand	Christchurch City
Business/Employment	Employees	Employees
ANZSIC06		
Total Industry	1,926,580	184,040
C241900 Other Professional and Scientific Equipment Manufacturing	660	140
C242100 Computer and Electronic Office Equipment Manufacturing	100	6
C242200 Communication Equipment Manufacturing	870	740
C242900 Other Electronic Equipment Manufacturing	2,780	640
Total Employees in ANZSIC: C2419: C2421: C2422: C2429	4,410	1,526

Source: Statistics New Zealand: (Mair, 2013)

From these data the LQ for the HTEI in Christchurch is calculated at 3.62. The number of HTEI employees in Christchurch recorded in 2012 is lower by approximately one third on the numbers reported by (Saunders and Dalziel, 2003).

4.3.4.5 Christchurch HTEI Location Factors

The firms in the HTEI are not located in a designated area, such as a Science or Technology Park or a particular quarter of the city. Rather they are dispersed in many city and suburban locations, with a small bias to the north western suburbs, which are near the International Airport, the University of Canterbury and also near Tait Electronics.

The location of Christchurch HTEI cluster firms was "*overwhelmingly*" based on the family origin of the founder and found to be particularly true for firms older than ten years, and younger firms were locating within the cluster because of other factors including the existence of externalities. This latter reason for location suggests a logic based on the maturing of the cluster, whereas the 'home town' reason could contain an element of convenience (Brown and McNaughton, 2003a:115). Seven years later this cluster was revisited by Brown, McNaughton and Bell (2010). They present empirical evidence from a statistical cluster analysis identifying *passive* and *active* demand-side externalities in the Christchurch, electronics cluster. All 23 cluster firms surveyed reported benefits from *passive* externalities and 40 per cent experienced *active* externalities whereby managers had developed capabilities that maximise network opportunities from the co-location of cluster firms, their collaboration, joint research and development which were based on trust and guided by the need to *"play by the rules"* in this small community (Perry, 2005:186).

4.3.4.6 Christchurch Survey

The following discussion provides insights into the origin and development of the HTEI cluster in Christchurch, based on the literature and personal contacts in the industry in Christchurch. To augment the available data a series of 29 interviews was conducted with Christchurch HTEI manufacturing firms and related organisations in April 2010. These interviews used the pre-prepared Discussion Agenda, which is shown in Appendix 2. The development and application of the survey is discussed in Chapter 3. The database containing these data is shown in Appendices 5 to 13 inclusive with a comparison of Christchurch data with data collected in five Australian cities, Adelaide, Brisbane, Canberra, Melbourne and Sydney.

A summary and discussion on the Christchurch survey results follows. Firm employee size in this survey ranged from one person to more than 800. The desire for self-employment, which is not emphasised in the literature on the Christchurch HTEI cluster, was the strongest start-up motivator at 44 per cent, with the 'technology' motivating 39 per cent and money motivating 11 per cent of manufacturing firms in the sample.

Their hometown was the location choice of 72 per cent. Their location in Christchurch was now more relevant to 44 per cent than at start-up and unchanged over time for 33 per cent of respondents. In Christchurch 25 per cent of firms would seriously consider moving to another city

The 'best' aspect of a Christchurch location at 44 per cent was 'collaboration' and the 'worst' aspect given by 44 per cent was 'travel'. The mean value of the local university to their business was rated at 2.69 on a Likert scale of 0 to 5 and was higher than the Australian mean at 2.09. All Christchurch surveyed firms create their own technologies, 17 per cent also use associated organisations and 28 per cent use non-associated organisations. Assistance was wanted from universities by only 27 per cent of firms, which is low compared to the Australian mean of 73 per cen.

The main requirement was 'management training'. Success in attracting long-term capital was rated at 2.19 and 2.39 in attracting short-term working capital. VC was sought and obtained by one firm, but not sought by any of the other manufacturing firms in the survey. The importance of retained earnings was rated at 3.39 which is close to the mean of 3.66 for the six Australasian cities. The importance of 'family assets' in the business rated at 0.89 against the six city mean of 1.62. A total of 89 per cent of the firms surveyed focus exclusively on small or niche markets and only three manufacturing firms surveyed do not export.

The importance of the National Government as a customer was rated at 1.25 and the regional government rated at 1.44. Low cost producers make up 3 per cent of the sample; 33 per cent are 'market led'; 42 per cent are market leaders and 22 per cent claim to be 'market makers'. Self-assessment of risk management performance is rated at 3.47 while self-assessment of their IP management performance rated at 3.58. The importance of engagement in networks rated highly at 4.11, well above the Australian mean of 3.00.

Barriers to growth by market access was reported by 47 per cent of firms while finance was a barrier to 11 per cent and qualified staff was reported as a barrier by 36 per cent. Government (non-financial) assistance had been sought by 67 per cent, and received by all applicants. Additional assistance was wanted from Local Government by 11 per cent, from both Regional and National Government by 25 per cent. Cost and delay caused by government regulations rated at 2.03. Current and past benefits from a major public institution (government, university or research institution) rated at 2.61. However, the future estimated value to the firms of these establishments rated at 3.28 which exceeded the Australian mean of 2.71.

Remoteness is a reality in Christchurch since the nearest alternative source of technical, business or government assistance is the national capital Wellington, more than 400 kilometres distant; including a 50 kilometre sea crossing between South and North Islands. Another source of assistance is Auckland, also on the North Island, and more than 1,000 kilometres from Christchurch. The Christchurch HTEI has developed its own local capabilities and networks over many years and appears generally content with using their own established collaborative industry relationships. A relatively high level of cluster self-sufficiency is a salient feature of the HTEI in Christchurch. Before the 2011 earthquake the HTEI in Christchurch represented 50 per cent of the New Zealand HTEI (Tantrum, 2003) in a small and remote city with 8 per cent of the national population; a remarkable achievement.

The influence on the origin and development of the Christchurch HTEI cluster by Sir Angus Tait - founder and leader of his company until his death at the age of 88 in 2007 - is extraordinary and his contemporary achievements are unmatched in the regions included in this study. Through the influence of Tait, the Christchurch HTEI cluster developed endogenously with minimal outside assistance and its development, its strength and the collaborative behaviour of its members appears also to be strongly influenced by its small size and comparative isolation from major national populations; a common observation in the second tier regions in this research.

4.3.5 Adelaide

Adelaide is rated by The Economist as the fifth *'most liveable city'* in the world (Economist 2013). Located on the southern coast of Australia, Adelaide city is arranged across a fully planned one mile square grid of wide streets and bounded on all sides by a half mile wide ring of public parkland. Wide roads lead from each corner of the city and additional major roads from the centre of the city lead north, south east and west. The outward development of the suburbs across the flat plain is uninhibited by major rivers or harbours or terrain. The radial road system results in moderate traffic densities and easy access between city and suburbs in this 'linear' city and faster than in cities beset with winding roads and rivers or intersected by bays or harbours.

Australia is a large and relatively sparsely populated continent with a population of 23 million, or slightly less than the population of the State of Texas but with more than ten times the land area of Texas. Adelaide, capital city of the State of South Australia is isolated from its major national population centres; 700 km from the nearest State capital city, Melbourne and 1,400 km from the next nearest State capital city, Sydney and 1,150 km from the National Capital, Canberra. *"Adelaide is remote from the major centers of government (Canberra) and business (Sydney, Melbourne)"* (Parker, 2008:840). Adelaide with 1.21 million population (ABS 3218, 2011), the smallest of Australia's five mainland State capital cities is a *second tier* city (Markusen et al, 1999) when compared to Sydney, with 4.63 million population and Melbourne with 4.14 million. Despite its remoteness and its small size Adelaide houses the cluster with highest concentration of HTEI employment in Australia with more than 40 per cent of all Australian HTEI design and manufacturing employment in a city with 5.4 per cent of its national population.

4.3.5.1 Early Years of Electronics Technology in Adelaide

The first practical demonstration of wireless telecommunication was conducted in Adelaide in May 1899 by Professor William H Bragg of the University of Adelaide and Sir Charles Todd, South Australia's Postmaster-General and Superintendent of Telegraphs. The demonstration, initially over a distance of about 200 metres was just four months after Marconi had sent wireless signals across the English Channel. In July of that year the first two-way wireless telegraph link in Australia was established between the meteorological Observatory in Adelaide and Henley Beach on the coast 8 kilometres west of the city (Ross, 1978:8). A maritime wireless telegraph service, the first commercial application of radio in Adelaide opened in October 1912 at Rosewater, near Port Adelaide, six months after the Titanic disaster had demonstrated the value of wireless telecommunication (Ross, 1978).

In the 1920s the Reverend John Flynn proposed an aerial medical service, the *'Flying Doctor Service'* to support people in the sparsely populated Australian 'outback'. The service required radio for communications as most outback properties had no telephone. Through a fortunate '*chance'* a mutual acquaintance referred Flynn to electrical engineer Alfred Traeger, an Adelaide two-way radio pioneer who established a two-way radio test site for Flynn at Alice Springs in Central Australia in 1926. In 1928 Traeger produced a novel two-way radio for outback homesteads to communicate with the new Flying Doctor Service. Since most of the homesteads had no electric power, his radio was powered by a generator fitted with bicycle pedals cranked by the seated operator (SLSA, 2013). With the *'pedal wireless'* homestead residents could summon medical assistance and communicate with Flynn's '*School of the Air'* and with neighbours and businesses hundreds of kilometres distant. Communication by high frequency radio or satellite phone is still the only link for many of these outback homesteads. Over 50 years the Traeger Transceiver firm developed and built advanced land-based and marine two-way radio systems and was taken over by Adelaide firm Tracker Transceivers in the 1980s.

Physics graduate Edward (Ted) Both worked with his mentor Professor Kerr Grant, Head of the Physics Department at the University of Adelaide on experimental projects. With encouragement and financial help from his mentor Edward Both founded an electronics business, E T Both in 1932, which may have been the *"earliest electronics manufacturing business in Adelaide"* (Pay, 2007), as distinct from firms producing two-way radio for communications and broadcast radio for entertainment.

The first Both product, in 1932 was a portable, battery operated direct writing electrocardiograph which overcame the limitation of the processing of the trace in the previous photographic recording process. The new system allowed the physician to see the trace in real time and to make an immediate diagnosis, at the bedside; a saving of hours or days over the previous photographic process.

A wartime development, the Both Visitel may be the world's first fax machine (Turner, 1995). This design was taken over by Australia's Defence Department and a patent refused as the design had *'security implications'*. Visitel machines were used at various Defence Department establishments during the war. After the war new Both products followed in quick succession including battery/electric delivery vehicles that overcame the severe shortage of petroleum fuel caused by the war (Pay, 2007). The Both business was taken over by its distributor, Drug Houses of Australia Ltd. in 1966 which was later taken over by financial firm Slater Walker Ltd. in 1968 and the Both business was later closed.

In the 1930s while Professor Kerr Grant was mentoring his former students, Edward and his brother Donald Both at the University of Adelaide, Prof Frederick Terman was mentoring his former students William Hewlett, David Packard, and the Varian brothers Russell and Sigurd at Stanford University. Professor (later, Sir) Kerr Grant and Professor Terman both recognised the combination of engineering knowledge and the innovative ability of their former students and encouraged and directly assisted the establishment of businesses to commercialise their innovations.

Prior to World War Two, South Australia was *"predominantly a rural industry state"* (Enright and Roberts, 2001:74). During the War the rapid build-up in the production of military vehicles and armaments permanently changed the manufacturing base and the economy of Adelaide. After the War manufacturing was retooled to supply the surge in demand, particularly for passenger vehicles, construction materials and household durables. Migrants were targeted, particularly from war ravaged England and Western Europe and manufacturing industry investment and technologies were attracted from England and USA.

4.3.5.2 British Security Concerns

Many new technologies were developed during the Second World War, notably jet propulsion, nuclear weapons and surveillance radar. After the war the British Government was driven by the fear of the rocket weapons used against England in the 1940s and their potential integration with guidance systems and atomic warheads. The knowledge that these three new technologies were possessed by their Cold War opponents led the British Government to develop its own nuclear weapons, guided missiles and surveillance systems (Morton, 1989).

The British authorities wanted the production of the required military hardware dispersed abroad and to collaborate on weapon design, production and testing with a British Commonwealth partner. Testing the new rockets required a launch and recovery site and the testing of nuclear weapons would need a separate large, remote and uninhabited location. New surveillance and instrumentation systems would require design and construction facilities. Two locations in the South Australia 'outback' were identified that offered the required 1,600 kilometre overland rocket range and a separate nuclear weapons test site. One Australian Government publication records the previously classified details of the negotiations, the establishment in 1947 and the ongoing development and operation of the Long Range Weapons Establishment (Morton, 1989).

The Australian Prime Minister, J. B. Chifley supported the proposal enthusiastically. *"The economy would receive a general boost from the establishment of new industries and the encouragement of scientific research"* (Morton, 1989:11). South Australian Premier Sir Thomas Playford was also *"eager to secure these facilities for his State"* (Morton, 1989:14). In 1946 the British and Australian Governments agreed to establish the facilities in South Australia. The Joint British and Australian Government Rocket Range was built at Woomera 450 kilometres north of Adelaide and the Nuclear Weapons Test Site was developed at Maralinga, 850 kilometres north-west of Adelaide. The associated government research and development laboratories, workshops and support facilities were established in the Adelaide suburb of Salisbury (Morton, 1989).

Since 1947 many UK, USA and Australian firms have established research, development and production facilities in a designated *contractor area* adjacent to government research laboratories at Salisbury, including many of the largest global defence contractor firms, BAE Systems, Raytheon, SAAB, Lockheed Martin and specialist defence electronics SME firms have evolved adjacent to the major contractors. Defence contractor firms employ approximately 4,000 well-trained and well-paid staff in Adelaide.

During more than 60 years the work at Woomera and Salisbury has moved from testing and research on guided weapons and nuclear weapons testing to the multi-national European Launcher Development Organisation; NASA space programs; the development and launching of Australia's first satellite in 1967 and to upper atmospheric research programs (Ferret, 2003).

During this period these defence facilities and contractor firms attracted engineers and scientists from within Australia and many from overseas countries, particularly the UK and at the end of their contract many of these specialists remained in Adelaide and joined other defence or civilian companies or started their own electronics businesses.

While the rocket range is no longer in regular use, the Adelaide research laboratories and workshops have expanded and are now known as DSTO (Defence Science and Technology Organisation). This organisation is Australia's major Federal Government defence research facility with high level expertise in communication, counter-measures, computing, surveillance, control systems and related research.

This government facility has a staff of more than 1,000 scientists and engineers plus hundreds of technical and support staff. Electronics has been and continues to be the principal technology employed and researched at these laboratories.

4.3.5.3 The Influence of DSTO

The DSTO is the major source of the science and technology that is embedded in defence systems engineered and produced in Adelaide by specialist defence contractor firms. The establishment in 1947 and the continuous operation and development of these government research facilities has been a major influence on the development of the Adelaide HTEI cluster; as a creator of innovative technologies for military, commercial, industrial, scientific applications and as a critically important training ground for engineers, scientists and technicians. Many former DSTO employees have moved on to employment in the defence contractor or non-defence sector or to establish defence or non-defence HTEI businesses in Adelaide. Important DSTO spin-outs have included Avalon Systems, DSpace, LADS, MRad, Sydac and Vision Systems, which have produced significant exit value for their founders.

The rigorous research methodologies and standards of DSTO provide a source of tacit knowledge which flows into and greatly benefits the local electronics industry. DSTO has provided the HTEI in Adelaide with the services of a "*surrogate university"* (Mayer, 2011:48). That the electronics industry cluster in Adelaide exists and has developed to its present nationally significant size is an example of the process reported by Doeringer and Terkla (1995:226) "*The presence of positive externalities explains the clustering process, whereas specific location sites for each cluster depend on either 'historical accident' or the cost advantages provided by immobile factors that attracted the firms anchoring the cluster."* A significant *'immobile factor'* is the location of the DSTO in Adelaide and the relative isolation of Adelaide from other major Australian cities encourages collaboration with nearby colleagues and DSTO alumni. Adelaide has benefited from the "*historical accident"* (Krugman, 1991:35) of the location of DSTO and the continuing presence of positive externalities and a cost-base in Adelaide that is the most favourable of all Australian State capital cities across a number of measures (KPMG, 2012). However, it is also noted that in Boise, Idaho HTEI firms Hewlett Packard and Micron Technology *"have helped the region move from a location known for its cost advantage to one that provides competitive advantage related to innovation and entrepreneurship"* (Mayer, 2013:2). Cluster researcher Professor Michael Porter shows the effect of *"chance"* and the role of "*government"* in his 'diamond' illustration of the '*Determinants of Competitive Advantage'* on industry clusters (Porter, 1990b:127). The confluence of the *'chance'* requirement for a post-war defence research facility and the *'government'* decision to establish these laboratories in Adelaide has had a profound, positive influence on the development of the electronics industry cluster in Adelaide and has provided the Adelaide electronics industry with a long-term sustainable competitive advantage.

The DSTO and its positive effect on its HTEI is Adelaide's enduring legacy from this Anglo-Australian Cold War project.

The relationship of Adelaide's HTEI and the DSTO has parallels with the relationship between the electronics industry in Albuquerque, New Mexico and the nearby USA defence research laboratories and particularly, Sandia National Laboratories. Many Sandia technology developments were adopted by local electronics manufacturers (DeVol, 2000). Sandia also collaborates with industry and was a major contributor to the SEMATECH, research laboratory in Austin which was discussed in 4.3.3.5 above. "*The movement of people between Sandia and industry as well as the many agreements for cooperative research helped many groups"* (Kassicieh, 2013).

While DSTO and the defence contractor firms are an important source of trained engineers, scientists and technicians for the larger non-defence sector of the electronics industry national security often prevents or delays the use of the defence technologies developed at DSTO or by contractors for use in non-defence applications. In one of very few publications on the Adelaide HTEI Professor Rachel Parker shows that the large MNC and SME contractor firms "*… that are geographically co-located with DSTO, do not engage in a process of communication and decision making regarding investment, marketing, or knowledge sharing in the way that characterizes the partnership model."* (2008: 840).

Technology transfer processes are addressed in a report: '*External Engagement of DSTO'* which shows *"DSTO's industry interaction drivers have been industry capability to serve Defence"* rather than technology transfer from DSTO to industry (Trenberth, 2004:32).

4.3.5.4 Arthur D Little Report

An important publication resulted from the South Australian Government's response to the collapse of the government owned State Bank of South Australia in 1991 which was a serious, multi-billion blow to the State finances (McCarthy, 2002). Boston consulting firm Arthur D Little was commissioned to identify and analyse future opportunities for the rebuilding of the South Australian sagging economy. Their report identified three industry sectors that possessed what the report described as the required *"combination of competitiveness and attractiveness"* (Little, 1992:34). The nominated sectors were; *"automotive components, wine and electronic applications."* While the automotive component and wine sectors were well known to the South Australian Government and community, the term *"electronic applications"* was not well known or understood.

This term, was used in the USA *'military-industrial complex'* establishments and in USA consulting firms and refers to the research and industry organisations engaged in the development of technologies and equipment for military use. The report gives examples of the adaptation of defence electronic technologies for civilian use. Importantly, the report drew attention to the Adelaide electronics industry and its design and manufacture of relatively small volumes of high technology electronic products and systems for industrial, commercial and government users.

This was the first public endorsement of the Adelaide HTEI and by an independent, expert firm and importantly, one with a strong international reputation for the development of regional economic growth strategies. The endorsement of Adelaide's electronics industry by this highly regarded international firm was noted as a '*call to action'* by members of the small volunteer industry association, Electronics Association of South Australia (EASA, hereafter) founded in 1972 to promote the State's electronics industry; the first association to represent the electronics industry in any Australian State.

4.3.5.5 Electronics Industry Taskforce

Responding to the Arthur D Little report EASA established a Taskforce of 16 senior industry, research and government representatives in 1994 to study the industry, its past and current performance, future opportunities and barriers to growth. The Taskforce also surveyed revenue and employment to measure growth since the first Adelaide electronics industry survey (ABS, 1990). The Report of the Strategy Taskforce for the Electronics Industry in South Australia (EASA, 1994), was a breakthrough for the industry. For the first time the current size and strong growth and industry structure were revealed publicly. The Taskforce Report verified the 1992 endorsement by Arthur D Little of the importance of Adelaide's electronics industry. The Taskforce Report was released in September, 1994 and reported next day in the local press in the front page lead story with a large, bold type headline '*12,000 jobs forecast: Boom for High-tech Industry'* (Kelton, 1994).

The Taskforce reported that Adelaide's electronics industry revenue had grown approximately 18 per cent per year between 1990 and 1994, with revenue at A$650 million in the 1993-94 year.

A separate report was produced concurrently with the Taskforce Report. This second report was commissioned by the South Australian Government and produced by the South Australian Centre for Economic Studies at the University of Adelaide (SACES, 1994).

The SACES report endorsed the forecast growth of 20 per cent per year by the Taskforce, and reported higher revenue in 1994 than the Taskforce "*… at least A$700 million…*" (SACES, 1994: i).

A 1996 survey of the Adelaide HTEI reported revenue at A$965 million (Manners, 1996), which exceeded the Taskforce forecast (EASA 1994) and revealed annual revenue growth of over 22 per cent in each of the years 1995 and 1996.

The Taskforce also warned of a future shortage of trained people to fill the future jobs. By 1997 the forecast shortage of trained staff and particularly electronic engineers had worsened and a Workforce Planning Study was commissioned by the South Australian Government, which quantified the shortages for the range of required qualifications and provided programs to overcome the identified shortages (EASA, 1997).

The South Australian Government funded a Skills Audit of the State's electronics industry (SACES, 2000) and this study mapped the demand for skills in all required qualifications out to 2007. Importantly, the Taskforce recommended that a funded body with a paid staff be established to expand the work of EASA, the volunteer body that had represented the HTEI since 1972.

4.3.5.6 Electronics Industry Association

With financial support from the South Australian Government and a small paid staff, a new body, the Electronics Industry Association (EIA, hereafter) was launched in June 1998 to extend the work of EASA (Pay, 2005). EIA promoted the industry and its firms and provided industry specific training, conferences, industry excellence awards, skills development programs and liaison with State and Federal Governments (EIA, 2008a).

EIA developed and implemented the Electronics Industry Strategic Plan for the industry (EIA, 2000) and a review (EIA, 2008b). Discussing technology industry development in Adelaide, Burns and Garrett-Jones (2002:195) state *"Some network programs have become little more than industry associations, while others such as the Electronic Industries Association are taking on all the characteristics of an industry cluster".*

A report by the national Australian Electrical and Electronics Manufacturers Association (AEEMA, hereafter) describing the structure of the electronics industry in Australia stated "*The Electronics Industry Association in South Australia is probably the best Australian example so far of a well-defined electronics industry cluster*" (AEEMA, 2002).

4.3.5.7 Electronics Industry Action Agenda

In 2003 an Australian Government development program, known as the 'Electronics Industry Action Agenda' (EIAA, hereafter) was implemented in the Australian electronics industry to facilitate its future development.

The EIAA defined the electronics industry as follows:

"… [A] group of companies which design, produce, service, install, and distribute products and systems made from electronic and photonic components and which may contain embedded or loaded software to provide an operational device or network. It also includes companies which provide services to support the production of electronic components and products." (EIAA, 2003:13).

The EIAA program document published by the Federal Government (EIAA, 2003) described the performance of the Australian electronics industry on the national scale as: "*lacklustre"* but also stated: "*Yet, within these overall national figures, there are both firms and regions whose performance has not been lacklustre. For example recent statistics in South Australia show that its electronics industry has been growing at 15-20 per cent per annum."* (EIAA, 2003:20).

The earliest turnover figure shown by the EIAA for the HTEI in Australia (EIAA, 2003) was A$8,786 million in 1995-96 and the final report of the Action Agenda (AEEMA, 2007) shows 2002-03 national HTEI revenue as A$8,284 million - a fall of more than A$500 million in the seven years 1996 to 2003.

However, in the same 7 years the revenue of the Adelaide HTEI grew from A$965 million in 1996 (Manners, 1996), to A$1,896 million in 2003 (SACES (2004), an increase of A$931 million or almost 100 per cent. So, while the national revenue was falling the Adelaide HTEI revenue was growing strongly. This highly unusual situation is, however, consistent with the statement in the Federal Government publication (EIAA, 2003) that the national performance of the electronics industry at the national level was *lacklustre* while the Adelaide-based industry had grown strongly.

4.3.5.8 Adelaide HTEI Structure and Cluster Dimensions

The HTEI cluster in Adelaide fits the categorisation developed by Mayer (2011:8), as a: *"high-tech hidden gem region."* A limited number of references in the literature identify the HTEI cluster in Adelaide.

Noting that neither Australia nor Germany perform well in the ICT sector at a national level Parker and Tamaschke (2005:1788) state; *"... both Dresden and Adelaide have developed some competence in parts of the ICT sector that depart from national patterns"*

Adelaide has a long history of traditional industrial-age manufacturing and its recent growth in new industries including ICT has been reported in the literature. Quoting ABS data for 2001 Parker shows that in Adelaide "*The relative size of the ICT sector, particularly in manufacturing and telecommunications, exceeds that for the nation as a whole"* (2008:840).

Parker shows that in 2001 Adelaide accounted for 12.4 per cent of national employment in ICT specialist manufacturing businesses (ABS 8126.0, 2002) and notes that this *"exceeds its share of national employment, which is around 5.5 per cent"* (2008:840).

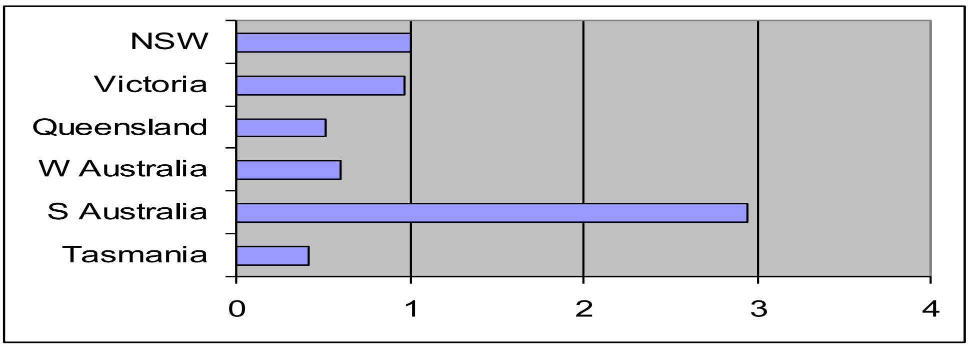
By 2003 the Adelaide share of national HTEI employment reached 22.4 per cent (ABS 8126.0, 2004), which is discussed in Grill and Coutts (2005). The high concentration of HTEI employment in Adelaide as a proportion of the State population is illustrated by the data reproduced below in Table 4.4 from Grill and Coutts (2005:4).

Table 4.4: Australian Electronics Manufacturing Industry Employment (2003)

State	Population Share (p) (percentage)	Electronics Share (e) (percentage)	Concentration (e/p) (ratio)
New South Wales	33.4	33.7	1.009
Victoria	24.7	23.8	0.964
Queensland	19.4	10.3	0.531
Western Australia	9.9	6.0	0.606
South Australia	**7.6**	**22.4**	**2.947**

Grill and Coutts (2005) *Australia's Electronics Industry,* Sydney, Communications Research Strategy Forum (CRSF). Data Source: ABS 8126.0, 2002-03, Table 2.8 page 20 and ABS 3101.0. *'Electronics Manufacturing Industry'* includes ANZSIC (1993) 2839, 2841, 2842, 2849 and 2852

Figure 4.4: The Data from the Table 4.4 above, Shown Graphically



HTEI manufacturing employment, as a proportion of State population (ABS 8126.0-2004; ABS 6203.0-2003)

Despite examples of localised industry cluster development in Australia, Enright and Roberts (2001) show that there is little formal interest in technology development, except in Adelaide and Canberra (Garrett-Jones, 2004:14).

A survey by the South Australian Centre for Economic Studies at the University of Adelaide reported A$1.896 billion revenue of the HTEI cluster in Adelaide in 2002-03 (SACES, 2004) which represented 22.9 per cent of the A$8.284 billion (2002-03) national electronics industry revenue (AEEMA, 2007).

This Adelaide HTEI figure of 22.9 per cent by revenue correlates well with the figure of 22.4 per cent of South Australia HTEI by employment for the same 2002-03 year (ABS 8126.0, 2004) and shown in Grill and Coutts (2005:4). It is noted that this high proportion of national revenue and employment in the Australian electronics industry was produced in Adelaide, a city with 5.4 per cent of the national population.

In a more recent paper Parker (2008) notes that Adelaide like Limerick, Ireland and Karlskrona, Sweden has several features that align it with a model of an '*entrepreneurial regional economy'*, including its restructuring from declining sectors such as automobiles to emerging sectors such as ICT manufacturing. Parker (2008:840) notes *"The entrepreneurial dynamics of the Adelaide region are further demonstrated by the growth of well-recognized innovative SME,s in ICT"* quoting Garrett-Jones (2004). In addition to the restructuring of the region and the growth of innovative SME's and start-ups in ICT, *"... the skills and research infrastructure of the region are increasingly oriented toward more dynamic sectors such as ICT"* (Parker, 2008: 840). These developments were discussed with Professor Parker at an interview in Brisbane (Parker, 2009).

Table 4.5: HTEI Employment Australia (2012)

ANZSIC	Description	Employment
2421	Computer and Business Machines	2,376
2422	Telecommunications Equipment	5,056
2429	Electronic Equipment & Components nec.	5,975
2419	Professional and Scientific Equipment	6,630
	Sub Total	**20,037**
2431	Electrical Wire and Cable	2,384
2313	Automotive electrical and instruments	2,854
	TOTAL	**25,275**

Source: IBISWorld (2012) Note: ANZSIC codes changed in 2006 and IBISWorld has adopted the new nomenclature. The ANZSIC codes shown in EIAA 2003; 2007 are 1993 ANZSIC codes.

Employment across Australia in these six ANZSIC codes has reduced from the 34,378 employees shown in 2006 in the Final Report (EIAA, 2007) to 25,275 (Table 4.5) which is a reduction of more than 26 per cent in six years. This national reduction contrasts with a continuing increase in employment in the HTEI in Adelaide over the same period.

The final EIAA report (EIAA, 2007) shows 34,378 employees in the national HTEI in 2006, (IBISWorld, 2010) while the latest (2012) data from same IBISWorld database is shown in Table 4.5 (above) for Australian employment in ANZSIC (2006) codes: 2419, 2421, 2422, 2429, 2431 and 2313 in the 2012 year. These are the six ANZSIC codes used in the EIAA (2003), while the code numbers have changed, the descriptors are essentially unaltered.

A sample survey of the Adelaide HTEI in 2012 shows that its revenue (2010-2011) had grown to A$4.02 billion (TIA, 2012), an annual increase of approximately 10 per cent from 2003 to 2011. This survey also reported that employment had increased to 11,700 in the 2011 year. This survey was conducted was jointly by this author and Clive Pay, the former EIA Secretary for TIA using a small sample. While its accuracy is limited, this survey suggests continuing growth in the Adelaide HTEI, but at a reduced rate when compared with the period 1990 to 2003.

Table 4.6: Employment Data Summary: National and Regional South Australia and Australia

Data Source and Qualification	Employees
HTEI Employees in South Australia: from Electronics Industry Sample Survey (TIA, 2012)	11,700
Total Employees in South Australia: Australian Bureau of Statistics (ABS 6202.0, 2012)	814,400
HTEI Employment Australia: ANZSIC: 2421, 2422, 2429, 2419, 2413 IBISWorld (2012) (1)	25,275
Total Employees in Australia: Australian Bureau of Statistics (ABS 6202.0, 2012)	11,497,000

(1) Note: ANZSIC code numbers were changed in 2006. The descriptors are virtually unchanged from EIAA (2003)

Using these employment data the LQ for the Adelaide HTEI is calculated at 6.54, a remarkably high figure considering that the Adelaide HTEI cluster is underrepresented in the literature apart from the limited number of references discussed above. The HTEI in Adelaide exactly fits the category of a *"high-tech hidden gem region"* Mayer (2011:8).

4.3.5.9 Adelaide HTEI Cluster Origin and Development

Literature on the origin and development of the electronics industry in Adelaide is limited and incomplete when compared with the comprehensive analysis of the origin and development of the electronics industry clusters in Cambridge, Silicon Valley and Austin and the moderate number of publications on the HTEI in Christchurch.

The role of universities in the origin and development of HTEI clusters is discussed above in Cambridge with the University of Cambridge and in Silicon Valley with Stanford University and in Austin with the University of Texas. However, successful clusters have developed in regions without a major university; "*... a university per* se *is not essential to the emergence of a successful cluster"* (Bresnahan et al, 2001:847).

Mayer (2011:10) states that: *"the role of universities is neither necessary nor sufficient for high-tech growth"* and provides evidence, discussed earlier of the development of dense HTEI clusters in three USA cities without research universities. The development of the high density HTEI cluster in Adelaide without significant university involvement supports the hypotheses of Bresnahan et al, (2001:847) and Mayer (2011:10).

While Adelaide has good universities, they have not produced the number of spin-out firms nor have their spin-out firms achieved the success of spin-outs from the Universities of Cambridge, Stanford or UT Austin. Parker, in her analysis of the electronics industry in Australia and Sweden states *"In Adelaide, universities have played a limited role in bringing global knowledge to the local region due to the underdevelopment of links with industry and limited commercialisation activities"* (2006:221).

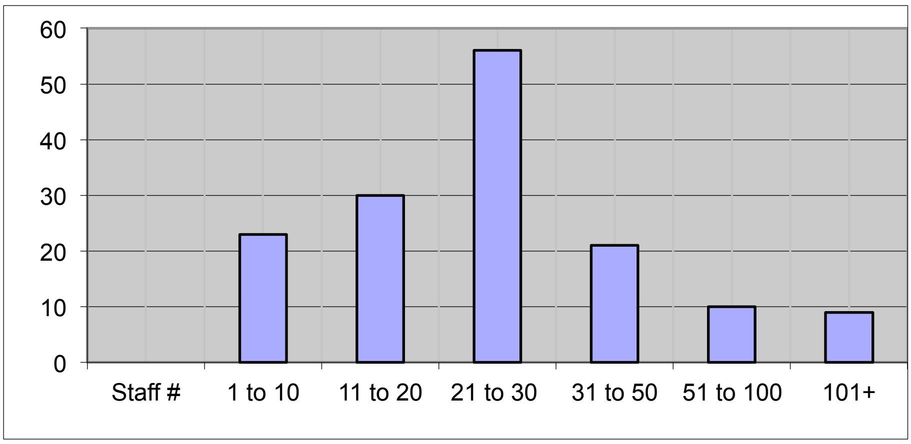
Two-way radio manufacturing pioneer Alfred Traeger was an active member of the Wireless Institute of Australia; he gave lectures to members and built a short-wave transmitter for the Institute (Ross, 1978). A public exhibition of locally built and imported radio receivers and components was held in Adelaide in 1925 (Ross, 1978). Traeger could have obtained radio components from these suppliers when preparing for the 1926 tests of the Alice Springs radio base and later for the production of his pedal radio. His colleagues at the Wireless Institute may also have assisted these projects. Four years later Edward Both may have obtained components for his products from these local radio firms.

Traeger and Both and the small group of radio firms could scarcely be called a cluster, but the linking of these people, the existence of an Institute and the exchange of information and business between them may have created the early vertical and horizontal connections that later grew into a cluster. While the Traeger and Both firms did not grow to the size of Cambridge Instruments, Hewlett Packard, Tracor or Tait, they were the first recorded manufacturers of professional (non-consumer) electronic equipment in Adelaide.

The major influence on the HTEI Adelaide cluster was not a university or a major firm, however, the Federal Government defence research institution DSTO acted as a "*surrogate university",* as described by Mayer (2005, 2011:48), noting the role of Tektronix in Portland, Oregon. This large electronics firm in a relatively small city trained many scientists and engineers. Some of these have moved to other firms or started their own electronics business in the city and thereby added to the growth of the HTEI cluster in Portland. The concept of the major influence on the development of an isolated, regional cluster from a non-university organisation was developed by Mayer (2011) and supported by her research beyond Portland, Oregon and Boise, Idaho, where Mayer shows that strong clusters of technology firms also developed through relationships with local electronics manufacturing firms in these cities. The role of Tait Electronics in Christchurch discussed in section 4.3.4 above also shows that a dominant firm can be a catalyst in the origin of a cluster in a second tier city. The DSTO performed that catalyst role in Adelaide.

The HTEI in Adelaide has grown through the typical spin-out and start-up processes. Spin-outs from Codan, the largest locally owned Adelaide HTEI company formed in 1959 include Long Distance Communications, Barrett Communications and Tekelek, which has its European operations in Shannon, Ireland. University spin-outs in Adelaide include ATRAD Atmospheric Radar Systems, Cohda Wireless and Minelab, a global leader in the manufacturer of metal detection systems. Successful local start-ups include Entech, Redarc and Sage Automation. Motorola established an electronics and software engineering centre in Adelaide in 1995 and employed approximately 300 engineers, but this centre closed in 2007. Freescale a Motorola subsidiary operated in Adelaide until 2006 and former staff started their own IC design business, Australian Semiconductor Technology Company, which now has 70 staff in Adelaide (Adelaide Now, 2007); another example of the working of the '*push*' factor. A rare earlier survey, primarily focused on locational preferences reported that 23 per cent of 61 Adelaide electronics manufacturing firms surveyed emerged as spin-outs from other firms or organisations (Kurgan 1997:118).

Figure 4.5: Percentage Revenue Growth 1993-94: Adelaide HTEI Firms by Staff Size



Source: Strategy Taskforce for the Electronics Industry in South Australia (EASA (1994:31)

In 1994 the Electronics Industry Taskforce identified an important growth characteristic in the HTEI in Adelaide. The fastest growth was in SME firms with 21 to 30 staff. Figure 4.5 above illustrates the growth performance of SME firms in 1993-94 (EASA, 1994).

Further discussion with the 14 firms in the 21-30 employee size-band identified two common factors. These firms that had been established for a mean of 8 years had 1.) introduced new products; they were no longer *one product companies* and 2.) they had also entered the export market and thus had two sources of increased growth, an expanded product range and an expanded market.

An important characteristic of the Adelaide HTEI was also identified in Christchurch - a relatively low level of direct competition between firms - and this characteristic was earlier reported in the electronics industry in Adelaide *"... there is very little product duplication, many firms are unique in what they do"* (Kurgan, 1997:113).

Enright and Roberts observe that Queensland and South Australia "*have played the most active role in supporting the development of clusters"* (2004:104). In the late 1980s 'networks' were formed in Adelaide through a Federal Government Business Networks Program, however, the program was terminated in 1998 and at that time, the State of South Australia, with 8 per of the national population had 30 per cent of all Australian Business Networks (Blandy, 2001). The program brought businesses, mainly SME's and people together (Fulop, 2000) and its influence has continued and relationships forged in those networks are still productive in the Adelaide HTEI cluster today.

A Federal Government 'Management and Investment Company' program (Espie, 1983) operated in the early 1980s until 1992, however, "*the benefits to the targeted companies were limited at best"* (Kowalick. 2010). In the early 1980s Technology Park Adelaide was established near the DSTO and the University of South Australia (Technology Park Corporation, 1985) with a focus on technology innovation (Burns and Garrett-Jones, 2002). Unfortunately, the potentially beneficial citywide engagement in a public and private sector 'technopolis' project, the Multifunction Polis Adelaide was abandoned in 1998 after ten years, having failed to define and deliver a joint focus on the industries of the future and a twenty-first century lifestyle (Castells and Hall, 1994; Inkster, 1991).

From the establishment of the rocket testing and the defence research and development laboratories in Adelaide since 1947 the linkages between the firms, individuals and institutions have developed. In the mid twentieth century interstate telecommunications and air travel were limited and relatively expensive, so reliance on local colleagues, suppliers and customers cemented the relationships that are the basis of early clustering in Adelaide. As spin-outs and the start-up of new firms emerged these relationships added to the evolving cluster. The relatively small size and isolated location of Adelaide has facilitated collaboration and the interchange of information and personnel.

The singular event that can be identified in Adelaide as the *origin* of its HTEI cluster is the 1947 government defence research institution, now DSTO. The industry that has evolved and developed into the Adelaide HTEI cluster of today is now the leading Australian HTEI cluster and continues to grow while the HTEI in other Australian States contracts.

4.3.5.10 Additional Indicators

A supportive explanation of the high concentration of the electronics manufacturing industry in Adelaide, when compared with other Australian States was provided by Professor Richard Blandy in a presentation to the Electronics Industry Association in August 2002 (Blandy, 2002). See Appendix 14.

In this presentation Blandy shows that in 1998-99 South Australia ranked in Gross Expenditure on Research and Development [8] (GERD hereafter), as a proportion of Gross State Product or Gross National Product (as applicable), at 1.93 per cent and in fourth place internationally after Finland (2.90 per cent), USA (2.74 per cent) and Germany (2.29 per cent). South Australia's share of GERD research and development investment was ahead of all other Australian States and Denmark (1.92 per cent) and UK (1.83 per cent).

Blandy (2002) also shows that South Australia at 0.69 per cent ranked well ahead of Finland (0.38 per cent), Germany (0.34 per cent) and USA (0.22 per cent) in Government Expenditure on Research and Development (GOVERD, hereafter).

This apparent anomaly is explained by the presence of the DSTO in Adelaide. The high level of GOVERD noted by Blandy included A$288 million Australian Government funding in 2002-03 for DSTO with more than 1,000 scientists, engineers plus support personnel engaged on scientific research and development to deliver defence capability to the Australian Defence Force (Trenberth, 2004).

On a population basis South Australia would expect approximately A$48 million as share of funding of Federal laboratories in the State. The A$288 million government investment in DSTO in Adelaide is a disproportionately large investment which is reflected in South Australia's high GOVERD share of 0.69 per cent of Gross State Product.

When considered together the data from ABS 8126.0 shown in Table 2.1 in Grill and Coutts (2005) which is reproduced as Table 4.4 (page 185) and the Blandy (2002) data on research and development spending that the disproportionately high density of the HTEI in Adelaide

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[8] GERD: Gross Expenditure on Research and Development, which includes Business Expenditure on Research and Development (BERD), Government Expenditure on Research and Development (GOVERD), and Higher Education Expenditure on Research and Development (HERD)

shows an association between the ongoing operation of DSTO in Adelaide and the performance of the regional electronics industry. DSTO Adelaide is a large facility in a small city and its influence has been strongly positive for the development of the Adelaide HTEI.

4.3.5.11 Survey of Adelaide's HTEI

While limited data is available from government and industry sources on the revenue and employment dimensions of the Adelaide HTEI, data on the origin and development of its individual cluster firms is scarce and incomplete. To overcome this lack of published data a series of interviews was undertaken with industry and related and supporting organisations to address the first two research questions in relation to Adelaide. First: *Why* did HTEI firms cluster in this 'second tier' city? Second: *How* has the HTEI cluster developed in this region?

This survey included 70 firms and the sample was stratified with ten firms in each of seven employee size bands and as discussed in Chapter 3 the process allows analysis of the firm responses across the range of businesses sizes and comparison with previous surveys using the same stratification.

The survey shows that in 35 per cent of Adelaide HTEI cluster firms the major start-up driver was the technology and the second most common foundation motive across businesses of all sizes was self-employment at 32 per cent. The technology was the start-up driver in 50 per cent of the large, (100+) businesses and none of these large firms were started for self-employment. With one person businesses the main start-up reason at 45 per cent was self-employment and the technology motivated 36 per cent of these individual start-ups. In the 5-10 employee range, 48 per cent of businesses were started to provide self-employment for their owner.

Across all employee size-bands, money motivated 22 per cent of Adelaide start-ups with a low of 9 per cent at the one person size to a high of 38 per cent at the 51-100 and 100+ businesses. Overall, 42 per cent of firms had a new technology at start-up with a high of 50 per cent in 21-50 employee firms. A total of 80 per cent of the 70 respondents addressed an existing market with an improved or differentiated product while the remainder *'created'* a market by offering a product that had no existing competitor, with the largest number of firms addressing *'latent'* markets in the 21-50 size range; this size band was also the fastest growing, as identified in the Taskforce Report EASA (1994:31), as shown in Figure 4.5.

The survey in Adelaide found that 74 per cent of firms chose their home town as their business location. This 'home town' proportion was lower than in the four other Australian cities surveyed. Comparable surveys in Cambridge, found that 86 per cent (Athreye, 2004) chose their hometown and Segal and Quince (1985) found 73 per cent and the lowest in Cambridge were 58 per cent (Pleschak, 1995) and 56 per cent (Bramanti and Senn, 1990).

In Adelaide 71 per cent of HTEI firms surveyed believe their location choice is more relevant now and would be unchanged today and 24 per cent were more satisfied with their choice and only 3 of the 70 respondents reported their location choice as less relevant. With this high proportion of firms initially selecting Adelaide and satisfied with their location, this finding suggests that the cluster has developed in a way that has been beneficial to a high proportion of firms.

The firms in this study have a mean age of more than 16 years and their responses to the questions on location are, therefore, based on long experience. In an open-ended response the 'best' factors in their location in Adelaide were in descending order: *'lifestyle', 'low cost', 'staff quality and availability', 'small size', 'access to customers and to DSTO'*. Unprompted responses to the 'worst' factors were in descending order: *'small size', 'none', 'parts availability', 'remoteness and isolation'.*

While remoteness and isolation are seen by some respondents as a negative, the long-term steady growth of the Adelaide HTEI cluster suggests that these factors are more positive for the HTEI cluster. Technology was developed in-house by 87 per cent of firms of all sizes, which suggests that the firms are relatively self-sufficient. Technologies were obtained from outside firms and this relationship is discussed below in Section 4.8m. Universities supplied technologies to 28 per cent of firms and government laboratories provided technologies to 17 per cent, predominantly to the mid-size firms.

The shortage of trained people was rated on a Likert scale of 0 to 5 (5 = maximum) at 1.81 with a slight bias towards the larger firms and these larger firms are the best able to recruit engineering staff from interstate and overseas, which is a common practice in larger firms.

The value to Adelaide firms of their universities was rated at 1.20 which is substantially lower than in the four other Australian cities included in this research which rated at a mean of 2.41 while Christchurch rated at 2.69.. The large difference between the rating of the value to the firms of Adelaide's universities and the universities in other surveyed cities suggests that a large, yet unrealised benefit is available to Adelaide's HTEI firms by collaborating with their local universities.

While the value placed on universities was not high, the list of training needs is long, with microwave and RF engineering skills strongly in demand, three times the need for the next skill, software engineering with some need for systems engineering, DSP engineers. Self-rating in 'innovation' performance produced 4.36; 'entrepreneurship' was self-rated at 3.46 and 'creativity' produced a self-rating of 2.72, over all firm sizes.

Success in attracting equity capital was rated overall at 3.33 with the highest rating across the larger firms and success in attracting short-term loan funds rated overall at 3.58 with a low of 2.64 in the smallest firms and a high of 4.26 across the larger firms. VC was sought by 17 per cent of firms and obtained by only 3 per cent [two firms] and the successful firms were in the 10 to 50 employee range. Notably a total of 80 per cent of all firms made no application for VC, which shows a large difference between firms in this Adelaide study and comparable firms in Silicon Valley and Austin, where VC is more readily available and more widely used. The low level of VC in Adelaide is partly explained by the responses to the next discussion topic. The importance of retained earnings rated evenly at 3.25 overall. The high reliance on retained earnings and low demand for VC describe a group wanting to retain financial control while accepting slower growth. Again this aligns with the Australian business style of making long-term trading profits compared to common USA quest for a capital profit at the point of sale of the business; the strategy of the founders of Xicor Inc. in California, discussed earlier in the section on Silicon Valley.

The involvement of personal assets in the business was rated as important at 3.64 in small firms and much less so at 0.375 in large firms, with a mean rating of 1.84. Niche markets were the primary target of 90 per cent of firms and 61 per cent of firms across all sectors were exporting. Importance of global surveillance of opportunities and threats was rated at 3.26. On the importance of the government as a customer the State was rated at 1.41 and Federal government was rated at 1.81. The position of 'market leader' is claimed by 41 per cent of firms and a further 42 per cent are 'market led'.

Since their start-up 75 per cent of firms have changed their strategic direction because of '*outsourcing', 'capability change', 'market moves'* or a *'takeover'*. The capability of the firm in risk management is self-rated at 3.04 and their IP management is self-rated at 2.74 with the highest rating at the larger firms. The value of clusters and networks was rated at 3.21 overall with a stronger response from the smaller firms. Non-financial government assistance was sought by 60 per cent of firms and obtained by 46 per cent. Financial assistance through government programs was sought by 51 per cent and received by 49 per cent with higher success rates at the larger firms.

Government assistance required, in descending order was: *'access to grants'* and *'training'*. The effect of cost and delay caused by government regulation was rated at 1.67. Current and past benefits of local institutions, including universities and government research laboratories was rated at 1.73 and their expected future value was rated at 1.84.

It is noted that the rating for both current and future value of local institutions in Adelaide is the lowest of the 6 cities surveyed and this is discussed below in Section 4.8 . Disadvantage of public institutions (as a competitor or for staff and funding) was rated at 1.33. Highest level of services wanted from education and research sector were *'access to equipment', 'staff training'* and *'collaboration with DSTO'*.

The technology or self-employment was the driver for the start-up of two-thirds of businesses and this is comparable with findings in Silicon Valley, Cambridge and Austin. While one-fifth of Adelaide start-ups were motivated by money, the survey shows a trend for owners to retain control and to accept lower rates of growth, consequently VC is not significant in the Adelaide HTEI. Niche markets were the primary target of 90 per cent of all firms and Government is not important as a customer overall, except to the defence sector of the industry where it is the only customer. Current and past benefits of universities and government research laboratories and their expected future value was not highly rated, suggesting an opportunity for future collaboration of industry and research.

In Adelaide 74 per cent of new HTEI firms chose to locate in the home town of the founder. However, it is noted that the Discussion Topic (Appendix 2) seeks to find if the location decision was made '*by analysis or a 'hometown' decision'.* Therefore it is relevant that 25 per cent of firms made their location decision by a process of analysis, and it is known that a small number had moved to Adelaide to start their business. This contrasts with the mean for a decision *by analysis* in other Australian cities of 14 per cent, which includes 1.79 per cent in Melbourne and 6.67 per cent in Sydney.

A larger number, 28 per cent in Christchurch also made their location decision *by analysis*. It is significant that the highest proportions of firms that made a reasoned decision to start-up were in Adelaide and Christchurch, the two cities with the highest density clusters and the two cities that would be known to potential start-up entrepreneurs for their developed clusters and therefore these cities would provide a better chance of success for the business. The low results in Sydney, 6.67 per cent and 1.79 per cent in Melbourne were recorded in the largest cities with the lowest density clusters. The attraction of start-ups to the cities with the higher density clusters suggests an answer to the question on how clusters develop in second tier regions.

These findings describe the HTEI industry in Adelaide that is firmly established, financially conservative and growing steadily within the control of the owners of its firms. Several of the *'hypothesised features*' reported by Markusen (1999:23) in '*New Industrial Districts'* are observed in the Adelaide HTEI cluster: domination of small firms, low scale economies, intradistrict trade and local financial decision making trough high levels of local ownership. The entrepreneurs behind the firms achieve personal goals and through past association or emerging needs they network with others in their region thus deepening and strengthening the cluster. The low value of universities in Adelaide to its HTEI firms provides a concern and a collaborative opportunity for industry and research.

4.3.5.12 Comparison of Five Clusters in the Principal Case Study

Table 4.7, below shows employment and LQ for the five regions in the principal case study The LQ for the cluster in Silicon Valley at 13.36 is the highest of the five selected regions and has risen from 11.38 in 2001. Some of this gain has been at the expense of Austin which had an LQ of 4.83 in 2002 and had fallen to 3.91 in 2012

While the Cambridge region has a relatively high 15.1 per cent of the national HTEI workforce employed, its relatively low LQ is a result of the wide spread of the HTEI across many regions in England, Northern Ireland, Scotland and Wales. Christchurch has 34.6 per cent of its national HTEI employment, less now than the reported by Tantrum (2003). Its LQ at 3.62 is therefore lower than it would have been in 2003 and this reduction is possibly caused by the 2011 earthquakes.

Table 4.7: HTEI Regional and National Employment Density and Location Quotient

REGION	Employment in Regional HTEI	Employment in National HTEI	Regional % of National HTEI	Employment LQ Region
Cambridge	18,300	120,900	15.1	1.66
Silicon Valley	108,367	1,103,588	9.82	13.36
Austin	24,541	1,103,588	2.22	3.91
Christchurch	1,526	4,410	34.6	3.62
Adelaide (1)	11,700	25,275	46.3	6.54

(1) Based on sample survey (TIA, 2012)

Based on the TIA (2012) employment data Adelaide has more than 40 per cent of Australia's employment in its HTEI and a significant LQ at 6.54 which is approximately half that of Silicon Valley, but almost twice that of Austin. The Austin figure is lower than may be expected, again as a result of the wide dispersal of the HTEI across a number of US States including, California, Texas, Massachusetts, Washington, Colorado, and Florida.

While the success of HTEI clusters in Cambridge, Silicon Valley and Austin is known from the extensive global literature and while a limited literature has reported and measured the origin and development of the HTEI cluster in Christchurch, with its relatively high LQ, the origin and development of the HTEI cluster in Adelaide with its significantly higher LQ has remained relatively undiscovered. Very few reports in the literature, including Parker and Tamaschke (2005), Parker (2006) and Parker (2008) identified the Adelaide HTEI's disproportionately high share of employment in the national ICT manufacturing sector. Grill and Coutts (2005) also noted Adelaide's high proportion of national HTEI employment reported in 2003.

The Electronics Industry Association in Adelaide was recognised as *"taking on all of the characteristics of a cluster"* (Burns and Garrett-Jones, 2002:195). Apart from these few references the strength of the Adelaide HTEI and its position of national leadership this cluster has remained relatively undiscovered as one of the: *"high tech hidden gem regions"* (Mayer, 2011:8).

Two major findings of this research are first, Adelaide has Australia's densest and only nationally significant HTEI cluster that it is growing while the industry is shrinking in other Australian States. Second the Adelaide HTEI cluster may have the highest proportion of its national HTEI in any one region.

Furthermore, its role in the transition of the regional economy of Adelaide and South Australia from a past dependence on industrial-age manufacturing to a new future in knowledge-age manufacturing will be of major importance to the community. The, Adelaide HTEI cluster is, however, relatively unrecognised in the literature and also not well understood by its governments or its community.

Table 4.7 above shows the LQ for the five regions in the principal case study, and also shows the regional proportion of the national HTEI employment in each region. While LQ is the standard measure used for industry comparison, the regional percentage of national employment shows an alternative view of the data with a localised focus.

Table 4.7 shows that while Silicon Valley has a very high LQ of 13.36 its share of the national HTEI workforce is 9.82 per cent. Adelaide with an LQ of less than half that of Silicon Valley employs more than four times the share of its national HTEI workforce. This high proportion shows that Australia's HTEI is highly concentrated in Adelaide which may suggest that this industry in Adelaide is more significant to the regional economy of Adelaide than is presently understood by its government and community.

4.4 The Second Case Study: Boston, Brisbane, Canberra, Melbourne and Sydney

The second case study includes five cities that are linked by two common characteristics. First, the endogenous origin of their HTEI clusters and the development of these clusters, generally without direct government plan or assistance. Second, these five cities have not achieved the high levels of concentration of HTEI firms found in Cambridge, Silicon Valley, Austin, Christchurch or Adelaide.

The four large cities in this case study; Boston, Brisbane, Melbourne, and Sydney each have a metropolitan population of approximately 2 to 5 million, while the Australian national capital, Canberra has a population of 368,000.

4.4.1 Boston

Boston is a large metropolis with almost 5 million population and the endogenous origin of its HTEI cluster is highly relevant to this research. However, the *industrial heritage* of Boston influenced the development of the HTEI cluster with very different characteristics to those found in the clusters discussed in the principal case study. The HTEI in Boston developed in a region with a long industrial history "*…characterized by conservative traditions that dated from the seventeenth century"* (Saxenian, 1994:60).

The industrialisation of New England grew from the development of the cotton textile industry and its location was chosen partly for its climate, where the humidity was suitable for cotton processing and for the availability of water for mill power (Losch, 1954). Cotton processing machinery was originally imported from Britain. Later these machines were built locally and the mechanical skills learned were extended in the nineteenth and twentieth centuries to the production of precision mechanical consumer products (Brauer, 2013). The *vertically integrated* organisation of the processing of textiles created a local culture of self-sufficiency and *in-house* processing and thus trained generations of manufacturing engineers and managers in this structured organisational culture.

The electronics firms of Boston inherited the vertically integrated structure developed during its industrial past, unlike the industry in Silicon Valley which, having no industrial background developed its own *"regional network-based industrial system"* (Saxenian, 1994:2). The culture in the HTEI in and around Boston was based on *in-house* processes, loyalty to the firm and security of technical and production information. "*Networking on Route 128 occurred almost exclusively within large firms, not between firms"* (Saxenian, 1994:72). In this structured environment Jack Turner Manager of Technology Licensing at MIT noted that skills learned at large companies are often found to be inappropriate in small companies and many spin-out founders had to re-learn many basic skills (Turner, 2006).

The electronics industry in Boston which emerged through the manufacture of broadcast radio receivers and components including electron tubes developed in the early twentieth century. During the Second World War, MIT received US$117 million in research funds from the USA Federal Government "*by far the most money awarded to any American university during the war*" (Berlin, 2005:29). The positive effect of this funding lasted well beyond the war.

The '*Massachusetts Miracle*' of the 1970s hailed the emergence of America's new high-tech industrial district in Boston and around Route 128 (Lampe, 1988). Lester Thurow (1988) noted that the high tech '*Massachusetts Miracle*' was assisted by the availability of highly skilled people and while it had begun in the 1950s, it had only been noticed in the late 1970s; another observation of the *hidden value* of knowledge-age industry. Massachusetts had the trained engineers and scientists, particularly, from MIT and the industrial background gave Boston its manufacturing culture (Etzkowitz, 2002).

4.4.1.1 Digital Equipment Corporation

A leader in the 'Miracle' was DEC (Digital Equipment Corporation), established by MIT electronics engineer Ken Olsen in 1957 in an old mill building in Maynard, Massachusetts, near Route 128. DEC developed the PDP and VAX range of minicomputers and in 1971 DEC opened its European manufacturing plant in Galway, Ireland, this plant is discussed below in Section 4.5.2. DEC became a world leader in minicomputers with 126,000 staff, and second only to IBM in the 1980s.

Competitors in the minicomputer market soon emerged around Boston including Data General, Wang and Prime. However, microcomputers developed quickly in the 1970s and 80s, particularly in Silicon Valley and became more powerful and began to displace minicomputers (Seeley-Brown and Duguid, 2000) and by the late 1980s and the locus of the computer industry began to shift to the west coast. The history of DEC parallels that of the '*Massachusetts Miracle*'.

The Massachusetts Miracle *"turned to dust with the abrupt loss of one third of the State's manufacturing jobs between 1986 and 1992"* (Best, 2001:17).

The HTEI, including *'computer and telecommunications equipment manufacturing'* (NAICS 334) in Boston lost another 30,000 jobs from 2001 to 2005 and its employment performance was ranked 53 in a list of 67 industries (Bradbury and Kodrzycki, 2007), leaving the previously strong HTEI cluster weakened.

4.4.1.2 Bank Boston Study

The power of knowledge-age industry and particularly electronics manufacturing is illustrated by the 1997 Bank of Boston Report which analyses high technology manufacturing firms started by alumni and faculty of MIT. Worldwide, by 1996 these 4,000 firms employed 1.1 million people, and produced US$232 billion revenue, roughly equal to a gross domestic product of US$116 billion (BankBoston, 1997; MIT, 2012). This extraordinarily high proportion is consistent with the performance of high technology companies, including electronics firms in the knowledge-age. The report shows that electronics firms in the study produced US$130 billion or 56 per cent of the total revenue and employed 635,000 people or 57 per cent of all employees.

Eighty per cent of the jobs in these MIT-related firms were in manufacturing, compared to 16 per cent nationally. The MIT-related companies had more than 8,500 plants and offices in the 50 states. The largest number of employees in MIT-related companies, 162,000 was in California; Massachusetts was next with 125,000 followed by Texas with 84,000.

Ten of the fifteen largest MIT related companies in the Bank Boston Report are electronics manufacturers and in order of size, from the largest, in 1996 were: Hewlett Packard; Raytheon; Texas Instruments; Intel and National Semiconductor. Hewlett Packard is included as an MIT-related company as its founders were MIT alumni. The capability of the Massachusetts HTEI and ICT sectors is illustrated in Table 4.8 below.

Table 4.8: Employment in Selected ICT Sectors: Massachusetts (2000)

USA Rank	MA Rank	Category	Employment in 2000
2	5	Analytical Instruments	58,500
7	3	Information Technology	50,300
4	11	Communications Equipment	28,600
4	15	Medical Devices	21,400
Total ICT Employment			**158,800**

Source: Porter (2003)

A follow-up study to the 1997 BankBoston Report (Roberts and Eesley, 2011) shows that 15 years later the number of companies founded by MIT faculty and alumni had increased from 4,000 to 25,800 and the number of employees in these companies had trebled to 3.3 million and their revenue had grown eightfold to almost US$2 trillion. The sustained growth rate of these MIT related firms illustrates the economic strength of knowledge-age industry and particularly in high technology electronics manufacturing.

While the HTEI in Boston has declined it is still very significant on a national and international scale and, importantly MIT is still a powerful teaching and research university with its influence reaching far beyond City, State or National boundaries.

Professor Jacob White, Director Electronics Research Laboratory, MIT, in an interview identified the culture of "*industrial impact"* as the criterion most valued at MIT and the most valuable to the community (White, 2006). The positive value of the *industrial impact* of MIT is felt worldwide.

In 2011 the LQ of the Boston-Cambridge-Quincy MSA was 2.45 (BLS, 2013) and in 2001 it was 2.69 (BLS, 2013), and significantly less than during the days of the *'Massachusetts Miracle'* and now approximately one fifth of the 13.36 LQ of Silicon Valley.

4.4.2 Brisbane

Brisbane, Australia's third largest city with a population of 2.15 million is the capital of the State of Queensland with its population of 4.64 million or approximately 20 per cent of Australia's total (ABS 3235.0, 2010). Almost 90 per cent of the State's HTEI is located in the south-east corner of the State, in the cities of Brisbane and the Gold Coast. Regional specialisation of the HTEI includes telephony, photonics, power supplies and monitoring equipment (AEEMA, 2005). Unpublished industry data shows the revenue of the Brisbane HTEI was A$800 million or 8.3 per cent of the national total in 2004 with 4,900 employees, but no later data is available from industry or government. The HTEI in Brisbane has not received the benefit of the location of an electronics research and development organisation such as DSTO in Adelaide or Telstra in Melbourne or a large company such as AWA in Sydney or Tait Electronics in Christchurch.

The Brisbane HTEI has received national government assistance under the AusIndustry banner (Volk, 2009). Canberra based AEEMA, assisted the Brisbane HTEI by locating its national export promotional office in Brisbane until 2008. A cluster program based on a *'new paradigm'* was implemented in Brisbane for AEEMA member firms under the Electronics Industry Action Agenda (Humphreys, 2004; Robinson, 2004). This 'top-down' program was based on a distributed model, rather than geographic proximity. The cluster was launched in 2003 and members participated in design and manufacturing projects. Killen and Hunt state that the AEEMA assisted clusters are developing well. "*The South Australia and Queensland clusters are seen as successful"* (2003:9). AEEMA was disbanded in 2008 and without its support the future of the Brisbane HTEI cluster is uncertain (Rose, 2013).

4.4.2.1 Knowledge Based Industry Cluster

The '*Brisbane IT and KBI Clusters Action Plan'* identifies three existing *'hotspots'* for IT and electronics development in the southern, western and northern suburbs of Brisbane. Brisbane aims to become a more innovative and competitive '*knowledge city'* and has developed city-wide '*Knowledge-based Urban Development'* policies (Yigitcanlar and Velibeyoglu, 2008), designed to attract and retain knowledge workers and is developing its *'music scene'* such as in Austin, Texas (Flew, 2001). Local and State authorities are responding to Brisbane's isolation from major Australian cities, Sydney and Melbourne and their *'Knowledge City'* program focus is contributing to the development of a local identity.

4.4.2.2 Survey of Brisbane HTEI

Interviews conducted for this research in October 2009 with 33 Brisbane electronics firms and related organisations shows that the technology was the driver in 59 per cent of HTEI start-ups with self-employment motivating 30 per cent. The hometown location was also chosen by 85 per cent and only 9 per cent of firms would consider moving. Shane Mooney, Production Manager explained that the location of Cochlear Ltd., Brisbane's largest HTEI firm through its purchase of the manufacturing facility of Crystalaid also secured the long-serving, key staff who would be reluctant to move (Mooney, 2009).

The survey shows that the 'best' aspects of Brisbane were '*cost', 'staff availability'* and '*lifestyle'*. The 'worst' feature was *'distance from customers'*. Technology development was reported '*in-house'* by 91 per cent of firms; a higher proportion than in Adelaide or Melbourne which may be related to the low rating in Brisbane of the benefits of universities and research institutions, discussed below.

Interviews reveal that the HTEI firms in Brisbane face challenges including poorly developed supply chains; retention of highly qualified staff; lack of an industry strategic plan and a shortage of technologies from universities. VC was sought by 22 per cent and received by 17 per cent, which is close to the national mean.

Government assistance was sought by 74 per cent of firms - the highest level in Australia - with all applicants successful. Strategy had changed in 83 per cent of firms since establishment, and *'access to markets'* was the major barrier to growth for 57 per cent, and both of these parameters were the highest in the five Australian cities. Current benefits to the firms from their research institutions was the lowest rating in Australia at 1.52 on a Likert scale with 5 as maximum and future expected benefits from these bodies was 2.98 and almost twice their *'current'* rating.

Exports were achieved by 83 per cent of firms and exporting firms had been exporting for 63 per cent of the life of the firm. Brisbane's relatively small electronics industry is dispersed across its large, undulating metropolitan area with an important concentration in the Brisbane Technology Park, an initiative of the Department of State Development, Trade and Innovation, and part of Queensland's *'Smart State'* program *"... designed to create/stimulate growth in employment and state economy."* (Hebbert et al, 2006) who noted a low level of interaction between tenant firms on the Technology Park. This low level was measured in the Brisbane HTEI survey with a rating of the 'value of networking' at 2.57, which aligns with the observation of Brown et al (2010) of '*passive*' rather than '*active'* externalities. As with other Australian States the mining industry is prominent in the industry policies of the regional government leaving less focus on the development of the electronics industry.

4.4.3 Canberra

Although it is smaller than the other cities in this second case study, Canberra is included in this research because of its position as the National Capital of Australia and the location of the National Government and headquarters of the Australian Defence Force and other major government customers. Since defence electronics is estimated to represent one-third of the electronics manufacturing industry in Adelaide and an important proportion in other states, particularly Victoria, and since the procurement of a large proportion of defence electronics is determined in Canberra, its relatively small industry cluster is important beyond its size. Regional HTEI specialisation in Canberra is on defence and aerospace (Robinson, 2002).

Canberra, with a population of 368,000 (ABS 3235.0, 2010) was purpose built as Australia's National Capital in the 1920s approximately 300 kilometres from Australia's largest city Sydney and 600 kilometres from its second city, Melbourne. Other Federal Government departments of Communications, Education, Industry, Energy, Environment, Health, Resources and Transport are headquartered in Canberra.

The requirements of these departments attract companies to the cluster and connects SME's and MNC's that contract to design and build electronic equipment and systems for the government. Defence is a major market for Australian HTEI firms and while Australia's largest defence electronics design and manufacturing cluster is located in Adelaide, liaison offices in Canberra connect the production and marketing functions. The HTEI in Canberra includes large firms; BAE Systems, Lockheed Martin, Boeing, and Raytheon - which have facilities in Adelaide - and many more SME firms that typically sub-contract with MNC's and others to provide the services and systems required for Australia's national defence.

One report on the Canberra HTEI is relevant (Thorburn, 2003). This report, initiated by the Electronics Industry Action Agenda raises the problem of industry definition and the use of *'statistical industry definitions'* or ANZSIC classifications and highlights the problem of underreporting or misreporting of HTEI economic activity; a common industry problem caused by the lack of precision in the ANZSIC categories. The report provides a *'Snapshot'* of the Canberra electronics industry as follows:

The largest sub-group of manufacturers produce electronics and photonics equipment:

- Average firm employment is 30
- Employment: about 7,600 people, or about 4.5 per cent of the ACT workforce
- High proportion of staff with science and engineering qualifications
- Average turnover is A$5.4 million per firm

The definition adopted in Thorburn (2003), however, includes retail and wholesale firms that supply electronic equipment and components and service provider firms, which together comprise 90 per cent of Canberra electronics firms. The remaining 10 per cent are manufacturers of electronic products and systems (Thorburn, 2003:19). Because the electronics industry as described in this report has a large proportion of *'service'* firms and retailers; these data are not comparable with the industry in other Australian cities or the global cities included in this research.

4.4.3.1 Survey of Canberra HTEI

The survey of 26 of the HTEI design and manufacturing firms and related organisations in Canberra conducted for this research in December 2010 identified a number of parameters where the national capital shows different results from those found in the Australian State capitals. A new technology was introduced by only 39 per cent of firms, the lowest response of the five Australian surveyed cities. At 39 per cent Canberra HTEI firms had self-employment as the strongest start-up reason and 36 per cent motivated by the technology and for 22 per cent money was the motivation; all close to the mean for Australian cities.

The location in the 'home town' of the founder was chosen by 81 per cent of founders also close to the Australasian mean of 79 per cent. On satisfaction with their location, 56 per cent were more satisfied than at start-up and 22 per cent were less satisfied. The 'best' aspects of their location, are in descending order; *'lifestyle', 'proximity to other cities', 'access to customers'* and *'collaboration'*. The 'worst' aspects were *'small market', 'lack of government understanding'* and *'skill shortage'*.

The technology source was 'in-house' for 94 per cent of firms, the highest recorded in Australia and the 6 per cent for universities and government laboratories was the lowest source of technology from Australian respondents. The value to the firms of the local universities was rated at 2.72, the highest of all Australian respondents. Exports sales were made by 56 per cent of firms, the lowest level in Australasia. This low export performance may be explained by the dominance of applications for the Australian defence sector with the major customer being the national government.

The defence customer base may also explain the low level of 'new technology' required by this conservative customer and why 'technology *push*' rated at 42 per cent is the lowest in the Australian survey. The largest proportion at 39 per cent - three times the national average - of firms are a *'low cost'* producer, possibly explained by the tendering process for all government requirements.

The importance of networks and clusters is highly rated at 4.22 by Canberra HTEI firms and significantly above the national mean of 3.00. The government being the largest customer and the city's comparative isolation from other major cities may positively influence the need for collaboration and the small size of the city may be a factor that facilitates more effective networking.

At 3.31 Canberra firms have the highest rating of the importance of surveillance of opportunities and threats, which may be explained by the high level of government business and the need of the firms to be aware of government requirements. The barriers to growth in 2009 were similar to those reported by Thorburn (2003), *'markets', 'skilled staff'* and *'finance'*.

An unsolicited remark from the manager of a defence sector SME during an interview in Canberra is instructive: "*… be helpful to everybody in the industry, you may need that firm as a customer or a supplier in future."* Small communities have limited numbers of potential collaborators and they are all important so firm performance and reputation are critically important.

The HTEI cluster in Canberra is small, networked and customer focussed, as would be expected in a small city with a narrow customer base. These data, when compared with Adelaide and Christchurch show strong correlations in parameters involving relationships, such as networking which is shown to be highly rated in small cities suggesting that proximity and easy access to industry peers may be linked to satisfaction from networking.

4.4.4 Melbourne

Melbourne, rated the *'most liveable'* city in the world (Economist, 2013) is the second largest city in Australia and capital of the State of Victoria. The population of Melbourne is 4.1 million or almost 18 per cent of Australia's 23 million and the State of Victoria has a population of 5.7 million or 25 per cent of the national total (ABS 3101.0 - 2012). The adjacent States on the southern Australian coast, South Australia and Victoria are recognised as Australia's *'manufacturing'* States with 13.0 per cent of GSP from manufacturing in South Australia and 12.2 per cent of GSP from manufacturing in Victoria. Queensland ranks third with 10.7 per cent and New South Wales produces 10.23 per cent (Woods, 2008).

The electronics design and manufacturing industry in Melbourne has traditionally been aligned with the telecommunications, instrumentation and automotive sectors (Robinson, 2002). Ford, General Motors and Toyota have operated major automotive manufacturing plants in Melbourne for decades, however all three manufacturers have announced that they will cease manufacturing operations by 2016. These closures will reduce opportunities for automotive electronics systems.

The HTEI in Melbourne has been positively influenced by the location in the city of the Research Laboratory of the national telecommunications carrier, founded as a government instrumentality and since corporatized and then privatised as Telstra Corporation Ltd. From 1923 until its closure in 2006 the Telstra Research Laboratory employed several hundred engineers and scientists developing technologies and training staff (Telecom, 1979).

Over time many of these talented people left to join other firms or institutions or to start electronics businesses typically in Melbourne. This laboratory performed a similar training role to that of DSTO in Adelaide, AWA in Sydney and Tait in Christchurch as a '*surrogate university',* similar to the role of Tektronix Inc. in Portland, Oregon (Mayer, 2005, 2011:48).

Changing technologies and the globalisation of telecommunications standards and equipment manufacturing economics caused the closure of many long established Melbourne telecommunications manufacturing plants, including Ericsson, NEC, Siemens and Fujitsu (Pollock, 2009). Both the telecommunications and automotive industries have moved from mechanical and electromechanical to electronic control systems, and the globalisation of these industries has reduced employment, significantly in telecommunications and automotive electronics sectors in Melbourne. Several studies of the electronics industry in Victoria have been published since the launch of the Electronics Industry Action Agenda (EIAA, 2003).

A report on '*The Victorian Electronics Industry Cluster'* shows that in 2000 the Victorian electronics manufacturing industry employed 11,681 people and produced a turnover of A$3.4 billion, which included 69 per cent of Australia's employment in *"automotive electronics and instrument manufacturing"* (Houghton, 2004:35). This category was not significant in any other State and since 2000 it has declined sharply in Melbourne. These components and assemblies are now largely imported for installation in locally built cars and the majority of cars sold in Australia are imported fully assembled.

Defence electronics is important in Melbourne. The Victorian Government Centre for Defence System Excellence website and the Office of Manufacturing and Service Industries website show: *"Victoria generates 41 per cent of Australia's ICT/electronics output"* (Victoria, 2009; Defence, 2013). Another Victorian Government website shows annual turnover in *'military electronics'* and *'aerospace electronics'* at A$140 million and *'non-aerospace electronics'* at A$80 million (InvestVictoria, 2013).

In 2006 the national electronics industry association AEEMA launched a new *'Electronics Cluster'* in Melbourne to facilitate collaboration in the telecommunications and automotive electronics sectors (Humphreys, 2006; AEEMA, 2006). Quoting (Beer, 2005) that the Victorian ICT industry was *'stagnating'* Hall (2006) proposed the creation of a new *'Victorian ICT Cluster'* in the marine and aerospace electronics sector to engage with Melbourne's universities.

The State Government's *'Victorian ICT Industry Survey Fact Sheet'* for 2010 shows revenue of the 'ICT Manufacturing' sector as A$1,360 million and employment as 7,830 (Victoria ICT, 2010). These data include all appropriate ANZSIC categories and are compatible with classifications used in the EIAA and other Australian and New Zealand data discussed above (Phillips, 2012). In the following year the *'Victorian ICT Industry Survey Fact Sheet'* for 2011 shows revenue from 'ICT Manufacturing' as A$900 million and employment as 6,118 (Victoria ICT, 2011).

These data show a disturbing fall of 34 per cent in revenue and 22 per cent in employment, or more than 1,700 positions in one year. Taken together with the data from Houghton (2004) the indication is that the HTEI in Melbourne has reduced its revenue and employment sharply since 2000 while the national revenue and employment in the HTEI remained almost unchanged between 1996 and 2006 (EIAA, 2003; AEEMA, 2007).

Employment in the HTEI in Melbourne appears to have declined by almost 50 per cent from its 2000 level of 11,681 (Houghton, 2004) to 6,118 (Victoria ICT, 2011), which assists the understanding of how the number of people and the proportion of HTEI employment in

Adelaide has continued to increase in the same period, while the national level of employment in the industry remained essentially unchanged. The loss of HTEI employment in Melbourne may have been approximately replaced by the increase in Adelaide.

The HTEI in Melbourne has an effective industry association, the Surface Mount and Circuit Board Association which provides certified training courses, technical publications and an annual conference all focussed on electronics manufacturing technology. Tangible networking benefits are achieved by its 170 members. No other Australian State has a comparable manufacturing process-based electronics association.

4.4.4.1 Survey of Melbourne HTEI

Interviews with 38 electronics firms and related organisations were conducted for this research in November 2010. The technology was the major start-up driver for 42 per cent of respondents in the Melbourne HTEI with self-employment at 40 per cent. Money motivated almost 24 per cent of firms, the highest response in all Australasian surveys. The home town was chosen by more than 98 per cent of start-ups and 87 per cent stated that they were more satisfied now with their location; both the highest responses in all Australasian surveys. The 'best' reasons for a Melbourne location were *'access to market'* and *'technology environment'*. The 'worst' features were *'staff availability'* and *'government assistance'*.

The value of universities was rated at 2.25 and value of TAFE colleges was rated at 2.18, both close to the mean for all six Australasian cities surveyed. The importance of creativity was 3.66, the highest rating recorded in surveys in all six cities from more than 240 respondents.

Success in attracting equity capital was rated at 1.69 on a Likert scale with 5 as maximum, the lowest rating in all Australian surveys, where the mean was 2.27. Success in attracting short-term, working capital was rated at 1.95, the second lowest Australian rating where the mean was 2.51.

VC was sought by 36 per cent of Melbourne respondents, the highest proportion of all Australasian cities, but obtained by only 14 per cent. The importance of retained earnings as a funding source was rated at 4.27, the highest in all six Australasian cities.

The level of global surveillance of opportunities and threats was rated at 2.66, the lowest in six Australasian cities. The importance of local and regional government as a customer was rated at 1.63 and the importance of the national government was rated at 1.39, both the lowest in Australia.

Current and past benefits of university or public research institution was rated at 2.46, the highest in all six surveyed Australasian cities and the estimated future benefits rated at 3.73, more than double the rating in Sydney at 1.87 and Adelaide at 1.84. The major barrier to growth was finance at 45 per cent, the highest in the six cities in this survey with its mean of 22 per cent. Firms rated networking at 3.34 and slightly above the national mean of 3.00.

The Melbourne HTEI has been impacted by the decline in the telecommunications and automotive electronics sectors. The HTEI survey responses in Melbourne reflect the concerns of many firms that their industry in 2010 was *'not thriving'* and with the subsequent large reduction in HTEI revenue and employment in Melbourne the industry has declined further.

4.4.5 Sydney

Sydney is the ninth '*most liveable'* global city (Economist, 2013) and capital of the State of New South Wales, the most populous State with 32 per cent of Australia's population. Sydney is the nation's largest and most international city with a population of 4.7 million or 21 per cent of the national total (ABS 3235.0, 2010).

The evolution of the electronics industry in Sydney is closely linked to one company. In 1909, the same year that the Federal Telegraph Company started in Palo Alto, Australian Wireless Ltd. was founded in Sydney and in 1913 was merged with Marconi's Wireless Telegraph Co Ltd. to form a new public company, Amalgamated Wireless (Australasia) Ltd. (AWA, hereafter). This company developed into the largest and most diversified electronics research, development, manufacturing and technical services company in Australia.

AWA played a major role in the development of the electronics industry in Australia, and particularly in Sydney. At its peak activities included design and manufacture of military and civil avionics equipment, broadcast and maritime communications equipment and electronic components including valves, transistors and integrated circuits, education, commercial radio and television broadcasting and manufacture of radio and television receivers for the consumer market. In 1984 AWA employed over 10,000 people in all Australian states and in several overseas locations, with the majority in Sydney (AWA, 2010). Ross Halgren, CEO of Haltec and a former senior engineer and manager at AWA provided background on the range of products and technologies and the range of the capability of AWA, developed over almost 80 years and through almost the total history of the electronics industry, until its unfortunate demise (Halgren, 2009).

In the 1950s AWA was one of few employers in Australia to provide relevant employment for trainees in telecommunications, radio and electronics while allowing part-time attendance at technical college, including this author. These AWA training programs were highly regarded by other employers and AWA alumni filled senior electronics engineering, technical and management roles in Australian electronics firms for decades. Similar, but smaller technical training schemes were operated in Melbourne by Telstra and in Adelaide by Philips and DSTO.

The CSIRO Radiophysics Laboratory in Sydney developed Distance Measuring Equipment (DME, hereafter) for civil aviation in 1945 as a progression of wartime systems and these were trialled in 1947 in Australian civil aircraft. AWA was contracted to build and install 95 ground stations across Australia to provide all-weather position information over a range of 300 miles. DME was a major milestone in air navigation and safety (Ross 1978:194).

CSIRO, Radiophysics Laboratory later developed a microwave approach and landing system, Interscan for aircraft operations in the 1970s. Interscan equipment is still built in Sydney and is in regular operation in many countries. In an interview Gary Doherty provided background of the long collaborative relationship of Radiophysics and AWA. For decades these two institutions provided Sydney with a powerful combination of research, development and production of advanced electronic systems (Doherty, 2009).

In 1987 AWA suffered large losses on foreign exchange dealings and over the next few years through the sale or closure of divisions it was reduced to a shadow of its former dominant position. The dismantling of the once iconic AWA deprived Sydney of a long-term relationship with the electronics industry that could have possibly been as beneficial to the HTEI in Sydney as DSTO has been to the HTEI in Adelaide.

4.4.5.1 Electronics Manufacturing in Sydney

Sydney has a long history of manufacturing of radio and electronic products and at the height of the radio boom of the pre-World War Two era and the television boom of the 1960s many locally owned firms competed in the consumer sector. The industry was impacted by the 1975 Federal Government decision to reduce all import tariffs by 25 per cent, which exposed local manufacturers of components and equipment to severe competition, particularly from Japanese manufacturers. Within a few years most component and equipment manufacturers has ceased manufacturing, some continued as importers.

Few of the electronics manufacturing firms made the transition from the consumer radio sector to the industrial, commercial, professional electronics sector and with the demise of AWA a very valuable training resource was lost to the industry.

Some firms adapted to the tariff reduction. John Dunn, Managing Director of Master Instruments, discussed the company transition away from the highly specialised manufacture of meters for the measurement of electrical parameters. With reduced import tariffs the meter market was being overtaken by imports. As part of their manufacturing the company required specialised batteries for some meters and these batteries were imported. The company is now almost exclusively engaged in importing and assembling batteries into packs for consumer and professional users (Dunn, 2009). Hugh Kelly, AEMS discussed the transition of the electronic assembly industry from a totally Australian operation to a blend of offshore and local assembly where cost, complexity and capacity are the decision factors (Kelly, 2009).

Regional specialisation in the Sydney HTEI includes communications and biomedical systems (Robinson, 2002). New and highly innovative firms have emerged. ResMed is a large Sydney-based manufacturer of sleep therapy systems and a major corporate success and exporter. In an interview Research Director Dr Bob Frater explained the origin of the product from the idea through to its commercial development and growth of the company to an annual turnover exceeding A$1.2 billion (Frater, 2009). Sydney was chosen for the company location as the largest city in the nation and as a base for operation into their largest market in USA. Dr Andrew Brawley, CEO of Sapphicon (now Silanna) explained the origin and development of the business from the foundation of semiconductor manufacture in 1965 by AWA in a joint venture with British Aerospace. Silanna is a specialist designer and producer of *Silicon-on-Sapphire* semiconductor devices. Discussion of the development of the company included the transition from custom chip maker to an engineering service to integrate the device into the customer product in niche markets (Brawley, 2009). Professor Rigby, Chairman of Coursemaster discussed the origin of the successful marine autopilot business from an idea by a yachting colleague (Rigby, 2009).

The New South Wales Government promotes its electronics industry within the ICT sector and states that it is a preferred location for *"46 per cent of all business in Australia that specialise in ICT"* (NSW, 2008:7). ICT specialist businesses including Hewlett Packard, IBM, Microsoft, Nokia, Oracle, Panasonic, and Sun Microsystems have chosen Sydney as the base for their Australian or regional distribution operations (Chapman, 2009).

Many of these foreign firms are located in the North Ryde Technology Park promoted by Ryde Council (Hirst, 1998). The NSW Government website shows that the State has *"half of Australia's electronic equipment manufacturing, including computers and business machines"* (NSW, 2009). In a discussion on the website statement and government programs for the development of the electronics industry, a senior NSW Department of State and Regional Development manager stated that the electronics industry was not a priority in Sydney and suggested that the website statement may have come from the *'NSW Competitiveness Report'* (Sonter, 2009).

In an interview with Steven Kerlander at the State and Regional Development Department it was explained that the website statement was based on a departmental estimate (Kerlander, 2009). No data on the revenue or the number of employees in the Sydney HTEI is available from the State Government.

Dr Neil Temperley, National ICT Australia Director described the role of this new organisation established to stimulate the ICT sector through the design and manufacture of electronic hardware, in part to address the imbalance of ICT imports and exports and to stabilise and grow the Australian electronics industry (Temperley, 2009).

4.4.5.2 AEEMA Cluster in Sydney

AEEMA facilitated the establishment of a Sydney-based electronics cluster now known as Embedded Systems Australia (Robinson, 2003), which is described as an industry cluster with a mission *"to facilitate the development of a sustainable Australian Embedded Systems industry"* (ESA, 2013). This cluster was created with government assistance and includes AEEMA members, associates, and other invited stakeholders who are committed to establishing sustainable networks in the electronics, ICT and electrical manufacturing industry sectors of NSW industry.

The group emerged as an outcome of the Electronics Industry Action Agenda (Killen and Hunt, 2004). This cluster which has strong links to the Australian Technology Park in Sydney *"is a horizontally aligned, project-based national industry cluster"* (ESA, 2013).

The development of this cluster was foreshadowed by Thorburn (2003). In 2013 the cluster continues to assist members with an online capability directory and joint projects including a heavy vehicle safety program.

4.4.5.3 Survey of Sydney HTEI

A total of 24 interviews conducted in Sydney in April 2009 found that the technology was the motivation for the start-up of 60 per cent of firms, the highest proportion in the six Australasian cities. The hometown location was chosen by 93 per cent of firms and 74 per cent were satisfied with the location decision. The best aspects of a Sydney base were *'workforce'* and '*customer-access'* and worst aspects were '*roads and traffic'*. The value to the firms of local universities was rated on a zero to 5 Likert scale at 2.2. Technology was developed in house by 93 per cent of firms and only 13 per cent purchased technology from 'non-associated' firms. Skill shortages were rated at 3.33. An open-ended comment on creativity [referring to Richard Florida's *'Creative Class'*] is informative: *"Creativity in Sydney and also Newcastle, possibly due to its isolation."* The identification of isolation is noted as a creativity factor in Newcastle, population 308,000, located 160 kilometres north of Sydney. In the Sydney HTEI 20 per cent of firms had applied for VC and 13 per cent had been successful. Most VC firms in Australia operate in Sydney so this low application rate is not caused by availability or access. A total of 87 per cent of Sydney HTEI firms export.

The value of networks and clusters was rated at 1.67 in Sydney, the lowest of all six Australasian cities, and less than half of the mean of 3.56. It is noted that the value of networks and clusters in all 6 Australasian cities is generally inversely proportional to their city population; with Canberra and Christchurch the smallest Australasian cities surveyed having highest ratings at 4.22 and 4.11 respectively. Size appears to matter, networks and clusters are significantly more highly valued in smaller cities, and the inference from these data is that clusters and networks work better in smaller cities where face-to-face interactions are known to be more frequent. The relationship of city size and the value to firms of networks and clusters is suggested as an area of further research. Non-financial government assistance was sought by 60 per cent and received by 40 per cent. Financial assistance was sought from government by 27 per cent and received by all applicants. Estimated future value of universities to the firm was rated at 1.87, well below the Australian mean of 2.71. The electronics industry in Sydney is well established and employs an estimated 8,500 staff, based on the ratios of employees shown in each Australian State in Table 4.4 and total national HTEI employment of 25,275 shown on Table 4.5.

Limited endogenous clustering is evident and the vast size of Sydney's metropolitan area, its traffic congestion caused by its topography is likely to inhibit the frequent face-to face contact that facilitates clustering in smaller and more easily navigated cities. As found in other Australian cities, State Government assistance is limited. No electronics industry association could be found in Sydney.

4.4.5.4 Summary: Second Case Study

This second case study shows that while these five regions have identifiable concentrations of HTEI firms and related organisations, the density of employment in the industry in each of these cities, as a proportion of the national total is lower than the five regions in the principal case study. The HTEI firms in many of these second case study regions are more widely spaced, so more loosely connected than the firms in the clusters in the smaller regions in the principal case study. However, more than density is required and it is possible that some of the HTEI firms in the regions in this second case study are not sufficiently connected to be classified as clusters. They may be classifiable as "*clump*" (Ffwocs-Williams, 2013). While these groups of HTEI firms are comprised of complementary and competitive firms, the level of inter-firm collaboration in these regions is limited.

As shown by Brown et al (2010) in their study of the Christchurch HTEI cluster that on the demand side passive externalities such as pools of skilled labour are available to all firms, but it is the active externalities, including collaboration through joint research, networking or co-marketing that create familiarity and trust and thus create and deepen clusters. Romanelli and Feldman (2006) note that many regions host firms but don't create clusters. In the large Australian cities Brisbane, Sydney and Melbourne HTEI firms encounter significant distance and topographical barriers to face-to-face meetings and with relatively lower densities and HTEI firms spread across large metropolitan areas, these loose aggregations have limited effectiveness.

Cluster density in Brisbane is higher than in Sydney and Melbourne, but with limited government assistance and no industry body to facilitate networking the links between HTEI firms are limited. Boston has had a traditionally strong HTEI cluster, but this has declined substantially in numbers and in its influence since the days of the *'Massachusetts Miracle'*.

MIT is very highly regarded for its research and for the education of engineers and scientists, but increasingly their graduates are employed in the firms located beyond Boston. The scattering of MIT alumni is demonstrated by the 1997 BankBoston Report and 2011 update. The HTEI in Canberra has many of the characteristics of the second tier cities in the principal case study and with shorter travel distances and a smaller city it is possible to maintain more regular contact with a higher proportion of cluster members, and in a small city it is possible for the industry to be noticed (Segal Quince, 1985).

Section 4.8 provides new insights on regional HTEI clusters derived from cross-case comparison of four cities in this case study and two cities from the principal case study.

4.5 The Third Case Study - *Ireland, Northern Ireland, Scotland and Singapore*

The discussion above on two case studies has focussed on the endogenous emergence process to address the first two research questions: *Why d*id HTEI firms cluster in the selected 'second tier' cities? *How* have HTEI clusters developed in the selected regions?

The third research question asks: '*What* variations exist between the HTEI clusters in the regions that emerged endogenously and those created or developed by government action? The focus now moves to HTEI clusters where government programs have been applied to the development of the HTEI to provide data and regional information on those variations. The cluster concept has been widely embraced and promoted by city, regional and national governments as an economic development policy. Inspired by the performance of endogenous clusters, particularly Silicon Valley, these national, regional and local administrations have developed and implemented plans that aim to replicate its performance.

4.5.1 The Created Cluster Process

Government assistance in the process of HTEI cluster development has been applied in many regions and the Republic of Ireland, Northern Ireland, Scotland and the Republic of Singapore have been selected for this research as representative of the process of 'assisted' or 'created' cluster development. These regions provide a range of opportunities to study the HTEI from its formative stages and the effects of the government policies and programs for the development of the industry. All of the countries studied in this section had some electronics industry before 1970, and in each region the existing industry has been affected by the actions of the respective governments. (Green, 2000; Gleeson et al, 2005).

4.5.2 Republic of Ireland

After the 1966 Anglo-Irish Free Trade Area Agreement Ireland's industrial policy pursued the generation of sustainable manufacturing jobs spread across all regions of the country (Gleeson et al, 2006) and most of the increase in manufacturing employment until 1980 occurred in newly established foreign firms (Kennedy et al, 1988). The economic success of Ireland in the late twentieth century can be traced to the coincidence of judicious industrial policy and global economic restructuring (Collins, 2007).

In the 1990s growth in employment and output in Ireland was the fastest of any OECD country with employment increasing by 42 per cent from 1990 to 1999 (Green, 2000). The process of the evolution of Ireland's ICT sector has been driven not only by market conditions but by the conscious design and delivery of public policy over a number of decades in the context of EU membership (Green, 2000, 2009) and, more recently, by social partnerships (Forfás, 2009). This has comprised measures to attract knowledge intensive FDI through the Irish Development Authority (IDA, hereafter), support for indigenous companies and networks through Enterprise Ireland, promotion of education and training at all levels and especially universities and technical colleges, development of a sophisticated telecommunications infrastructure, increased funding support for research in third level [university] institutions and strengthened linkages between companies and the education sector (Green, 2000, 2009).

The Industrial Policy Review Group of the Department of Enterprise, Trade & Employment (DETE, hereafter) recommended the promotion of industrial clusters '*focused on niches of national competitive advantage'* and a number of enterprise development and support programs were introduced to highlight the advantages of clusters as '*desirable or necessary to improve productivity.'* These cluster programs focussed on three sectors, ICT (including electronics hardware and software), bio-pharmaceuticals and internationally traded services. The existing electronics and ICT sectors in Galway, Shannon/Limerick, Cork and Dublin were promoted and MNC's established branch plants in targeted regions including Apple, 1980; Microsoft, 1985; Intel, 1989 and Dell, 1990 (DETE, 2008).

The generally homogenous distribution of manufacturing that was evident in 1979 had disappeared by 1993 as concentrations of MNC's were establishing in the high-technology computer, electronics, software and pharmaceutical sectors (O'Leary, 2002). These firms were moving into Dublin and also to the second tier cities of Cork, Galway and Limerick. Advantages promoted by IDA attracted USA firms, including the English language, low wages, EU membership, a low corporate tax rate and the Euro currency.

The advantages of the link into Europe through the Euro currency were quoted by Australian firm Tekelek, as the attraction for the location of their European operations in the Shannon/Limerick region (McCarthy, 2006). Dublin, the centre of the Irish software industry also has an important HTEI cluster and is the seat of the national government and the source of industry development programs and funding. Ireland's association with MNC's initially produced electronics hardware assembly jobs and these have been overtaken by more complex integrated manufacturing processes (Green, 2000). Galway has a long association with the electronics industry and has gained employment and population through the national economic turnaround; however, the development of the electronics industry in Galway predated the major government programs by more than two decades.

In 1971 DEC (Digital Equipment Corporation) the highly successful computer firm which began in Boston and discussed in 4.4.1.1 above, opened its first European electronic hardware assembly and distribution facility and software centre in Galway (IEI, 2000). Employee numbers at the DEC plant in Galway had reached 500 by 1973 and 1,100 in 1993 when the assembly plant was closed, but the software centre, now the Hewlett Packard European Software Centre continues. Following the closure of the hardware operation the Galway Task Force established the Galway Technology Centre in 1994 on the former site of the DEC plant. Many former DEC staff remained in Galway and started successful HTEI businesses at the Technology Centre.

During more than twenty years in Galway DEC employed many engineers and recruited significant numbers of secondary school level employees and provided them with comprehensive in-house training. This emphasis on training had a beneficial effect as former employees moved to other electronics or engineering based companies in Galway or to other cities in Ireland; a valuable benefit from the presence of DEC has been retained. Paradoxically, while the closure of the DEC plant caused immediate hardship, it also "*provided the catalyst for Galway's economic transformation*" (Green et al, 2001:2). Replacement employment for staff of departing electronics MNC's is also discussed later in this chapter in the HTEI in relation to the HTEI in Scotland.

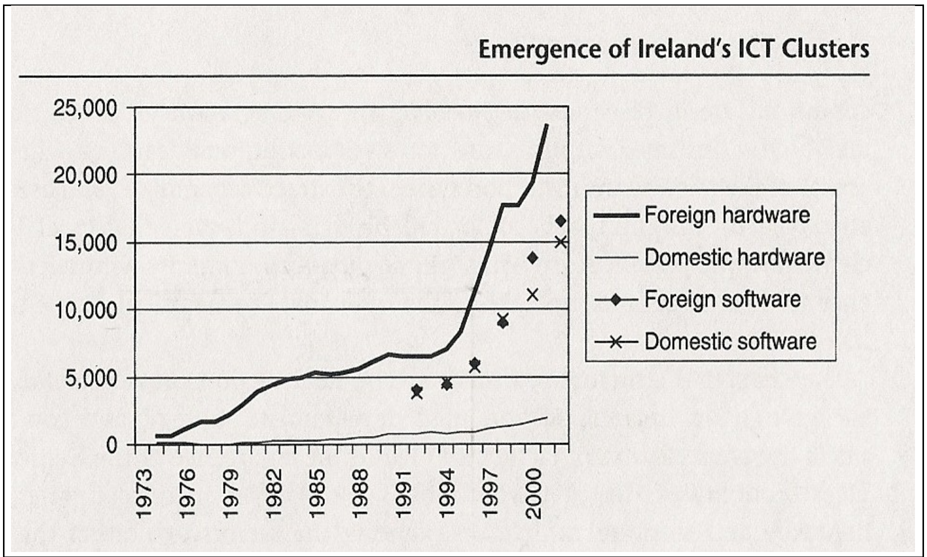
Ireland is the European Union's most FDI dependent economy, with about half of the manufacturing industry workforce employed by foreign-owned firms (Barry, 2006:148). *"Since 1980, 40 per cent of all new US investment in European electronics has come to Ireland*" (Cornell, 2001:44). Galway is a *"very desirable place"* for electronics development and manufacturing and with its significant number of HTEI firms it was stated in an interview that it was easier to recruit staff from other regions, particularly for medical electronics projects that have developed in Galway (Ferguson, 2006). In 2012 Ireland was the top high technology manufacturing provider as a percentage of gross domestic product in the developed world, at over 6 per cent compared with the USA, which has about half that level. This is partly due to Ireland's current focus on high-value manufacturing rather than volume (O'Brien, 2012). But not all government initiatives are successful; Webworks Galway an incubator was established in 2009 with government funding to provide office accommodation, but has never been fully occupied (Irish Examiner, 2011).

The HTEI in Ireland's second city Cork has 9,000 employees including 7,200, or 80 per cent engaged in foreign owned firms (McElroy, 2013), which contrasts with Adelaide where the locally owned proportion of the HTEI firms is about 80 per cent (TIA, 2012).

An interview with Professor Peter Kennedy, Vice President for Research at University College Cork identified a focus on research, IP creation and training in innovation and commercialisation for scientists and engineers, to provide high value-adding, high paid jobs to replace the diminishing low paid assembly work (Kennedy, 2006).

The high level of employment in the manufacture of *computer hardware* by foreign firms is illustrated in Figure 4.6. The extraordinary rate of growth of employment in the 'Foreign hardware' category shown below illustrates one of the major differences between endogenous clusters and assisted clusters: the ability of the Irish Government to attract MNC's using the power of financial incentives. However, this level has since been reduced as assembly process work moves to Eastern Europe and Asia.

Figure 4.6: Employment in Irish Foreign and Domestic HTEI Firms



Source: Barry (2006:149), Fig 8.1 in Cluster Genesis; Braunerhjelm and Feldman.).

Figure 4.6 shows approximately 2,000 employees in locally-owned 'computer hardware' manufacturing firms in 2002 and approximately 24,000 employed in foreign-owned firms. The foreign-owned firms increased their employment by 17,000 in the period from 1994 to 2002, while the locally-owned firms added approximately 1,000 employees. Therefore more than 90 per cent of the growth in employment in the manufacture of electronic hardware was in the foreign firms.

The Republic of Ireland Policy Advisory Board for Enterprise, Trade, Science, Technology and Innovation, (Forfás, hereafter) reported that in 2006 a total of 5,166 firms were engaged in '*Electrical and Electronic Equipment Manufacturing'*, of which only 244 [4.6 per cent] were locally owned (Forfás, 2009:22).

A total of 3,043 *'Medical Devices and Instruments'* manufacturers, included 142 locally owned firms, which represented 4.7 per cent of the total. In 'software development' the proportion of locally owned firms was 1,031 or 10.5 per cent of a total of 9,836 (Forfás, 2009:22). Figure 4.6 also shows that growth in employment in locally owned software firms is approximately equal to the growth in foreign firms.

The 'Electrical and Electronic' and the *'Medical Devices and Instruments'* categories are not further disaggregated to reveal the 'electronic' equipment proportion of the total, but it is expected that the 'electronics' proportion is greater than the 'electrical' proportion. The clear indication is that the vast majority of the firms in these two published categories are foreign owned. Across the wider Irish technology sector, over half of all employment and as much as 80 per cent of revenue are provided by foreign owned companies (IDA, 2009).

Enterprise Ireland is the Government agency that supports the development of manufacturing and traded services businesses. Programs discussed included 'High Potential Startup' and funding for SME's of 10 or more staff and large firms (Bolger, 2006). Export growth is a major aim of Enterprise Ireland in its assistance of the electronics industry (Madden, 2006). Tommy McCabe, Director Telecommunications Industries Federation outlined the support programs of their peak body the Irish Business and Employers Confederation (McCabe, 2006). Hannah Green, ICT Ireland described their programs for the development of smaller ICT firms that will be needed to provide replacement employment as the MNC's depart (Green, 2006).

Multinational companies locating in Ireland have been almost entirely responsible for developing this sector, supported by Ireland's industrial development policies which recognised in the 1970s that growing '*fragmentation*' within this sector could provide a role for indigenous firms, as sub-suppliers of assemblies and parts of the final or intermediate products (Ruane and Gorg, 1999).

In this context '*fragmentation*' refers to the breaking-up of vertically integrated production processes into various production activities allowing production to be placed with a number of smaller, contractors (Killeen, 1975; White, 1982).

The presence of creative activity can contribute to the competitiveness of urban economies (Florida, 2002; Gertler, 2004) and Ireland's economic transformation over the period known as the 'Celtic Tiger' era, 1993-2007 had been widely reported in one of Ireland's second-tier cities Galway which managed to reap the rewards of the national economic turnaround (Collins and Fahy, 2011).

An element in the growth of Galway was its cultural history as well as its technology training institutions and the operation of USA computer firm, DEC for more than 20 years with constant technological change and high value returns on innovation (Peck, 2005). The industry development authorities in Ireland now have a clear focus on the development of local HTEI and other knowledge-age enterprises that are needed to create employment for staff displaced by the inevitable closure of foreign owned businesses when an alternative and usually lower cost location is established. Some benefit of the MNC's is retained and this is often the tacit knowledge and an *internationalised* outlook absorbed by engineers and managers during their employment by foreign firms. The displacement of staff when the foreign firm moves on produces the '*push*' effect on some redundant staff to open their own business; an action not planned until forced. Many good businesses in Galway and other places have been started in these circumstances (Ferguson, 2006).

The Celtic Tiger boom which began in the early 1990s had its strongest annual GDP growth at 9.4 per cent from 1995 to 2000. House prices doubled between 2000 and 2006 and then in 2008 the economy went into recession, electronics manufacturing plants closed and unemployment reached 14 per cent; the boom had ended. A clear difference between the locally owned firms in endogenous HTEI clusters and the HTEI firms in assisted clusters is their commitment to *place*. Enterprise Ireland is promoting indigenous electronics firms to redress the previously heavy reliance on foreign firms. Government attempts to create clusters in the HTEI must contend with the still high levels of foreign ownership.

4.5.3 Northern Ireland

Recovering from the decline of its shipbuilding industry, which had built the Titanic in Belfast, with its Marconi wireless telegraph and the civil unrest of the 1970s to the 1990s; the government of Northern Ireland has targeted both MNC's and indigenous HTEI start-up businesses (Baoag, 2006). The small electronics industry in Belfast is well supported by angel investors, government seed capital or loans and equity funding for *early export* businesses. Keith Johnston of InvestNI described how they assist one hundred local client firms.

NITech a government VC fund is active and is managed externally by a funds management firm. Queens University has a successful incubator for new technology businesses and within the Belfast metropolitan area a total of ten incubators are operating, in this small city. Networking is encouraged by InvestNI and universities, but it is *"hard work"* (Johnston, 2006).

Northern Ireland Science Park has been established on the former Titanic shipyard site and houses 90 companies and organisations from micro start-up businesses to the £40 million Queen's University Institute for Electronics, Communications and Information Technologies. These facilities are extensive and comprehensive, particularly in a relatively small city with only 280,000 of the total Northern Ireland population of 1.8 million.

The Queen's University promotes a *'System on a Chip Cluster'* which comprises 11 businesses at various stages of development and provides access to the very expensive design tools required for product design and lists 27 patents filed by staff and research associates in the cluster (ECIT, 2013).

The Government in Northern Ireland competes with the governments of England, Scotland and Wales for British Government funding and for European Union funding for the ongoing development of their HTEI firms. Belfast must compete also with Dublin only 100 miles away in the Republic of Ireland with its lower tax rate. The focus on government as a source of funds and of leadership in the development of the industry may overshadow the development of the spirit of individual enterprise that, working together with other small firms is an essential for the development of a truly indigenous form of clustering.

4.5.4 Scotland

The role of Scotland is important in the evolution of electronics technology. Scotland performs exceptionally well academically. James Clerk Maxwell, born and educated in Edinburgh made a major contribution to science with his theories on electromagnetism which led to the discovery of radio waves. The country has the highest concentration of universities in Europe and a long history of groundbreaking academic research and Scotland produces thousands of graduates every year in electronics based subjects (SDI, 2013).

A small indigenous radio industry developed during the early twentieth century and the development of the industry was later assisted by branch plants. Ferranti established a plant in Edinburgh in 1943 (Education Scotland, 2013) and in the 1950s IBM and Hewlett Packard moved into Scotland. In 1960 Raytheon established a plant in Scotland's post-war 'new town', Glenrothes, north of Edinburgh and Beckman and Hughes followed later and the name of *'Silicon Glen'* was promoted. At its peak in the 1980s Silicon Glen produced about 30 per cent of Europe's personal computers, 80 per cent of its workstations and 65 per cent of its automated teller machines (Education Scotland, 2013).

Growth accelerated from the 1970s in Glasgow and Edinburgh and by 1996 the electronics industry employed 14 per cent of the country's manufacturing workforce. These firms produced 20 per cent of Scotland's manufacturing GDP and accounted for almost one third of all manufacturing investment (Botham, 1999). Products included defence electronics, computers, semiconductors and telecommunication systems. The industry was dominated by foreign companies, and growth was driven by FDI. Overseas companies accounted for over 85 per cent of investment and 77 per cent of the industry's output (Botham, 1999). Scotland obtained 26 per cent of all inbound foreign investment in electronics projects and 70 per cent of all electronics projects locating in the UK (Scottish Enterprise, 1998). These data show the effectiveness of the Scottish Government attraction programs and financial inducements. However, the low level of clustering of Scotland's FDI driven electronics industry is a noted characteristic (Molina and Kinder, 2001). Silicon Glen in Scotland is cited as an example of an industry cluster with mostly light manufacturing and sales operations*, "... and as a result does not have the 'deep roots' of an indigenous cluster"* (Birkinshaw, 2000:97). By the end of the 1990s foreign companies had begun to move out of the Scottish electronics industry showing the limited public policy hold on MMC's (Commendatore et al, 2007). Dr Kevin Cullen, Director of Research and Enterprise, University of Glasgow noted that one effect of the MNC withdrawals was a renewed focus on the growth of locally owned firms and the start-up of new firms, particularly through the commercialisation of technologies developed at local universities, with assistance including grant funding, IP management and professional development (Cullen, 2006).

The effect of the 1993 closure of the DEC plant in Galway had been noted by industry association Electronics Scotland which developed a proactive program to train and prepare senior employees [mostly engineers] of the HTEI MNC's in Scotland for the possible closure or employment reduction of these large firms (Aitken, 2003).

The objective was to overcome the "*upas tree"* effect (Checkland, 1976:48) noted years earlier with the collapse of the once dominant Glasgow shipbuilding industry. This policy and the training to encourage start-ups by retrenched staff was approved and assisted by the MNC's. Several successful firms were started by the former MNC staff, motivated by the *'push'* factor or their redundancy (Aitken, 2003).

Several large defence electronics firms including SELEX Galileo in Edinburgh and Thales Optronics, BAE Systems and Kelvinside Electronics in Glasgow have more recently established operations (Scottish Enterprise, 2013) showing that the Scottish government remains active in the attraction of firms.

Support programs for local industry are funded by Scottish Enterprise, British Government, Scottish Government, Scottish Executive and the European Union through an array of technology commercialisation and support services. Professor Ian Hunt, Napier University provided information on support programs and training of business skills for engineers and scientists (Hunt, 2006).

At the Scottish Microelectronics Centre, University of Edinburgh, CEO Dr Ian Hyslop, provides technology services and training in law, finance and business topics. Since the downturn in 2000 more clients have come from industry than from universities and the services of the Centre are aimed at reducing or removing the barriers to entry; high capital cost, high running cost and long lead-times (Hyslop, 2006). The University of Edinburgh, founded in the sixteenth century, and alma mater of James Clerk Maxwell, Charles Darwin and Alexander Graham Bell is a leader in the support and commercial development of technologies and includes Edinburgh Research and Innovation which provides consulting and services from the departments of the University of Edinburgh. Wolfson Microelectronics is a spin-out success from the University of Edinburgh.

Interface Edinburgh facilitates engagement between its partners which are all of the universities and higher education institutions across Scotland and with industry and community. Dr Siobhan Jordan, Director explained that Interface is funded by the Scottish Funding Council. Since August 2005 its clients have come approximately 50 per cent from the SME sector, 25 per cent from large companies in Scotland and 10 per cent from international companies and organisations. The remainder of clients have come from within their member universities and institutes in Scotland (Jordan, 2006). Interface in 2013 has a full-time staff of 17 people and this is an example of the increased level of government assistance now provided to Scottish firms which is a departure from the previously high concentration on attraction and assistance provided to foreign multinational businesses.

Scotland's 2013 population is approximately 5.3 million and 55,000 or approximately 1.04 per cent of its population are employed in its electronics industry (SDI, 2013). In 1996 the Scottish electronics industry employed 48,900 people in approximately 400 companies (Botham, 1999). After a fall at the end of the 1990s employment in the ICT and electronics industry has now recovered and in 2013 has 900 companies (SDI, 2013).

It is noted that while the increase in employment is small the number of businesses has more than doubled showing strong growth in the number of small businesses that include many indigenous start-ups by engineers displaced by the closure of foreign firms.

The wireless telecommunications sector is unique in that it has grown from literally nothing to £647 million in just 20 years (SDI, 2013). Scottish Development International, the investment and trade promotion agency of the Scottish Government website shows *"Recently, the [electronics] industry has reinvented itself as a successful producer of high-end electronic technologies"* (SDI, 2013).

The Scottish electronics industry is now listed as one of the nation's seven *'key industries'*, which also includes chemicals, energy, business and financial services, life sciences, textiles and creative industries, including film, fashion, music, games, architecture and arts (Scotland, 2013). The Scottish electronics industry that was overshadowed by foreign firms for decades is regaining control of its future. "*As other nations develop their manufacturing bases, Scottish companies have reinvented themselves as high-end electronics producers as opposed to high-volume manufacturers. This shift in focus appears to be where the future lies for Scotland's electronic industry"* (Scotland, 2013).

4.5.5 Singapore

In 1960 Singapore had limited raw materials and investment capital, a small, low value-adding textile and toy manufacturing industry and no electronics industry. In 1961 the government led by the Prime Minister Lee Kwan Yew established the Economic Development Board (Lee, 2000). When Singapore gained its independence from Malaysia in 1965 it also lost sources of raw materials and domestic markets for its goods on the Asian mainland. In 1965 the per capita GDP of Singapore was US$516 (Hsu, 2012).

The Singapore Economic Development Board attracted foreign export-oriented investors to establish assembly plants (Perry et al, 1997). Texas Instruments, the first electronics manufacturer to establish in 1968 (Lee, 2000) agreed to invest S$6 million in a plant to process and assemble semiconductors and integrated circuits. This investment marked the start of Singapore's electronics industry (EBD, 2013). European semiconductor firm SGS established a Singapore assembly plant in 1970 and later the nation's first wafer fabrication plant. Over the following 40 years hundreds of electronics firms have established increasingly complex facilities to produce sophisticated electronic components and equipment. By 1993 electronics provided 45 per cent of the national manufacturing revenue (Perry et al, 1997). Output of electronic components and equipment increased from S$25 billion in 1990 at a productivity rate of S$500,000 per employee to an output of S$65 billion in 1997 with productivity at S$1.3 million per employee, which was achieved with an increase of only 3 per cent in employee numbers (Mathews, 1999:61).

By 2010 the per capita GDP in Singapore had grown to US$43,867 from US$516 in 1965 (Hsu, 2012). In 2011 manufacturing produced 20.9 per cent of the national GDP of S$327 billion (EDB, 2012). The origin and early development of the electronics industry in Singapore can be directly attributed to the attraction by the Economic Development Board of foreign firms to establish electronics assembly facilities. Industry clusters "… *such as those seen in Singapore emerged in large part through foreign investment"* (Birkinshaw, 2000: 93).

4.5.5.1 Recent Trends in the Electronics industry in Singapore

Recessions in Singapore in 1985 and 2001 caused significant downsizing in the electronics and other industries and *"exposed the vulnerability of an economy over-dependent on foreign capital"* (Choo, 2005:365). The global financial crisis of 2007 caused further employment reductions.

Emerging characteristics in the Singapore electronics industry include technology transfer (Perry et al, 1997) and the changing ownership balance of electronics firms. Recently established plants are owned and managed by Singaporeans and some have significant government equity. Some of these new firms are spin-outs from the larger foreign firms and universities and research establishments. However, entrepreneurship is neither a strong characteristic in Singapore nor are successful entrepreneurs accorded high status (Choo, 2005). An interview with Professor Wong Poh Kam, Director of Technology Transfer at the National University of Singapore provided important background. Entrepreneurship is *"not a natural characteristic in Singapore"* and Singaporeans tend to be *"not the risk-taking type"* (Wong, 2006). The actions of the government to attract MNCs and the recent trend for various levels of government ownership of large electronics firms have tended to stifle local entrepreneurship (Choo, 2005; Choo and Wong, 2006). Therefore, the universities provide training for engineers and scientists in finance, marketing and entrepreneurship to prepare them to start-up and manage their own businesses (Wong, 2006).

While there is growth in Singapore in the number of electronics firms and in employment and industry revenue, a new threat to the electronics industry in Singapore is emerging. Small but growing numbers of established and primarily foreign-owned firms are moving out of Singapore to lower wage countries in Asia, typically to Malaysia, Indonesia, Vietnam and China. Computer hard disk manufacturer Seagate moved its manufacturing operations out of Singapore's Ang Mo Kio Industrial Area in 2011 and retrenched about 2,000 workers, but retained its disk research and development facilities (Reuters, 2013).

A related threat is that Singapore has an estimated one million foreign workers undertaking the low-wage jobs that Singaporeans will generally not perform. However, many of these migrant workers from nearby Asian countries are now returning to their home countries where cultural conditions are familiar and where new jobs have now been created typically in Malaysia, Indonesia, Vietnam and China. This leaves Singapore with a shortage of low-wage workers, so Singapore is losing competitiveness as wages and the cost of living rises.

4.5.5.2 Cluster Programs in the Singapore Electronics Industry

In Singapore the form of clustering that has emerged as a result of the high proportion of foreign firms attracted to the region by government action contrasts with the form of clustering known in the five regions discussed earlier in the principal case study. In these five regions clusters emerged endogenously from the spontaneous collaboration of typically small firms in these relatively small and isolated regions and their motivation to cluster with other small firms was an instinctive action of the firms and individuals without government assistance. The plants established in Singapore, particularly in the early years of the electronics industry by offshore owners and managers were structured to be relatively self-sufficient and independent of local support facilities that were limited at that time.

A government plan to *'develop'* clusters in Singapore was introduced in 1991 with a S$2 billion investment under the National Technology Plan, 1991- 1995. "*Mutually supporting industries were identified and developed to entrench entire clusters…"* (MTI, 2011). The three industries selected for this *cluster* program were electronics, petrochemicals and engineering. The rationale was that by competing on the basis of clusters, development plans could emphasise the core capabilities that were common to industries within the cluster. By the late 1990s firms involved in the electronics *cluster* accounted for over half of the manufacturing output of industry in Singapore (Mathews, 1999). The website of the Singapore Semiconductor Industry Association, established in 2009 lists more than 50 industry members, university and public bodies and provides networking and career promotion programs (SSIA, 2013). This type of industry led networking is still uncommon in Singapore.

The group of electronics firms in Singapore is not a cluster of the endogenous form that is observed in the five regions in the principal cluster discussed earlier.

Nor is it a cluster in the form described by Porter (2000a:16) which requires three essential and distinctive characteristics: (1) '*geographic proximity'*, (2) '*interconnected companies and institutions',* and (3) '*linked by commonalities and complementarities'.*

While the firms and organisations of the electronics industry in Singapore have '*geographic proximity',* there is limited *interconnection* between the companies, particularly since many of the large MNC's are strong competitors in their markets. Linkage of the firms by *commonalities and complementarities* is also limited. Mathews posits that Singapore is becoming an industrial cluster *"through deliberate public policy"* (1999: 71).

An understanding of the electronics industry in Singapore assists with the resolution of the third research question*: "What variations exist between the HTEI clusters in the regions that emerged endogenously and those created by government action?"* The variations are significant. The endogenous clusters in the principal cases study emerged without government policy, assistance or cost to the community and indeed generally without the understanding or recognition by government or community. In contrast the electronics industry in Singapore came into existence through an attraction policy of the Lee government and with considerable promotional effort and cost and more recently with a significant level of capital investment by the Singapore Government as an investor in electronics manufacturing facilities.

4.6 Characteristics of Created or Facilitated Clusters

An indigenous electronics industry in Scotland developed on the foundation of the education, research and innovation that has been a salient characteristic of Scotland for centuries, but the major growth in employment in the late twentieth century was through FDI and government funded industry attraction policies. The Scottish electronics industry was dominated by foreign firms during the high volume computer manufacturing era of the 1990s and now the innovative design capability that is inherent in the Scots has resurged and growth of indigenous firm numbers and employment is reported.

As local living standards and wages increased lower-paid workers were attracted to Scotland and Ireland from Eastern Europe which suggests a future problem with some of the characteristics of the industry in Singapore; where foreign workers were attracted to low wage jobs which have not been sustained. Both Ireland and Scotland are now rebuilding their indigenous electronics industries and both governments and universities are actively encouraging and supporting this process, while governments continue to encourage foreign direct investment in technology-based industry.

Northern Ireland is pursuing similar policies and drawing funds from its local administration, from the UK and EU. The competition is intense between Northern Ireland, Scotland, England and Wales for industry development funding from UK and EU while the Republic of Ireland competes with the British for EU funding for the development of their indigenous electronics firms and for the attraction of foreign electronics firms.

The Government of Singapore began its involvement with the electronics industry in the 1960s by the attraction of foreign companies that established assembly facilities to take advantage of its low labour costs. Limited development of new products was originally undertaken locally and the education system has now produced engineering and science graduates who now undertake an increasing proportion of design and product development. Foreign workers from less developed neighbouring countries were attracted to perform the assembly work and now that the MNC's are moving assembly work to less developed countries, foreign workers are moving back to their homelands to find work. The Singapore Government is now investing as an equity partner with Singaporean entrepreneurs to manage the development of the industry, not at the assembly stage, but at the design, development and advanced manufacturing stage.

It is noted that each of these reactive policies in Ireland, Northern Ireland, Scotland and Singapore has been taken to correct a problem that has arisen from a previous phase of government action. The action of the Singapore Government to take equity in their electronics industry is a policy that may have the long-term effect of retaking control of the future of their knowledge-age industry; however, a policy of state ownership of knowledge-age industry is not evident in either Ireland or Scotland and while politically practicable in Singapore may not be readily acceptable to communities in Ireland or Scotland.

4.7 Variations in the Selected Endogenous and Created Clusters

The third research question seeks an understanding of variations between the two divergent processes in the formation of clusters of HTEI firms. The first, the endogenous process has produced dense, self-organised and resilient clusters over many decades in the five regions in the principal case study. Also over many decades the same endogenous process produced more loosely interconnected and less successful examples in the larger cities in the second case study.

The third case study examined the late twentieth century development of groups of electronics firms in Ireland, Northern Ireland, Scotland and Singapore where government policies and programs attracted MNC's with subsidies and tax advantages to locate manufacturing facilities typically to assemble high volumes of electronic products, employing local workers on relatively low wages in 'created' clusters.

Table 4.9 below summarises the characteristics of endogenous HTEI clusters and 'created' HTEI clusters in the regions included in the three case studies.

Table 4.9: Characteristics HTEI Endogenous and Created Clusters in Selected Regions

Endogenous Clusters	Created Clusters
• Unplanned and unaided cluster emergence	• Planned and assisted cluster creation
• Unrecognised by community, government	• Large firms attracted by governments
• Often located in second tier cities or regions	• Small number of large firms dominate
• Small and locally owned and managed firms	• Many branch plants remotely owned
• Investment decisions made locally	• Investment decisions made remotely
• Firms committed to the city or region	• Low level of commitment to place
• Interaction and collaboration between firms	• Low level of collaboration with local firms
• High trust between collaborators	• Low level contracting with local firms
• Higher levels of local innovation and design	• Vertical integration of manufacturing
• Majority of high skill/high wage employees	• Higher proportion of assembly workers
• Flexible local labour market	• Internal labour market and less flexibility
• Long-term local contracts with cluster firms	• Local and regional government policies
• Patient capital available locally	• High reliance on public infrastructure
• Networking that is supportive of local firms	• Collaboration with firms external to region
• High levels of intra-district and cluster trade	• Dependent on other large foreign firm
• Independent of large foreign firms	• Vulnerable to remote firm closure decision
• Customisation and low volume production	• High volume and scale economies
• Evolution of local culture and identity	• Sustainability requires government funds
• Trade associations promote cohesion/liaison	• Trade associations benefit foreign firms
• Self-sustaining in all five case study regions	• Dependent on remote owners for survival

Three highly relevant characteristics found in the endogenous clusters discussed above are critically important to their development and sustainability and it is noted that these three characteristics are not evident in 'created' clusters and cannot be legislated or procured:

1. A commitment of the cluster firms to the region
2. High trust between cluster collaborators
3. Self-organised and self-sustaining structure

A major differentiator of the two types is that government actions to 'create' clusters have not produced the steady and sustained employment growth that is observed in the endogenous HTEI clusters in the five cities in the principal case study.

It is noted that the fourfold employment growth in the computer hardware sector in Ireland from 1994 to 2000, [Figure 4.6] was not sustained and, and as wages rose in Ireland many labour intensive operations moved to lower wage countries. The policy of the establishment of electronic assembly factories in Singapore started earlier and lasted longer but as wages rise these facilities are moving to other Asian countries with lower wages.

A major variation in the two types of aggregations, therefore, is the lower level of sustainability of 'created' HTEI clusters. Four phases of created clusters are observed:

1. Government attraction of foreign firms to employ local workers on low wages
2. Wages for local workers rise and low-wage workers are recruited from other countries
3. Wages for the foreign workers rise, reducing profitability of the foreign plants
4. Foreign firms move the plants to lower-wage countries and low-wage workers follow

After the exit of the MNC's a regrowth of locally owned HTEI industry is observed. The emergence and growth of small indigenous HTEI firms in Galway after the closure of the DEC plant in 1993 was noted (Green, 2000; Collins and Fahy, 2011) and this model was adapted in Scotland (Aitken, 2003) and SME growth in the HTEI is reported (Cullen, 2006).

The emergence of HTEI firms and their endogenous coalescence into successful clusters is reported in a small number of regions in developed nations and arguably the most successful clusters are found in second tier cities that are removed both physically and economically from major national populations. This phenomenon has occurred in only a limited number of second tier cities, but, importantly it has not occurred in most second tier cities. The firms that collaborate within these clusters are typically SME's and their high technology, IP-based, high value-added, and typically customised, niche products are examples of *"flexible specialisation"* (Piore and Sabel, 1984) by locally owned firms often in low volumes by well-trained and well-paid staff, including high proportions of scientists and engineers.

The five endogenous HTEI clusters discussed above in the principal case study have been found to be resilient and sustainable. Silicon Valley has undergone four distinct phases of development between 1950 and 2000 (Henton et al, 1997) [Figure 4.3] and while total employment in the HTEI in USA has declined by 37 per cent in the ten years to 2011, the Silicon Valley share of national HTEI employment has increased by 17 per cent.

Employment in the Australian HTEI declined by 23 per cent in the ten years to 2011 while employment in the Adelaide HTEI, based on TIA (2012) survey has increased and Adelaide's share of the national total has doubled to 46 per cent in the 10 years 2012.

A major difference between the HTEI in the small regions of the principal case study and the larger cities in the second case study is the strong, endogenous growth of HTEI clusters in the small cities while the industry in larger cities is less dense, their firms are less effectively clustered and provide reducing employment.

In Ireland between 2001 and 2007 ‘value added’ in 244 Irish owned ‘Electrical & Electronic Equipment’ manufacturing firms fell by 15.9 per cent (Forfás, 2009). While the time periods and the industry categories are not identical and the Silicon Valley and Adelaide examples use employment and the Irish example uses value added, the level of overlap is sufficient to indicate a fall in output in the Irish HTEI during the period when employment grew in Silicon Valley and Adelaide. These data illustrate major variations in the performance of the two cluster types in these regions.

The endogenous clusters in the principal case study are resilient, have grown their revenue and employment over a period of decades while the performance of the created clusters has been varied. Many of the foreign firms have moved out of Ireland, Scotland and Singapore to improve their competitive position by reducing their labour costs. On the positive side, the foreign firms have contributed to rising standards of living and have left a well-trained, internationalised workforce and with industry experience and ‘reusable’ tacit knowledge.

4.8 Cross Case Comparison: Five Australian Cities and Christchurch

Following is a discussion of the results of structured interviews with 241 representatives, mostly HTEI manufacturers and small numbers of research, government and industry organisations in six regions: Adelaide, Brisbane, Canberra, Christchurch, Melbourne and Sydney. The discussion topics are listed in Appendix 2, 3 and 4 and the raw data from these interviews are shown in Appendix 5 to 13 inclusive.

The results show that 43 per cent of firms were established with a focus on technology and 39 per cent were established to provide employment to the business owner while 15 per cent of start-ups were for financial reasons and for social or community benefit. In earlier chapters the desire to see the technology developed and used was reported and a major motivator in the regions studied, including Robert Noyce and Intel in Silicon Valley (Berlin, 2005) and ‘personal independence’, ‘self-employment’ and the desire to ‘put theory into practice’ were also found to be a strong motivator in Austin (Smilor et al, 1990). Money was the motivator in 15 per cent of start-ups in the six regions surveyed, whereas wealth is a stronger motivator in USA, as seen in the case of Xicor discussed in Section 4.3.2.12.

All surveyed firms employed a new technology including 67 per cent of Sydney firms, 48 per cent in Brisbane, 42 per cent in Adelaide, 39 per cent in Melbourne and a low of 28 per cent in Christchurch. Existing but unsatisfied markets were addressed by 80 per cent in Adelaide, 65 per cent in Brisbane, 53 per cent in Sydney and 42 per cent in Melbourne and the mean was 59 per cent.

A latent market where their product created a new category was the target for 53 percent of Sydney firms, 50 per cent in Sydney, 42 per cent in Christchurch and 35 per cent of Brisbane firms. The mean for this group was 39 per cent and the low of 19 per cent in Adelaide may suggest that the HTEI in Adelaide is less entrepreneurial than the other five regions surveyed or may show that Adelaide HTEI firms address different markets.

The hometown of the entrepreneur was the location choice of 72 per cent of Christchurch firms and 74 per cent in Adelaide, but significantly lower than the 93 per cent who chose their home town of Sydney and 98 per cent who chose their home town of Melbourne. Location in Christchurch was now 'more relevant' to 44 per cent of firms than at the time of their start-up and unchanged over time for 33 per cent of respondents while location for 22 per cent of Adelaide HTEI firms was more relevant now and the same for 71 per cent. The present location for 87 per cent of Melbourne firms was 'more relevant' now than at start-up, but in Sydney only 13 per cent of firms reported their location now as 'more relevant' while 80 per cent found the relevance of their location to be the same.

The highest response at 22 per cent to their location being 'less relevant' was in Canberra and the lowest was 4 per cent in Adelaide. In Sydney 47 per cent of firms would seriously consider moving to another city compared with 25 per cent in Christchurch, 24 per cent of Adelaide firms with 14 per cent in Melbourne and only 9 per cent in both Brisbane and Canberra would consider moving.

The choice of a location to be near a particular equipment, such as research or test facility was rated on a zero to 5 (most important) Likert scale with a mean of 1.20 across the six regions; a high of 1.64 in Adelaide and a low of 0.5 in Canberra with the other regions grouped from 0.82 to 0.96. Importance of location near a 'major institution' (i.e. university or research organisation) rated from a low of 1.64 in Adelaide to a high of 2.20 in Sydney and all other regions at 1.85 to 2.17 and a mean rating across the six regions of 1.89.

The source of the technologies in their products was 'in-house' from a high of 100 per cent of Christchurch firms, 94 per cent in Canberra, 93 per cent in Sydney to a low of 87 per cent of firms in Adelaide, with a mean of 91 percent. Technologies were sourced from financially 'associated' firms from a high of 39 per cent in Brisbane, 32 per cent in Adelaide and 28 per cent in Canberra to a low of 3.6 per cent in Melbourne with a six region mean of 27 per cent.

Technologies were obtained from financially 'non-associated' firms i.e. in 'arms-length' transactions by a high of 43 per cent of Adelaide firms and a low of 13 per cent in Sydney with a cross regional mean of 29 per cent. The large difference in the level of these purchases between Adelaide and Sydney suggests that the process of sub-contracting such an important input requiring a high level of reliance on local cluster firms could be related to the smaller size, lower traffic density and shorter commute times in Adelaide. These may facilitate more frequent face-to-face meetings leading to a higher level of trust and collaboration than is possible in Sydney with almost five times the population. This could be seen as a proxy measure for 'clustering' activity. Further research on these cluster factors is discussed in Section 5.5.

University developed technologies were employed by 28 per cent of firms in Adelaide and 27 per cent in Sydney with a mean of 19 per cent and a low of 5.6 per cent in Canberra. The low level by Canberra firms is offset by their high of 94 percent of 'in-house' technology development.

Technologies were obtained from government institutions by 26 per cent of Brisbane firms, 20 per cent in Sydney and 17 per cent in Adelaide with a cross regional mean of 18 per cent and a low of 5.6 per cent in Canberra. In Canberra 5.6 per cent of firms use university technologies and 5.6 per cent use government technologies which is offset by 93 per cent of 'in-house' technology development.

The value to the firm of local universities was rated at a high of 2.72 in Canberra, 2.69 in Christchurch, 2.33 in Brisbane and Sydney with a cross-regional mean of 2.43. The lowest rating at 1.2 in Adelaide was less than half the mean. The value to the firm of TAFE colleges (Polytech in Christchurch) rated from a high of 2.33 in Sydney with a mean of 2.14 and a low in Adelaide of 0.55. The low level of the value of these institutions to Adelaide HTEI needs understanding and may suggest an opportunity for the development of research and industry collaboration in Adelaide, which is discussed in Section 5.4.

The problem with staff shortage - both quantitative and qualitative - was rated at a high of 3.33 in Sydney, 2.82 in Melbourne, 2.57 in Brisbane, with Adelaide at 1.81 the least affected of these four State capital cities. The data suggest an association between staff shortage and city population. A possible explanation is the additional travel time and cost in the larger cities may reduce the availability of staff in some areas. However, with the low value placed on the training institutions in Adelaide, further investigation is indicated.

The importance of innovation was rated at a high of 4.65 in Brisbane and 4.36 in Adelaide to a low of 4.25 in Canberra with a mean of 4.44. The importance of entrepreneurship was rated from a high of 4.28 in Brisbane with a mean of 4.09 and a low of 3.46 in Adelaide. Since Adelaide was the first of these cities and for some years the only city to offer postgraduate entrepreneurship courses a higher level of importance could have been expected.

The presence of creativity and the perception of a 'Creative Class' (Florida, 2002) rated from 3.66 in Melbourne, 2.72 in Adelaide to a low of 2.47 in Sydney with a mean of 3.22. Success in attracting long-term capital rated at a high of 3.33 and short-term capital access rated at 3.58 in Adelaide. Low ratings of 1.68 for long-term and 1.95 for short-term capital were recorded in Melbourne with six city means of 2.27 and 2.51 respectively. Success in attracting VC shows a wide range of variation. In Melbourne 36 per cent of firms applied and 14 per cent succeeded, in Canberra 28 per cent applied and 17 per cent succeeded. In these cities more than half of all applicants succeeded. In Adelaide 17 per cent of firms applied and 4.4 per cent or one quarter of applicants succeeded. However, across the six regions 85 per cent of firms did not seek VC. The pattern of VC uptake is clearer when read in conjunction with the response to the question on the importance of retained earnings to the firm. The highest rating was 4.27 in Melbourne, Canberra rated at 4.14, Sydney at 4.07 and Adelaide at 3.25 was slightly lower than the mean of 3.66. Taken together these data show relatively conservative financial management strategies across the industry with a low level of expansion through external funding and significantly lower than reported in Silicon Valley (Florida and Kenny, 1988) and Austin (Smilor et al, 1990).

Niche markets were targeted by 100 per cent of Canberra firms, 92 per cent in Melbourne, 91 per cent in Brisbane and 89 per cent in Adelaide and Christchurch, with a mean of 92 per cent. Across the six regions 75 per cent of firms export, with a high of 87 per cent in Sydney and a low of 56 per cent in Canberra, possibly explained by their focus on the Australian Government and its defence requirements. The firms surveyed have a mean age of 17 years, with a range of 11 to 22 years and 75 per cent of all firms surveyed are exporters. This finding confirms the need to overcome the relatively small home market by exports discussed in Section 2.5.2 (Yetton et al, 1992; Gibson and Gurr, 2001). These firms have been exporting for a mean of 70 percent of their operating life with a range of 37 per cent to 86 per cent. A near balance of 'market-pull' and 'technology-push' was reported across almost all of the six regions except in Sydney where 'technology-push' was twice the level of 'market- pull' revealing a more proactive marketing strategy than the other five regions.

The importance of State and local government as customers was rated from a low of 1.42 in Adelaide to a high of 2.13 in Brisbane with a mean of 1.63. The importance of the national government as a customer was rated from a low of 1.25 in Christchurch with a mean 1.63 to a high of 3.28 in Canberra which reflects the dependence of the Canberra HTEI on defence and other national government requirements.

Given four options to describe their market 'stance', 39 per cent of Canberra firms selected 'low cost' which reflects their tender based government sales environment. 'Market leader' was the stance of 60 per cent of Sydney firms, 41 per cent in Adelaide and 40 percent of Melbourne firms, again suggesting a proactive strategy in Sydney. The level of product differentiation was rated at a high of 4.00 in Sydney, a mean of 3.44 and a low of 2.92 in Adelaide. The performance of the firm in risk management was self-rated from a low of 3.04 in Adelaide to a high of 3.90 in Sydney with a mean of 3.48. Intellectual property management performance was self-rated from a low of 2.74 in Adelaide with a mean of 3.46 and a high of 3.61 in Melbourne and Canberra.

The value to the firm of networks and clusters rated at 4.22 in Canberra, 4.11 in Christchurch and 3.21 in Adelaide with a mean of 3.56 and with rating in Sydney at 1.67. This large discrepancy is discussed above in 4.4.5.3 where an inverse relationship with city size was proposed and further research on this relationship is suggested.

Markets were found to be a 'barrier to growth' by 57 per cent of Brisbane firms, 47 per cent in Christchurch and 46 per cent in Adelaide with a mean of 45 per cent. Technology was a barrier to 2.2 per cent of Brisbane firms and to 1.6 per cent of Adelaide firms and zero to firms in Canberra, Christchurch, Melbourne and Sydney. Finance was a barrier to growth in 45 per cent of firms in Melbourne, 43 per cent in Adelaide, 30 per cent in Brisbane and 11 per cent in Christchurch. Human resources were a barrier for 16 per cent in Canberra, 14 per cent in Adelaide and 13 per cent in Melbourne.

Non-financial government assistance was sought by 66 per cent of all firms surveyed with the highest recorded at 74 per cent in Brisbane, 68 per cent in Melbourne and 67 per cent in Christchurch, 60 per cent in Sydney and 59 per cent in Adelaide. All applicants received this form of assistance in Brisbane and in Christchurch while 56 per cent received assistance in Canberra, 54 per cent in Melbourne, 46 per cent in Adelaide and 40 per cent in Sydney. Financial assistance through grants for commercialisation and export development were sought by 46 per cent of firms and received by 45 per cent of firms evenly spread across Australia, however, 33 per cent of all firms did not seek these financial assistance.

Local Government assistance is required by few of the firms surveyed with a mean of 12 per cent; State or Regional Government assistance is required by 47 per cent of Sydney firms, and only 22 per cent of Brisbane firms with a mean of 28 per cent. Additional national government assistance is wanted by 17 per cent of Brisbane firms, and 42 per cent of Melbourne firms, with a mean of 29 per cent. The cost to the firm and delay by government regulation was rated from 1.67 in Adelaide, 2.00 in Sydney and 2.50 in Melbourne with a mean of 2.02.

The current and past benefits from a major local institution (including university, firm or research institution) was rated from a low 1.52 in Brisbane, 1.73 in Adelaide, 2.33 in Sydney, 2.39 in Canberra, 2.46 in Melbourne to a high of 2.61 in Christchurch. The reason for the low rating in Brisbane is not revealed by the data, however, the relatively low rating in Adelaide suggests that the influence of DSTO on the origin and earlier development of the Adelaide HTEI cluster does not impact the majority of firms that are not engaged in defence related activities. The higher rating in Christchurch is supported by the literature on the region's largest firm, Tait Electronics. Tantrum (2003:2) quotes Peter Maire, founder of Navman; *"It's thanks to Sir Angus Tait that we have an electronics industry."*

Disadvantages from the location of the major institution in the region (as a competitor for staff or other resources) rated from a low 0.96 in Melbourne, 1.09 in Brisbane, 1.28 in Christchurch and 1.33 in Adelaide to a high of 2.66 in Sydney and a mean of 1.43. The future estimated benefits from the local institution were rated from a high of 3.73 in Melbourne, 3.38 in Christchurch, 3.14 in Canberra, 2.98 in Brisbane and a low of 1.84 in Adelaide. The low rating in Adelaide suggests that further research is needed to understand the value of its institutions to the HTEI firms of Adelaide. It is noted in all cities that the estimated future benefits exceed the current and past benefits.

Important findings across the surveyed regional HTEI clusters are that the hometown of the entrepreneur was the chosen location in a large majority of cases, which is consistent with the literature on USA and UK second tier regional HTEI clusters. Their location was 'more relevant' or 'as relevant' for a large majority of firms and only a small number would move to another city. Most firms in this survey were started with a focus on the technology, the next rated motivator was self-employment and this finding deviates from the typical USA start-up with its higher proportion of financial motivation. Technologies were developed 'in-house' by a majority of firms in all survey regions, but in Adelaide a high proportion of firms also purchased technologies from unrelated firms while only a small number of Sydney firms did so and this significant difference is discussed above.

A large difference was found in the value to the firm of local universities. Brisbane, Canberra, Christchurch, Melbourne and Sydney all rated consistently close to the mean, however, Adelaide rated at less than half of the mean and further research on this difference is suggested together with actions to encourage greater collaboration. Adelaide firms were more successful at attracting capital from traditional sources and less successful and less active and less successful in attracting VC, which may be related to the small number of VC firms in Adelaide and the larger number in the east coast cities. Further research on the inverse relationship of the value of clusters and networks with city size is suggested above and the understanding of these relationships may be important in the ongoing success of the HTEI in the smaller cities of Adelaide, Canberra and Christchurch. Government assistance is not uniform across the cities surveyed and each has separate regional governments. Brisbane and Melbourne firms received higher levels of assistance with no positive effect noted in Melbourne where the fall in HTEI revenue and employment is discussed in Section 4.4.4.

The data discussed above is derived from a sample of 214 HTEI firms in six Australasian regions comprising firms of a representative range of ages and sizes from relatively new and mostly small to medium and larger firms established for decades. The HTEI firms in these six antipodean regions show that their industry is firmly established and tightly held by typically local owners who manage their enterprises within their technology and business management capability for long-term sustainability rather than accelerated growth.

4.9 Chapter Summary

The existence of endogenously formed clusters, including HTEI clusters is widely reported in the literature; however there is no universal endogenous cluster origin theory. The HTEI clusters discussed in the principal case study have many similarities; including their endogenous origin and the existence of an action or event that was a trigger or catalyst for the coalescence of these firms and institutions into localised clusters.

In Cambridge and Austin the spin-out of scientific instrument firms, one from each of their local universities is identified as the foundation event. In Silicon Valley, university faculty and technologies coalesced in the founding of pioneering a radio communications firm and several years later an instrumentation firm, while the cluster in Christchurch grew from a privately owned radio two-way manufacturing firm and its spin-outs.

In each of these four clusters, identified individuals were directly involved in the actions that led to the emergence of the cluster. In Adelaide the HTEI cluster origin was not a single firm or person and while two pioneering electronics firms emerged over 80 years ago, it was the government defence research centre established in 1947 that was the catalyst in the development of the cluster.

The origin of each of the clusters in the second case study was also endogenous, however, each of these five regions have developed concentrations of HTEI firms that have not reached the density or to the extent of interconnectedness found in the principal case study.

Small numbers of locally owned HTEI firms in the third case study were known to operate in Ireland and Scotland when the respective governments launched their various programs to attract foreign firms and foreign companies accounted for the majority of HTEI investment and output over recent decades. No electronics design and manufacturing industry existed in Singapore in 1968 when the first foreign electronics firm agreed to establish a branch plant. Ireland, Northern Ireland, Scotland and Singapore all have government networking and clustering programs and local HTEI start-ups, but participation rates are low.

It is also noted that each of the electronics industry clusters in the principal case study formed in regions geographically widely separated from each other with limited communication between the nascent clusters and little opportunity or apparent action to conform to a predetermined pattern of 'cluster' behaviour. While these clusters have developed independently, they each have characteristics which are unique and they share two characteristics that are found only in this group of regions. First, they have formed in second tier cities - places with relatively small populations - and second in places that are relatively isolated from major national populations. Each of the clusters selected in the principal case study group has a unique origin, a causal action or event. Each of their origin events is different and each is essentially non-reproducible elsewhere. Since the literature search began in 2003 a number of highly relevant articles and books have been published including Parker and Tamaschke (2005); Parker (2006, 2008); Braunerhjelm and Feldman (2006); Fornahl et al (2010) and Mayer (2007, 2009, 2011). These recent publications focus on the endogenous emergence and self-organised development of technology-based clusters in second tier cities. The contribution of this work, its policy and practical implications and indications of future research are discussed in the following chapter.

Chapter 5: Conclusions and Future Research

5.1 Introduction

Over more than a century the scientific instrument industry, the radio communications industry and the electronics industry evolved into the HTEI of today that designs and builds increasingly complex technology-based products for diverse global markets. In the twenty-first century dense clusters of primarily small HTEI businesses that emerged endogenously and developed unaided over a minimum of many decades are firmly established in relatively few of the many second tier cities in developed economies. Firms in these clusters produce small volumes of high technology, customised and IP-based electronic products for industrial, commercial and government users in non-consumer markets.

The first of three research questions seeks to understand the origin of the HTEI firms and clusters that have emerged in selected 'second tier' cities. The second research question examines the development of these clusters.

Following the success of naturally created clusters, governments in a number of developed and developing countries have implemented programs to *create* clusters in selected regions, typically by the attraction of MNC's to establish manufacturing operations requiring large numbers of local employees. The third research question explores the variations in endogenous and created clusters in selected global regions.

To address these research questions, three case studies were undertaken. The principal case study examined the origin and development of highly successful, endogenous HTEI clusters in five second tier regions. The second case study examined less successful endogenous HTEI clusters in five cities with a wide range of population. The third case study examined the HTEI in eight cities in four countries where government programs have been implemented to create and develop clusters. The three case studies were informed by the literature, by government and industry data and by surveys and structured personal interviews with knowledgeable industry, research and government representatives. In regions where limited data were available from the literature, industry and government sources, larger numbers of interviews were conducted to augment the available data.

While the extant literature provides a detailed understanding of the *development* of clusters - that is the stage after their *emergence* - knowledge of the *origin* of clusters is incomplete. Recent scholarly contributions acknowledge that *"cluster evolution is an understudied area"* (Mayer, 2011:26), and Braunerhjelm and Feldman (2006) state that there is little understanding of the origin of successful clusters.

Michael Porter, who revived interest in clusters, stated: "*Clusters often emerge and begin to grow naturally"* (1990b:655), highlighting their endogenous origin and self-organising characteristics. While a universal theory of cluster *origin* is elusive, common characteristics have been identified in the origin of the clusters studied in the five endogenous regions in the principal case study. Visits to these five regions and surveys and interviews provided data and contextual background on the origin and development of firms and organisations that are representative of the cluster populations.

The literature provides a temporal dimension in that firms must exhibit growth rates above average for at least a certain time to contribute to the formation of a cluster (Jacobs, 1969), and the evolution of firms and institutions is required until their number reaches a critical mass (Menzel et al, 2010). Beyond a certain threshold agglomeration economies, regional labour market pooling, specialised suppliers and knowledge spillovers will develop (Arthur, 1994).

A locational dimension shows that emergent clusters form in proximity to key network nodes or 'hubs' (Cooke, 2010) and emergence of successful regional clusters relies on the formation of spin-off firms (Oakey,1995; Feldman et al, 2005; Mayer, 2011; Klepper, 2011).

It is known from the literature that the clusters in Cambridge, Silicon Valley and Austin have developed successfully over many decades and in the case of Cambridge and Silicon Valley, more than one hundred years. These long established and widely reported clusters provide knowledge that may be implemented in already established clusters that are younger, less understood and less supported by regional development and promotion policies and programs. It was noted that the level of government and community understanding and the level of support by governments and universities for the three well developed clusters in Cambridge, Silicon Valley and Austin was higher than in Christchurch and Adelaide. These two Australasian clusters have emerged and developed unaided, and relatively unnoticed by their regional governments and communities.

Knowledge of the origin, development and structure of the three well developed and well researched USA and UK clusters may be employed to inform industry and government of the capability and capacity of the less researched clusters in Christchurch and Adelaide. This knowledge can also inform the development and implementation of policies and programs to facilitate the sustainable growth of these clusters and for their essential role in the transition of their regional economies from a dependence on industrial-age manufacturing to their future in knowledge-age industry.

5.2 The Contribution to Knowledge

The principal case study obtained data and information on their origin and development from structured interviews with 146 firms and related organisations in five regions. A major contribution of this case study is the identification and quantification of HTEI clusters in the relatively isolated second tier cities of Christchurch and Adelaide. Each of these clusters has the highest proportion of their national HTEI employment and each has the positive attributes found in the three well-reported clusters studied in USA and UK. The Adelaide HTEI cluster emerged endogenously in the smallest of the five Australian mainland State capitals, and has developed relatively unobserved through self-organisation over many decades. The HTEI in Adelaide employs more than 40 per cent of Australia's HTEI workforce; more than 8 times its 5.4 per cent share of national population. The Adelaide HTEI cluster, as reported in Chapter 4 has a relatively high LQ of 6.54, approximately half that of the global exemplar, Silicon Valley at 13.36, but almost double the LQ of the Christchurch cluster at 3.62 and Austin at 3.91. However, since the introduction of the measurement of LQ (Haig, 1927), transport and communications options have evolved and the use of alternative metrics is discussed in Section 5.5.

The processes of the emergence and development of the Adelaide HTEI cluster has important similarities to those in the widely studied development of HTEI clusters in Cambridge, Silicon Valley and Austin and also with the less studied HTEI cluster in Christchurch. The first of two major similarities is the relatively small size of these five second tier cities and the second similarity is their relative isolation from major national populations.

However, there is one important difference. The commercialisation of university technologies and involvement of faculty members from a local university are both widely reported and confirmed in this research as major factors in the emergence and development of HTEI clusters in Cambridge, Silicon Valley and Austin. However, these were not factors in the origin or subsequent growth of the HTEI clusters in either Christchurch or Adelaide. In both of these cities the universities had limited involvement with the formation or development of the regional cluster.

While cluster origin is not fully understood, it is known that HTEI clusters have emerged and developed through the formation of businesses that have commercialised technologies developed in universities. Prime examples include CSI and W G Pye in Cambridge, (Segal Quince, 1985). Hewlett Packard in Palo Alto (Saxenian, 1994) and Tracor in Austin (Smilor et al, 1989) which are discussed in Chapter 4.

These firms commercialised technologies developed at their local university and each of these firms has produced a number of spin-outs and as discussed in Chapter 4 these firms are reported to be the nucleus of the cluster in their regions (Segal Quince, 1985; Smilor et al, 1989; Gillmor, 2004).

The absence of the involvement of a university in the formation and development of the clusters in Christchurch and Adelaide is a major departure from the widely reported process of cluster formation in the exemplars, Cambridge, Silicon Valley and Austin where university technology and faculty member assistance are widely reported as significant factors. While the absence of university involvement in the evolution of the HTEI clusters in Adelaide and Christchurch is a major departure from the cluster development processes in the three exemplar regions, it is not unique. Endogenous HTEI cluster formation in USA in the relatively remote second tier cities of Portland, Oregon and Boise, Idaho, without university involvement was recently reported (Mayer, 2011).

Tektronix in Portland produced numerous spin-outs and became a *"surrogate university"* (Mayer, 2011:89) in the region and acted as an incubator for staff who later started their own businesses, thereby increasing the number of firms, regional employment and clustering activity in the region. The origin and development of the HTEI cluster in Portland has important similarities to the evolution of the HTEI clusters in Adelaide and Christchurch. A major similarity is the lack of recognition by its government and community.

The Christchurch electronics industry has appeared infrequently in the literature over more than 20 years: (Crocombe et al, 1991; Ffwocs-Williams, 1996; Briss, 1997; BERL, 1998; Brown, 1999; McCarthy, 2000; Tantrum, 2003; Brown and McNaughton, 2003b; Saunders and Dalziel, 2003; Christchurch, 2005; Green, 2005; Steeman, 2007; Brown et al, 2010). Tantrum (2003) and Saunders and Dalziel (2003) quantified the Christchurch HTEI cluster.

The Adelaide HTEI has been less reported in the literature and with less emphasis on it as a cluster, and more emphasis as a part of the developing ICT industry (Parker and Tamaschke, 2005; Parker, 2006; Parker, 2008). Grill and Coutts (2005) identified and quantified the structure of the Adelaide HTEI cluster and its high proportion of national HTEI employment, which has increased from 22.4 per cent in 2003 (ABS 8126.0, 2004) to more than 40 per cent in 2011 (TIA, 2012). Three of the four papers on the Adelaide HTEI were written or co-written by Professor Rachel Parker and these compare the Adelaide HTEI respectively with the same industry in Dresden, Karlskrona and Limerick. The other paper referenced above (Grill and Coutts, 2005) was co-written by this author.

The three papers by Parker and her co-author are the only independent reports on the Adelaide HTEI cluster. Two earlier reports are (Little, 1992) and the Taskforce Report (EASA, 1994) which was initiated by this author through its industry association.

The findings from the principal case study, discussed in Chapter 4 on the HTEI clusters in Christchurch and Adelaide directly relate to the first and second research questions; respectively why clusters emerge in second tier cities and how these clusters develop. While a universal theory of cluster origin remains elusive (Mayer, 2011; Braunerhjelm and Feldman, 2006; Porter, 1990b) the basic requirements are known to include the formation of firms (Feldman et al, 2005) and related organisations, spin-outs from local incumbents (Oakey, 1995; Klepper, 2006) and locational opportunity (Storper and Walker, 1989) or expressed as an *"innovative opportunity in geographically proximate space"* (Cooke, 2010:24) for the meeting and the collaboration of cluster participants.

It is argued here that the small size and isolation of regions such as Adelaide and Christchurch can increase opportunities for face-to-face meetings so that the random factor of 'chance' (Porter, 1990b), or 'serendipity' (Braunerhjelm and Feldman, 2006) or "*the persistent effects of historical accident via 'path dependence'*". (Krugman, 1998:16) can provide the connections between individuals, firms and organisations that may grow into relationships that evolve into a cluster; this aspect of cluster formation is discussed below.

Factors of the origin and ongoing development of the individual firms and related organisations that populate endogenous HTEI clusters were surveyed in the cities in the principal case study are discussed in Chapter 4.

The second case study obtained data from the literature and from industry and government sources and through personal interviews and surveys during visits to five additional cities that have HTEI clusters that are less dense and less successful than the clusters in the principal case study. Four of the five cities in the second case study have populations ranging from more than two million to almost five million and consequently the HTEI firms and related organisations in these regions are spread over a larger geographical area.

Surveys in the four larger cities in the second case study provide a contrast to the performance of HTEI clusters in the small, second tier cities in the principal case study. The surveys for the second case study found that the value of networks and clusters to HTEI firms was less in the larger cities where firms are not as physically connected as in smaller cities with their denser clusters and consequently the effectiveness of the clusters in the larger cities is limited.

The survey in Canberra shows that 'the value to the firm of networks and clusters' is the highest in Australia at a rating of 4.22 on a Likert scale of zero to 5, and it is noted that Canberra is the smallest of the five Australian cities surveyed, with a population of 368,000. A relatively high rating of 4.11 was also received for this question in Christchurch, which has a population of approximately 350,000.[9] The next highest rating was 3.61 in Adelaide which is the smallest of the five Australian mainland State capitals with a population of 1.21 million. The lowest rating on the question of the 'value to the firm of networks and clusters' was 1.67 obtained in Sydney, Australia's largest city with a population of 4.63 million.

An inverse association between *'the value to the firm of networks and clusters'* and the size of the cities is indicated by these data. No papers that address this issue have been found and this contribution to knowledge assists our understanding of the superior performance of the clusters in the small second tier cities of Adelaide, Canberra and Christchurch.

City and regional electronics industry employment data required for the calculation of the LQ of the HTEI in Australian cities are not published by the ABS. However, with more than 40 per cent of Australia's HTEI employment in Adelaide (TIA, 2012) the proportion of employment in HTEI firms in the three larger cities of Brisbane, Melbourne and Sydney is relatively smaller and their employment LQ in the HTEI would be low.

HTEI employment data is published by the State Government of Victoria showing 6,118 HTEI employees (Victoria ICT, 2011) and this would produce an employment LQ of less than 1.0 in the region.

Despite the large size of its host city the HTEI cluster in Boston had a significant employment LQ of 2.45 in 2011, while lower than the 2.69 recorded ten years earlier (BLS, 2013). The success of the HTEI in and around Boston and the 'technology culture' of the region are generally attributed in the extensive literature on this cluster to MIT and the commercialisation of technologies developed in its laboratories. The reports of BankBoston (1997) and Roberts and Eesley (2011) provide ample evidence of the technological capability, commercial value and the extensive reach of technologies developed at MIT.

In the third case study, variations in the origin and development of the HTEI were established from the literature and from government and industry data and through visits to eight cities across Ireland, Northern Ireland, Scotland and Singapore to conduct structured interviews with industry, government, research and facilitator representatives.

[9] Due to a series of serious earthquakes in 2010 and 2011, the population of Christchurch has varied.

While similarities were found in the origin of the industry across these eight cities, as a group their development processes differ greatly from those in the endogenous clusters in the five cities in the principal case study and five cities in the second case study. The HTEI in each of the cities in the third case study has received high levels of assistance through government policies and programs. Common themes in these programs are the attraction of MNC's by a range of financial measures including periods of reduced tax. A low corporate tax rate applies in the Republic of Ireland, tax rates in Singapore are reducing and policies are in place in the UK to offset the effect of its higher tax rate. The agglomerations of HTEI firms in these four economies, many of which were attracted by subsidies and tax incentives do not have the strong cluster characteristics found in the endogenous cluster case study regions.

The Government of Singapore has policies in place to encourage clustering, but with a high proportion of MNC's being direct competitors, clustering is less successful than in the endogenous cluster regions. Some evidence of networking of indigenous HTEI companies in Ireland and Scotland was found, but the levels of collaboration are not high. Singapore has a Semiconductor Industry Association which has MNC and local members.

In Ireland the second tier city of Cork with a population of 120,000 has 80 per cent of its 9,000 HTEI workforce employed by MNC's (McElroy, 2013), but its industry association supports both MNC's and its indigenous firms.

The foreign MNC's in the regions of the third case study employ a large proportion of the industry workforce, but in Scotland in particular, while employment numbers are steady, the number of indigenous firms is increasing as is the level of collaborative interchange of information, particularly between growing number of locally owned firms.

The major variations between the HTEI in Ireland, Northern Ireland, Scotland and Singapore and the endogenous clusters in Cambridge, Silicon Valley and Austin, are the long established firm-to-firm and industry-to-research collaborations in the endogenous clusters compared with the more cautious, less productive relationships in created clusters.

The Cambridge cluster is arguably the oldest global technology cluster. The first scientific instrument firm in the town, CSI incorporated technology from the University of Cambridge in its products and the business start-up in 1878 was assisted by senior Cambridge academic staff (Cattermole and Wolfe, 1987). This university-industry relationship developed in Cambridge with spin-outs from CSI including W G Pye and more than 20 of its second generation spin-outs and subsidiaries (Segal Quince, 1985).

These firms and other Cambridge spin-outs and start-ups in this isolated region, with its interconnected industry and research sectors and facilitated by their proximity, evolved naturally through information exchange and collaboration into an endogenous cluster.

Thirty years after the start-up of CSI in Cambridge, financial, technical and management input from Stanford University faculty assisted the start-up of the Federal Telegraph Company in 1909 in the small and relatively isolated university town of Palo Alto (Sturgeon, 2000; Vance, 2007). The first of many spin-outs from FTC was established a year later and the spin-out entrepreneurs, mostly Stanford alumni who had worked together, and being isolated from the large radio firms on the east coast shared common interests and collaborated with local colleagues creating the environment for the endogenous emergence of the local cluster.

Thirty years later a new technology developed at Stanford University and the assistance of a senior academic were major factors in the start-up of Hewlett Packard in 1939 (Morgan, 1967). Spin-outs from these and other local firms would meet and discuss their interests and to trade both goods and services thus extending and deepening the cluster. The continuing efforts of Professor Frederick Terman and particularly his role in the establishment of the Stanford Industrial (now Science) Park are recorded in the literature as major events in the development of the Silicon Valley HTEI cluster (Saxenian, 1994; Gillmor, 2004).

Technologies developed at the University of Texas were incorporated by faculty in the products of spin-out, Tracor Inc. in the small city of Austin where the university was the technology source and an incubator of many new electronics firms (Smilor, et al, 1989; Barchas, 2006). UT alumni also created spin-outs from Tracor. UT and local start-ups collaborated and traded information, goods and services creating the endogenous Austin HTEI cluster.

The effectiveness of the clustering of the firms in the principal case study is reported in the literature to be high in Cambridge, Silicon Valley and Austin. The ethos of university and industry interconnection and collaboration in these clusters is, in Marshall's (1890) often quoted words *"... in the air"* and can be sensed in the university corridors and in the streets in these small cities.

Survey responses show that this factor is less evident in Christchurch and Adelaide and less again in the HTEI in cities where government policies and programs have attracted HTEI firms including a high proportion of MNC's.

Recently several Singapore MNC's have moved labour intensive operations to lower cost Asian countries, while retaining design and development in Singapore. MNC's have also recently moved labour intensive operations from Ireland and Scotland to Eastern Europe and Asia. The outmigration of MNC's may provide the remaining indigenous HTEI firms with opportunities to reshape the industry over time into a self-managed cluster.

The concentrations of trade related businesses, the interchange of industry information and the division of labour identified by Adam Smith (1776) were central characteristics of the aggregations of related firms described in '*industrial districts'* by Alfred Marshall (1890; 1919). Through the twentieth century even as mass production and mass consumption increasingly dominated developed economies, a new concept of the '*knowledge worker'* was introduced (Drucker, 1946) and the continuing success of local, small and skilled manufacturers was observed (Jacobs, 1969). These same characteristics were present in science and information-based industries (Bell, 1974) and the concept of *'flexible specialisation'* (Piore and Sabel, 1984) where small volumes, high quality, customisation and price premiums for IP-based products and services coexisted with high volume mass production in other parts of the economy. Complexity, customisation and low-volume, IP-based production are common characteristics in the HTEI in the clusters in Cambridge, Silicon Valley and Austin and these characteristics have also been identified by this research in the less reported HTEI clusters in Christchurch and Adelaide.

A century after Marshall (1890) described '*industrial districts'* similar characteristics were described in *'clusters'* by Porter (1990b). The cluster characteristics of geographic proximity, interconnected industry firms and related organisations, commonalities and complementarities are reported in Porter's principal case study (1990b:179) of the German printing machine cluster; the ceramic tile cluster in Italy; the USA patient monitoring cluster and the Japanese robotics cluster. While not emphasised by Porter, each of these regions was small and relatively remote from major populations at the time of the origin and during the long period of development of these clusters.

It is noted that the factors of small size and remote location that are present in all five of the regions in the principal case study in this work are also present in the regions included by Porter (1990b) in his principal clusters case study. Porter states that the regions in his study were selected to represent the cluster development process in unrelated industries that emerged over time. The time period of the origin and cluster development in Porter's case study is more than one hundred years. However, small size and remote location are not included in his selection criteria, yet all four of the clusters in Porter's principal case study developed endogenously in regions that are both small and remote from major populations. The finding of the same cluster characteristics described by Porter in the small and remote regions of Adelaide and Christchurch is proposed as a modest extension to the seminal contribution to knowledge of Michael Porter (1990b).

These same characteristics of relatively small size and remoteness are reported in the literature and confirmed by this research in the origin and development of the HTEI clusters in Cambridge, Silicon Valley and Austin. While Cambridge and Austin are both still relatively small and comparatively remote from major national populations, the growth of the previously small communities around Palo Alto masks the fact that during the first half of the twentieth century, when the HTEI cluster in Silicon Valley emerged and began to grow into a connected cluster of technology scholars and entrepreneurs, this region was a small and isolated agricultural community.

The characteristics of HTEI clustering in small and comparatively remote regions are also reported in Christchurch (McCarthy, 2000). These characteristics, also found in the HTEI cluster in Adelaide and reported in the previous chapters provide an original contribution to knowledge of the Adelaide HTEI cluster. Small size and remote location from major populations are factors in the endogenous HTEI clusters reported by Mayer (2011) in the second tier cities of Portland and Boise.

It is argued that the endogenous emergence and self-organised development of successful technology-based clusters in small and isolated regions has now been identified in twelve places. It is also argued that the comparative isolation of a region from major populations may also increase the propensity for scientists, engineers, and entrepreneurs to connect and collaborate and thus create or enhance the conditions for cluster formation and development.

The cluster literature proliferated after Porter (1990b) and contributions that are particularly relevant to this research include the divergent characterisation by Saxenian (1994) of the HTEI clusters in Silicon Valley and on Route 128 around Boston and Markusen et al (1999) who identified the rise of ‘second tier cities’ and particularly their attractiveness to knowledge-age workers and industry. Cortright and Mayer (2001) analysed the performance of HTEI clusters in fourteen US regions including Austin, Silicon Valley and Boston, showing that in 1997 the employment LQ for Silicon Valley was 13.1 and for Austin it was 4.9. These two regions were respectively the first and second in their rankings by LQ of fourteen HTEI clusters studied. These studies add to our understanding of the phenomenon of HTEI cluster formation in small and remote regions.

Three recent contributions are highly relevant to this research. Braunerhjelm and Feldman (2006), Fornahl et al (2010) and Mayer (2011) studied the origin and development of technology clusters in second tier cities and these three recent contributions assist our understanding of how the HTEI cluster in Adelaide with its high LQ of 6.54 in this small city could remain relatively unrecognised by its regional government and community; a situation also reported by Mayer (2011) in Portland, Boise, and Kansas City.

It is important to note that these three most recent and relevant contributions were published after this present research had been undertaken. The relevance of three works, Porter (1990b), Mayer (2011) and this thesis is that all have identified successful HTEI clusters in small and remote, second tier cities, and Mayer goes further to identify the emergence and successful development of technology clusters in cities without the involvement of a research university. While the literature on Cambridge, Silicon Valley and Austin shows that the development of their HTEI clusters was closely linked through faculty, alumni and technology with their universities, Mayer finds that contrary to this previous pattern that the clusters in Portland, Boise and Kansas City developed without a research university. Adelaide and Christchurch have good universities, however, these were not significantly linked to the origin and development of the HTEI clusters in either of these cities.

The Christchurch HTEI cluster grew around a company, Tait Electronics and its spin-outs (Saunders & Dalziel, 2003; Green, 2005; Brown et al, 2010). The major influence on the development of the HTEI cluster in Adelaide was DSTO, the government defence research establishment established in 1947 (Morton, 1989; Grill and Coutts, 2005; Parker, 2008).

The endogenous emergence and unaided development of clusters in Christchurch and Adelaide is consistent with the cluster development pattern identified in Portland, Boise and Kansas City showing that involvement of a research intensive university is *"neither necessary nor sufficient"* (Mayer, 2011:10) for the growth of high technology industry clusters in small and remote regions. The three cities in which Mayer identified and quantified endogenous high technology clusters have relatively small populations and are also isolated; hundreds of kilometres from major national populations. These three technology centres conform to Mayer's typology of *"high-tech hidden gem regions"* (2011:8). Christchurch and Adelaide also qualify for this same typology as both have significant HTEI clusters not well recognised by their regional governments or communities.

The identification and quantification of the endogenous, self-organised HTEI clusters in Adelaide and Christchurch confirms and extends the work of Mayer (2011) and contributes to knowledge by describing the endogenous emergence and self-organised development of technology clusters in these two relatively isolated second tier cities. These two antipodean clusters exhibit the characteristics found by Mayer in three USA second tier regions that are also relatively remote from major national populations and without the involvement of universities. Furthermore, the application of Mayer's (2011:8) typology *"high-tech hidden gem regions"* to Adelaide and Christchurch makes a contribution to knowledge that may be of significant future value to these communities if the recognition by their regional governments and communities can be increased.

5.3 Policy Implications

"Policy makers should pursue policies that leverage a region's cluster strengths" (Porter, 1990b, 2003). "Our evidence thus reinforces the view that policy action should focus on building upon pre-existing comparative advantage" Delgado, Porter and Stern (2010), 'Clusters, Convergence, and Economic Performance'.

There are important policy implications for the Adelaide HTEI and possibly for the HTEI in Christchurch in the capability and sustainability and the high levels of interconnection in the HTEI clusters in Cambridge, Silicon Valley and Austin. Industry to industry and industry to research sector collaboration is firmly established and its continuity is facilitated by well-resourced local organisations in each of these USA and UK regions. The implications for Adelaide include the opportunity for the development of comparable networking relationships within the HTEI cluster and beyond the cluster with the community and government in the region.

As discussed in Chapter 4, interviews conducted for this research produced a rating in Adelaide of 1.20 on a Likert scale of zero to 5 in response to the question on the *" What is value to your firm of your universities'.* This question produced ratings of 2.25 to 2.72 in Brisbane, Canberra, Melbourne, Sydney and Christchurch. The low rating Adelaide suggests the need for an industry policy to develop collaboration of industry and research sectors.

As discussed in Chapter 1, statistical methods of measurement of manufacturing industry which have evolved from traditional industrial-age classifications, do not adequately measure knowledge-age manufacturing so the value of these *future* industries is not easily identified or generally understood by governments or communities. Many of the inputs to Adelaide HTEI manufacturing processes - as is typical in a cluster - are supplied by collaborating local firms, including circuit, software and industrial design, sub-assembly production and contract logistics and final assembly and distribution of HTEI products.

These essential inputs are typically counted by current statistical data collection methods as a 'service' and are not recorded as part of the manufacturing process, causing significant underreporting of the real value of HTEI manufacturing (Roos, 2012).

The value of currently available data on the Adelaide HTEI is limited since the last comprehensive survey collected data in 2003. Without adequate data the regional government and community cannot appreciate the value of this industry. With accurate, current information on its dimensions the South Australian Government could include the Adelaide HTEI in its recently launched *'Manufacturing Works'* program (DMITRE, 2013).

This 10 year strategy is focussed on *'advanced manufacturing'* in which it includes: "*water recycling equipment, premium wine, cars and automotive parts, submarines, agricultural equipment, health and medical devices, defence equipment, consumer electronics, building materials and mining supplies"* (InvestSA, 2013). It is noted that '*consumer electronics'* is included, but no reference to the products of Adelaide's HTEI. The Manufacturing Works program aims to facilitate the transition of the industry of the region from its past reliance on *industrial-age* manufacturing to a new future in the 21st century where *knowledge-age* manufacturing will contribute an increasing proportion of wealth and employment.

Manufacturing is vital to the regional economy of Adelaide, but its high wage rates limit its success in labour intensive, industrial-age manufacturing. However, with its high levels of education, engineering and manufacturing capability, good universities and research institutions Adelaide can succeed in the knowledge-age manufacturing industry.

The HTEI sector has the desirable characteristics of high and potentially sustainable growth in revenue and employment and high value-adding through its creation of intellectual property based products and services and will be a pivotal industry in this transition.

The South Australian Government website describes the State's A$9 billion manufacturing industry as the State's largest with 80,000 employees (InvestSA, 2013). This equates to productivity per person of A$112,500. The productivity of the Adelaide HTEI was measured at A$251,000 in 2003 (SACES, 2004:26).

Based on the sample survey (TIA, 2012) productivity per person in the Adelaide HTEI had risen to A$343,000, or more than three times the productivity of the traditional manufacturing industry of the region. High productivity per employee is an important characteristic of knowledge-age manufacturing and highly desirable for the regional economy of Adelaide.

Productive collaboration between the industry, government and the research sectors requires a cohesive industry association with a high proportion of the industry firms included as members. In 1998 the EIA in Adelaide replaced and expanded the work of the volunteer-based Electronics Association of South Australia, which had operated since 1972. In 2008 the EIA merged with a local software association, but the merged body failed and was replaced in mid-2012 by a new body, the Technology Industry Association. Its website shows that it represents a very broad range of activities, including *'manufacturing, biomedical, cleantech, consumer products, mining, transport, education, defence, research, ICT, software* and *electronics'* (TIA, 2013) and its effectiveness in representing the Adelaide HTEI is unproven.

Industry to industry, industry to research and industry to government interconnection and networking are vital for the ongoing development and for the integration of the Adelaide HTEI into the 'advanced manufacturing' structure proposed by the Manufacturing Works strategy. In Cambridge these activities are facilitated by the Cambridge Network, which has a large membership for such a small community (Hewkin, 2006). This organisation, discussed in Chapter 4 could be considered as a model for the development of the HTEI in Adelaide.

An industry policy to establish an incubator or accelerator facility could assist start-up and spin-out firms during their establishment and early growth with facilities and advice. The Austin Technology Incubator, discussed below, could be the model for a technology-based incubator in Adelaide.

The lack of understanding by government of the Adelaide HTEI is discussed above and Mayer (2011:11) also found in three isolated USA second tier technology regions that *"...state policymakers were reluctant to embrace this new type of economy."* The application of the *"high-tech hidden gem regions"* typology (Mayer, 2011:8) to Adelaide could catalyse policies to promote the HTEI to the regional government and community.

5.4 Practical Implications

Data published by the Australian government body, ABS does not include revenue or employment in the electronics industry at city, MSA or regional level. The classification methods, as discussed above do not adequately capture the revenue or employment value of the HTEI. No formal measurement of the Adelaide electronics industry has been undertaken since the SACES (2004) survey.

The revenue of the Adelaide HTEI in 2003 was reported as A$1.896 billion, an increase of 17.8 per cent on the 2002 year. Employment in the Adelaide HTEI was reported as 7,500 to 8,000 in 2003. This work was funded jointly by EIA and the South Australian Government.

The sample survey in 2012 reported industry revenue of A$4.02 billion and employment of 11,700 in the 2011 year (TIA, 2012), but this survey used a small sample and its accuracy is limited. Without accurate data to update the results of the last major industry survey (SACES, 2004) it cannot be expected that the South Australian Government would fully understand the value of the Adelaide HTEI or include this industry in its *'Manufacturing Works'* strategy. A survey, comparable in scope and accuracy with the SACES (2004) survey is required to establish industry revenue and employment, and also its exports, R&D intensity, current staff and future requirements. The State Government could fund or share the funding of the survey with the industry. If State Government funding is not available a practical alternative is that the industry could secure the required funding by requesting a voluntary contribution from Adelaide HTEI firms.

Government support is needed in promoting the value of the industry to the community as a wealth and employment creator and as a leader in the transition of the regional economy to knowledge-age industry. In particular, the State Government, at little or no cost could include the region's electronics industry in its current *'advanced manufacturing'* program in its '*Manufacturing Works'* strategy.

A low rating was obtained in the survey in Adelaide of 1.2 with a mean across five Australian regions and Christchurch of 2.43 to the question: *'what is the value to your firm of your local universities?'* The value of TAFE (Polytech in New Zealand) to Adelaide firms rated 0.55 against a mean of 2.14. These data suggest a challenge and an opportunity that could be addressed by an industry organisation with programs to facilitate two-way communication to inform industry and research sectors of their capability and facilities and the potential benefits of a closer working relationship.

The role of a facilitating organisation is as a catalyst and it is known that in other places including Cambridge, Silicon Valley and Austin that these relationships, once established are self-directed and independent; the important step is the initiation of the connection. The Cambridge Network is a relevant model for the facilitation of closer working relationships between firms and between industry and research sectors. This model is also appropriate for the development of active networking between industry, research and government; the 'triple helix' model.

Activities required for the achievement of these objectives include regular networking meetings with qualified and relevant speakers, and facilities for the exchange of the information on business and technical topics. The Cambridge Network also provides recruitment and connection services, salary surveys and industry media liaison, which are also relevant for Adelaide.

The Austin Technology Incubator, discussed in Chapter 4 is a specialist technology centre for the development of young technology businesses. Owned and operated by the University of Texas at Austin it provides office and laboratory accommodation on flexible terms with business, finance and marketing advice and business development assistance for start-ups to assist their development into successful high-growth technology businesses. Adelaide has State Government incubator facilities for biotechnology and information technology start-ups and a similar facility is required for the early stage development of electronic products and related systems. The Austin Technology Incubator may be an appropriate model.

5.5 Future Research

The relationship of the small size of a city or region and its remoteness from major populations and the attractiveness of these characteristics to HTEI firms, entrepreneurs and employees discussed in Section 5.2 above may be a productive area for further research and particularly on two interrelated characteristics, observed in the HTEI clusters.

In the HTEI clusters visited for the principal case study in this research the dyadic relationship of *proximity* and *isolation* has been observed as a factor associated with their development. In this context *proximity* and *isolation* are not treated as separate conditions of *'closeness'* and *'separateness'* but operating together in the development of a cluster in a small city which is *isolated* by distance from major national populations and where the participants gain advantage from their *proximity* to other cluster members by cooperating and collaborating within the cluster. The propensity of the firms to collaborate in clusters may also be increased by the knowledge that alternative collaborators are distantly located and relatively difficult to access. The literature on this topic includes limited observations on proximity and isolation (National Research Council, 1994) and collaboration in isolated regions (Niles, 1998:132) and innovation in isolation (Mercury, 2004), discussed in Section 2.22. The positive effect of the conjunction of *proximity* and *isolation* in the development of industry clusters is observed in the five regions in the principal case study, in the three case studies of Mayer (2011) and is seen in the four clusters in the principal case study of Porter (1990b).

Since little attention has been paid in the literature to the joint influence of these two factors in HTEI clusters it is suggested that further research be undertaken to establish the joint effect of *proximity and isolation*, particularly in the endogenous emergence and development of industry clusters, and particularly in HTEI clusters in small and isolated regions.

The following is a suggested list of factors that may be further examined for their involvement in the development of collaborative relationships with proximate colleagues in isolated HTEI clusters; these factors may also be applicable in other contexts. These factors have been observed in other contexts, but all have been observed in the HTEI clusters studied in this research:

1. With a small number of available contacts, it is possible to meet and collaborate with a higher proportion of that smaller total than would be possible in a larger community
2. A cluster is more visible to its members in small communities and has higher 'intensity'
3. Physical isolation from major populations limits access to alternative collaborators
4. Proximity: Short travel distance/time-walking/cycling between collaborators
5. Low traffic congestion and parking availability/cost at both ends of the journey
6. Trust is developed and knowledge exchanged through face-to- face meetings
7. School, university or workplace relationships, based on trust that fosters collaboration
8. The limited number of available collaborators in small populations encourages good collaborative behaviour. *"... be helpful to everybody in the industry, you may need that firm as a customer or a supplier in future"* (Unprompted interview response, SME manager Canberra, December, 2009) and the need to *"play by the rules"* in a small community (Perry, 2005:186).
9. Wide recognition in small regions of the need to cooperate with firms and institutions to increase ability to compete with larger competitors or firms in major cities or regions

In relation to 1. above: Evidence of the effectiveness of face-to-face meetings is provided by Pinch et al (2003:375) who find that with tacit knowledge *"Frequent face-to-face interactions between the numerous actors in such regions can facilitate the exchange of this knowledge through learning-by-doing."* A further observation shows that *"Face-to-face is particularly important in environments where information is imperfect, rapidly changing, and not easily codified, key features of many creative activities."* (Storper and Venables, 2003:1).

The Mott Committee (1969) found that beyond a geographical limit of 5 miles, personal contacts start to break down. Porter's paradox in clusters is highly relevant: *"... the enduring competitive advantages in a global economy rely increasingly in local things - knowledge, relationships, motivation - that distant rivals cannot match"* (1998a:78).

The common factors of small size, proximity and isolation however, are not generally emphasised in the cluster literature and it is argued that the combination of the factors of small size, proximity and isolation may be contributory factors in the emergence and development of endogenous HTEI clusters and that these factors may be relevant factors in the emergence of clusters in other industries and worthy of further study.

It is noted that the concept of Location Quotient which compares the regional share of economic activity in a particular industry to the national share of economic activity in the same industry (Haig, 1927) may now be dated.

Since 1927, telecommunication and transport systems have provided options that reduce the negative effects of distance. However, HTEI clusters emerged and developed through the twentieth century and have reached their highest concentration in small and isolated regions of developed countries. LQ relates four parameters and to interpret the LQ of a region requires an understanding of these parameters and their influence on the LQ of a region. Cambridgeshire houses 15.1 per cent of all HTEI employees in the UK, but, because the HTEI is dispersed across England, Scotland, Northern Ireland and Wales the LQ of Cambridgeshire is a relatively low 1.66.

An alternative measure of '*concentration'* was adopted by Grill and Coutts (2005) and used to analyse the data shown in Table 4.4 and graphically in Figure 4.4. This simpler measure shows regional HTEI employment as a percentage of national industry total.

Table 4.7 shows the of national HTEI employment in a region as LQ and as a percentage of national HTEI employment. This presentation of the same data shows a limitation of the LQ calculation, particularly in relation to Cambridge, Silicon Valley and Adelaide and suggests that further research on these measurements may produce an improved method.

5.6 Research Limits and Generalisation

The observations and conclusions on the HTEI clusters in this thesis are necessarily limited to the regions researched. However, the literature shows that the phenomenon of endogenous emergence and self-organised development of technology-based clusters in geographically isolated and small cities has recently been reported in three USA regions (Mayer, 2011) that have many similar characteristics to those in the five regions in the principal case study presented here. Additional work on comparable clusters may lead to a generalisation of the findings of this thesis and of the work of Mayer.

The similarities in the eight cluster regions considered above to the characteristics present in the four clusters researched by Porter (1990b) suggest the potential for generalisability and for further work to be undertaken by others towards the goal of generalisation of some of the findings on this work.

Finally, it is noted that endogenous cluster emergence does not occur in all second tier cities nor indeed does it occur in most second tier cities; it has occurred only in a relatively limited number of small regions. The phenomenon of endogenous HTEI cluster emergence and development in second tier regions is rare.

Appendix 1: Letter of Endorsement, Electronics Industry Association

26 August 2004

Mr Ronald Grill
425 Gilles Street
ADELAIDE SA 5000

"The origin and growth factors in Adelaide's electronics industry; a comparison with selected global regions and the development, implementation and measurement of programs for its sustainable growth"

With respect to the above Research PhD which you have begun, I wish to advise that the EIA Board at its meeting held on 19 August 2004, resolved to endorse your research project.

The EIA would encourage electronics companies to participate in interviews for the purposes of gathering information about the industry, when contacted by you.

Should any company that you approach wish to discuss this project further with the EIA, they can contact me on 8272 5222.

Yours faithfully

Jason Kuchel
Executive Director
Electronics Industry Association

Appendix 2: Discussion Topics – Electronics Industry

Discussion Topics: Electronics Industry

Year of Business Commencement: ………………..

Start Up Driver
1. Major start-up motivation: Technology / Money / Self-employment / Fame / Social. (select one)
2. A new technology, i.e. a breakthrough at start-up: yes/no
3. A perception of a latent Future market or an Existing but unsatisfied market
4. An incremental Improvement on available product or service: yes/no

Location Factors
5. Choice of start-up in this city: By analysis or a 'home-town' decision
6. Is the location reason: More relevant / Less relevant / Similar now as at start-up? (select one)
7. What are the best and worst factors about running your business in this city now?
8. Would you move from this city? If yes, why would you move?
9. Access to Design or Test Facility as a location factor (e.g. Electron Microscope?) Scale: 1 to 5 (1 = low, 5 = high)
10. Importance of a University or other major institution as a location factor Scale: 1 to 5 (1 = low, 5 = high)

Technology Source
11. Do you generate IP within the firm? (% of your total R&D?)
12. Do you obtain IP from associated (i.e. financially related) entities? (% of your total R&D?)
13. Do you obtain IP or have R&D joint-ventures with non-associated companies? (% of your total R&D?)
14. Have you purchased or licensed technology from a University? (% of your total R&D?)
15. Have you purchased or licensed technology from a Government Research Institution? (% of your total R&D?)
16. Problem with cost or availability of IP or with the technology transfer process. Scale: 1 to 5 (1 = low, 5 = high)

Intellectual Capital
17. Value to your firm of your Universities: Scale: 1 to 5 (1 = low, 5 = high)
18. Value to your firm of other post school training institutions. Scale: 1 to 5 (1 = low, 5 = high)
19. Problem with staff shortages [quant] /skills shortages [qual] (e.g. RF/ DSP / C++) Scale: 1 to 5 (1 = low, 5 = high)
20. What additional University or other post school training assistance is required?
21. Importance of innovation to the firm: Scale: 1 to 5 (1 =low, 5 = high)
22. Importance of entrepreneurship to the firm: Scale: 1 to 5 (1 = low, 5 = high)
23. Creativity & Creative people (Richard Florida) Is there a '*Creative Class'* in this city. Scale: 1 to 5 (1=low, 5=high)

Physical Capital
24. Success in attracting equity capital: Scale of 1 to 5 (1 = low, 5 = high)
25. Success in attracting shorter-term (bank or other) loans as *'working capital':* Scale: 1 to 5 (1 = low, 5 = high)
26. Venture Capital: Sought / Obtained / Not obtained / Not sought
27. Importance of retained, after tax earnings as a source of finance : Scale: 1 to 5 (1 = low, 5 = high)
28. Importance of personal or family assets, as a source of company finance: Scale: 1 to 5 (1 = low, 5 = high)

Markets
29. Do you target niche or smaller markets- If so why?
30. Do you export? If so, year of first export:……………
31. Your marketing strategy: Market Pull or Technology Push: (select one)
32. Level of global surveillance of Opportunities & Competition. Scale: 1 to 5 (1 = low, 5 = high)
33. Importance of the Local/Regional Government as a customer: Scale: 1 to 5 (1 = low, 5 = high)
34. Importance of the National Government as a customer: Scale: 1 to 5 (1 = low, 5 = high)

Management and Strategy
35. Is the firm: a low-cost producer / market led / market leader / market maker
36. Products differentiated from competitors. Scale: 1 to 5 (1 = low, 5 = high)
37. Strategy now same or different to start-up strategy? Why?
38. Company ethos: Corporate culture or Stakeholder focus: (select one)
39. Risk Management performance: Scale: 1 to 5 (1 = low, 5 = high)
40. Intellectual Property Management performance: Scale: 1 to 5 (1 = low, 5 = high)
41. Value of Networks / Clusters / Collaboration / Partnering / Linkages etc. Scale: 1 to 5 (1 = low, 5 = high)
42. Major barrier to growth: Markets / Technology / Materials / Finance / Human resources / Regulation (select one)

Government Factors
43. Non-financial Government assistance; Sought / Received / Not received / Not sought
44. Government financial assistance (Grants or Loans). Sought / Received / Not received / Not sought
45. Do you require any other Local / Regional / National Government assistance? (financial or non-financial)
46. Local / Regional / National Government interference, by Regulations / Delay / Cost: Scale: 1 to 5 (1 = low, 5 = high)

Major Institution as a Factor
47. Current and past benefits from a major local institution (university/research inst.etc) Scale: 1 to 5 (1 = low, 5 = high)
48. Disadvantages from the location a major local institution (i.e. a competitor for staff) Scale: 1 to 5 (1 = low, 5 = high)
49. Services or assistance wanted from a major local institution?
50. Estimated future value of a major local institution on your ongoing operations: Scale: 1 to 5 (1 = low, 5 = high)

Appendix 3: Discussion Topics – Facilitators: Economic Development

Discussion Topics: Facilitators: Business / Economic Development

Organisation Background: Type / Functions / Scope / Ownership / Relationships

Organisation's Drivers

1. New business creation / Improvement of existing business / Import replacement / Other
2. Outcome: Employment / Wealth / Technology Commercialisation / Regional Development / Fame
3. Clients: Individuals / Companies / Groups / University (Dept. or Faculty) / Members / Government
4. Market perception: Identified but unsatisfied market / Creation of new markets

Technologies

5. Origin: Personal / Group / Research Institution / Faculty / Peer / Grant driven /Policy driven
6. Breakthrough Technologies / Incremental improvements / Proportions / Trends
7. Origin: Parent Institution / Joint venture / Region / Licensed in or out / Government / Other
8. Specialisation: People / Equipment / Tradition / Market focus / Policy Driven
9. Proportion of Research V's Development / Trend

Industry Collaboration

10. Sought / Encouraged (Passive / Active) / Discouraged: Increasing / Decreasing / Trend
11. Barriers: Traditional / Cultural / Financial / Resources / IP Security (whose?)
12. Constraints: Your Staff Time / Industry Staff Time / Equipment / Competition sensitivity / Other
13. Collaboration proportion: Local / State / National / International

Location for Business (inc. Start-ups)

14. Desirable / Attractive / Appropriate / Unfriendly / Hostile
15. Lifestyle: Does it attract the right technology staff / the right commercialisation staff
16. Job opportunities for Graduates & Postgraduates: Research/Industry/Teaching/Alternatives/ Other
17. Location Barriers: Physical location / Logistics / Entrepreneurial Culture / Cost of Business & Living

Human Capital

18. Staff numbers: Expanding / Contracting / Barriers / Constraints
19. Shortage of staff: Quantitative - Availability / Qualitative - Skills
20. Budget Constraints: Your staff / Trends
21. Creativity / Creative People / Creative Class in the region (ref: Richard Florida)

Financial Capital

22. Your Funding: Expanding / Contracting / Constant / Barriers & Constraints
23. Sources of economic development funding: Federal / State / Local / Endowments
24. Industry Contribution: As a shareholder / Sponsorship / Membership / Joint ventures
25. Cost of service delivery / Cost of staying in front in chosen fields

Government Factors

26. Government assistance/grants (Regional, State, Federal): Sought / Received / Not sought / Not recd.
27. Government Grants: Value / Importance / Trends / Control / Funding Contraints / Donor Expectations
28. Require any other Regional / State / Federal Government support or assistance
29. Regional, State or Federal Government interference: Regulations / Delay / Cost
30. Importance of Local Government as a customer of Electronics Industry
31. Importance of State Government as a customer of Electronics Industry
32. Importance of Federal Government as a customer of Electronics Industry

Major Institution as a Factor

33. Why here, why now: *'Major institution'* shaping your Innovative / Entrepreneurial environment
34. Diffusion of Technology from *'Major institution':* Value of flow down effect / Mechanisms / Gaps
35. Your *'Major organization'* and benefits from: Linkages / Joint Ventures / Specific Values / General
36. Research Standards & Rigor / Reputation & Values of *'Major institution'*
37. Services or assistance obtained from *'Major institution'* or wanted
38. Disadvantage of *'Major organization'* e.g. As a competitor for staff or funds

Management and Strategy

39. Regional technology commercialisation culture: Market pull / Technology Push / Trends
40. Competitor Analysis - Onshore and Offshore: Scale 1 to 5 (1 = low , 5 = high)
41. Risk Management / Intellectual Property Management: Scale 1 to 5 (1 = low , 5 = high)
42. Targeting partners, by necessity or by desire / Strategic interaction between Industry & Research
43. Corporate culture: Stakeholder focus / Outcome focus
44. Value of each: Networks / Clusters / Partnering / Vertical &/or Horizontal Linkages (Scale 1 to 5)
45. Consulting Service to Industry: Cost recovery / Premium rates / Competition with firms
46. Industry Sponsorship of your activities: Desirable / Realistic / Necessary / Practical

Appendix 4: Discussion Topics – Research and Higher Education Sector

Discussion Topics: Research and Higher Education

Research Background

1. Driver: Individual / Group / Department / Faculty / University / External / Grant driven
2. Outcome: Publication / Promotion / Public Benefit / Fame
3. Strength of Faculty Research Policy: (e.g. outcome focus with KPI's) Scale of 1 to 5 (5 = high)
4. Teaching V's Research Ratio: Scale of 1 to 5 (Teaching %, Research %) - Trend

Research Topics

5. Topic Selection by: Individual / Group / Department / Faculty / University / External / Grant driven
6. Proportion: Basic Research / Applied Research: (Basic %, Applied %)
7. Future Trend: Basic Research / Applied Research (Basic %, Applied %)
8. Shared with other institutions / Joint venture (Shared %, Not shared %)
9. Value of Shared interests: other Disciplines/Institutions (<u>Crosscutting</u>) - (Basic = 1, Applied = 5)

Collaboration

10. University/Industry/Government Collaboration: Sought / Encouraged / Tolerated / Discouraged
11. Value of collaboration with: Industry / Government: Scale of 1 to 5 (Basic = 1, Applied = 5)
12. Value of collaboration with: Other universities & research institutions. Scale of 1 to 5 (5 = high)
13. Collaboration Trend: Decreasing / Increasing.
14. Constraints: Staff hours limit / Funding / Facilities
15. Barriers to Collaboration: Traditional / Cultural / Financial / Resources / Policy

Regional Location

16. Desirable / Attractive / Unknown / Avoided
17. Lifestyle as an attractor of the right research & teaching staff - Scale of 1 to 5 (5 = high)
18. Lifestyle as an attractor of the right undergraduate & PG candidates - Scale of 1 to 5 (5 = high)
19. Regional job opportunities: Research / Industry / Teaching / Other / Alternatives
20. Barriers: (internal) Not invented here / (external) Could this come from such a (small/remote) place
21. Creative People / Creative Class in region (ref: Richard Florida) Scale of 1 to 5 (5 = high)

Intellectual Factors

22. Staff numbers : Expanding / Contracting: Longer-term trend
23. Student numbers : Expanding / Contracting /: Longer-term trend
24. Shortage of staff: Availability / Qualification
25. Budget Constraints : Salaries / Staff Facilities - Longer-term trend

Financial Factors

26. Funding: Expanding / Stable / Contracting - Longer-term trend
27. Funding Sources: Federal / State / Local / Endowments / Other
28. Funding Method: Grants / Industry contracts / Government contracts / Sponsorship / Alumni
29. Difficulty of staying in front in chosen fields Scale of 1 to 5 (1 = low, 5 = high)
30. Importance of non-traditional funding: Foundations / Endowments Scale of 1 to 5 (5 = high)

Management and Strategy

31. Technology Push (by research sector) / Market Pull (by industry)
32. University Commercialisation Policy: Outcome focus (e.g. KPI's): Scale of 1 to 5 (5 = high)
33. Faculty/Department Commercialisation Policy (e.g. KPI's): Scale of 1 to 5 (5 = high)
34. Competitor Analysis in Australia and Offshore: Scale of 1 to 5 (5 = high)
35. Risk Management Performance: Scale of 1 to 5 (1 = low, 5 = high)
36. Intellectual Property Management Performance: Scale of 1 to 5 (5 = high)
37. Value of <u>Each</u>: Networks / Clusters / Partnering / Vertical &/or Horizontal Linkages (5 = high)
38. Is Industry a Stakeholder / Client / Sponsor
39. Consulting Service to Industry / Cost recovery / Premium rates / Competition with firms
40. Sponsorship by Industry / Desirable / Necessary / Palatable / Undesirable / Avoided

Government Factors

41. Importance of Local or State Government as a research client
42. Importance of Federal Government as a research client
43. Difficulty: Delay, Cost or Barriers: Local, State or Federal Regulations - Scale 5 = high
44. Government Grants: Value / Importance / Trends / Control Expectations

Major Institution as a Factor

45. Current and past benefits from the location of a *'Major institution'*: Scale of 1 to 5 (5 = high)
46. Value of diffusion of IP from *'Major institution':* Scale of 1 to 5 (1 = low, 5 = high)
47. Research Standards, Rigor & Reputation & Values of *'Major institution'*: Scale 5 = high)
48. Services or assistance wanted from *'Major institution'*
49. Disadvantage of *'Major organization'* e.g. As a competitor for staff or funds
50. Estimated future value of a major institution on your ongoing operations: Scale 5 = high)

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Appendix 5: Survey Data – Topics 1 - 4

	Operating years	Start-Up Driver								
		1					2	3		4
		Technology %	Money %	Self Employment %	Fame %	Social %	New Technology %	Latent Market %	Unsatisfied Market %	Incremental %
Adelaide	19.04	35.26	22.46	32.36	0.00	4.10	42.03	18.84	79.71	44.93
Brisbane	11.09	58.70	8.70	30.43	0.00	2.17	47.83	34.78	65.22	78.26
Canberra	12.89	36.11	22.22	38.89	0.00	2.78	38.89	27.78	61.11	44.44
Melbourne	19.36	42.25	23.68	40.46	0.00	0.00	39.29	50.00	42.86	50.00
Sydney	22.40	60.00	20.00	26.67	0.00	13.33	66.67	53.33	53.33	73.33
Australia	16.96	46.46	19.41	33.76	0.00	4.48	46.94	36.95	60.45	58.19
Christchurch	16.72	38.89	11.11	44.44	0.00	5.56	27.78	41.67	58.88	44.44
Australia + New Zealand	16.84	42.68	15.26	39.10	0.00	5.02	37.36	39.31	59.66	51.32

Appendix 6: Survey Data – Topics 5 - 10

	Location Factors										
	5		6 Location relevance - Now			7 Location Features		8 Would you move		9 Availability	10
	Analysis %	Home Town %	More %	Less %	Same %	Best	Worst	Yes %	If yes, Why?	Equipment or Facility Likert	Major Institution Likert
Adelaide	24.64	73.91	21.74	4.35	71.01			24.64		1.64	1.13
Brisbane	15.22	84.78	39.13	13.04	47.83			8.70		0.96	1.85
Canberra	19.44	80.56	56.56	22.22	22.22			8.70		0.50	2.17
Melbourne	1.79	98.21	87.05	14.29	33.93			14.29		0.82	1.88
Sydney	6.67	93.33	13.33	13.33	80.00			46.67		0.93	2.20
Australia	13.55	86.16	43.56	13.45	51.00			20.60		0.97	1.85
Christchurch	27.78	72.22	44.44	11.11	33.33			25.00		1.06	1.94
Australia + New Zealand	20.67	79.19	44.00	12.28	42.16			22.80		1.02	1.89

Appendix 7: Survey Data – Topics 11 - 23

	Technology						**Intellectual Capital**							
	11	12	13	14	15	16	17	18	19	20	20	21	22	23
	In Firm %	Assoc-iated %	Non Assoc-iated %	University %	Govern-ment Instiution %	Tech-nology Transfer Cost Likert	Value of University Likert	Value of TAFE Likert	Skills Shortage Likert	Wants Assist-ance Required %	Wanted from University or TAFE	Importance of Innovation Likert	Importance of Entrepre-neurship Likert	Importance of Creativity Likert
Adelaide	86.96	31.88	43.48	27.54	17.39	0.84	1.20	0.55	1.81	69.56		4.36	3.46	2.72
Brisbane	91.30	39.13	34.78	17.39	26.09	1.57	2.33	1.63	2.57	60.87		4.65	4.28	2.87
Canberra	94.44	27.78	27.78	5.56	5.56	1.33	2.72	2.17	2.64	77.78		4.25	4.06	3.50
Melbourne	89.29	3.57	28.57	17.86	14.29	1.02	2.25	2.18	2.82	71.43		4.41	4.00	3.66
Sydney	93.33	33.33	13.33	26.67	20.00	1.67	2.33	2.33	3.33	86.66		4.60	4.03	2.47
Australia	91.06	27.14	29.59	19.00	16.67	1.29	2.17	1.77	2.63	73.26		4.45	3.97	3.04
Christchurch	100.00	16.67	27.78	16.67	11.11	1.06	2.69	2.50	3.06	72.22		4.42	4.22	3.39
Australia + New Zealand	95.53	21.90	28.68	17.84	13.89	1.17	2.43	2.14	2.85	50.24		4.44	4.09	3.22

Appendix 8: Survey Data – Topics 24 - 28

	Physical Capital							
	24	25	26 Venture Capital:				27	28
	Long Term	Short Term	Sought by	Obtained by	Sought and Not Obtained	Not Sought	Importance of Retained Earnings	Importance of Personal Assets
	Likert	Likert	%	%	%	%	Likert	Likert
Adelaide	3.33	3.58	17.39	4.35	11.59	79.71	3.25	1.84
Brisbane	2.13	3.28	21.74	17.39	4.35	78.26	3.87	3.09
Canberra	1.94	1.78	27.78	16.67	11.11	72.22	4.14	2.44
Melbourne	1.68	1.95	35.71	14.29	17.86	68.86	4.27	1.98
Sydney	2.70	2.60	20.00	13.33	13.33	80.00	4.07	2.37
Australia	2.36	2.64	24.52	13.21	11.65	75.81	3.92	2.34
Christchurch	2.19	2.39	5.56	5.56	0.00	94.94	3.39	0.89
Australia + New Zealand	2.27	2.51	15.04	9.38	5.82	85.38	3.66	1.62

Appendix 9: Survey Data – Topics 29 - 34

	Markets									
	29 Niche Markets		30 Exports			31		32	33	34
	Yes %	Why? %	Yes %	Export Years	Export Years / Operating Years	Market Pull %	Technology Push %	Global Surveillance Likert	Govt. as a Customer State or Local Likert	National or Federal Likert
Adelaide	89.86		60.87	13.63	0.72	53.62	46.38	3.26	1.42	1.81
Brisbane	91.30		82.61	11.89	0.63	45.65	45.65	3.04	2.13	1.61
Canberra	100.00		55.56	11.10	0.86	47.22	41.67	3.31	2.06	3.28
Melbourne	92.86		78.57	12.06	0.62	55.54	44.46	2.66	1.63	1.39
Sydney	88.67		86.67	8.33	0.37	33.33	66.67	3.17	1.88	1.93
Australia	92.54		72.86	11.40	0.64	47.07	48.97	3.09	1.82	2.00
Christchurch	88.89		77.78	16.67	0.75	52.78	36.11	3.78	1.44	1.25
Australia + New Zealand	90.71		75.32	14.04	0.70	49.93	42.54	3.43	1.63	1.63

Appendix 10: Survey Data – Topics 35 - 38

	Management and Strategy								
	35 Market Stance				36	37 Strategy		38	
	Low Cost %	Market Led %	Market Leader %	Market Maker %	Product Differentiation Likert	Changed %	Reason for Change	Corporate Culture %	Stake-holder %
Adelaide	14.49	42.03	40.58	21.74	2.92	79.36		13.04	23.19
Brisbane	4.35	26.09	34.78	34.78	3.11	82.61		21.74	78.26
Canberra	38.89	22.22	22.22	22.22	3.78	77.78		19.44	80.56
Melbourne	0.00	14.29	50.00	35.71	3.43	67.86		14.29	85.71
Sydney	6.67	26.67	60.00	46.67	4.00	66.67		20.00	80.00
Australia	12.88	26.26	41.52	32.22	3.45	74.86		17.70	69.54
Christchurch	2.78	3.33	14.67	22.22	3.44	94.44		11.11	88.89
Australia + New Zealand	7.83	14.80	28.09	27.22	3.44	84.65		14.41	79.22

Appendix 11: Survey Data – Topics 39 - 42

	Management and Strategy cont.								
	39	40	41	42 Barriers to Growth					
	Risk Management Likert	IP Management Likert	Value of Clusters and Networks Likert	Markets %	Technology %	Materials %	Finance %	Human %	Regulation %
Adelaide	3.04	2.74	3.21	46.03	1.58	0	42.85	14.28	4.76
Brisbane	3.63	3.30	2.57	56.52	2.17	0.00	29.70	7.96	3.61
Canberra	3.33	3.61	4.22	40.74	0.00	0.00	43.52	15.74	0.00
Melbourne	3.50	3.61	3.34	32.14	0.00	0.00	44.64	13.07	7.14
Sydney	3.90	3.47	1.67	38.80	0.00	0.00	0.55	0.55	0.55
Australia	3.48	3.35	3.00	42.85	0.75	0.00	32.25	10.32	3.21
Christchurch	3.47	3.58	4.11	47.22	0.00	0.00	11.11	36.11	5.56
Australia + New Zealand	3.48	3.46	3.56	45.03	0.38	0.00	21.68	23.22	4.39

Appendix 12: Survey Data – Topics 43 - 44

	Government Factors											
	43 Government Assistance				44 Grants							
	Sought %	Received %	Not Received %	Not Sought %	COMET %	Start or Comm-ercial Ready %	EMDG %	Other %	Sought %	Received %	Not Received %	Not Sought %
Adelaide	59.42	46.38	13.04	40.58	17.39	21.74	26.09	1.45	51.47	49.28	2.19	48.53
Brisbane	73.91	73.91	0.00	21.74	13.04	21.74	30.43	30.43	69.57	65.22	4.35	21.74
Canberra	61.11	55.56	5.56	38.89	11.00	27.78	27.78	11.00	44.00	44.44	0.00	33.33
Melbourne	67.86	53.57	14.29	32.14	14.29	14.29	39.29	28.57	39.29	39.39	3.57	21.43
Sydney	60.00	40.00	20.00	40.00	16.34	20.63	38.54	16.61	26.67	26.67	33.33	40.00
Australia	64.46	53.88	10.58	34.67	14.41	21.24	32.43	17.61	46.20	45.00	8.69	33.01
Christchurch	66.67	66.67	0.00	33.33								
Australia + New Zealand	65.57	60.28	5.29	34.00								

Appendix 13: Survey Data – Topics 45 - 50

	Government Factors cont.					**Major Institution as a Factor**			
	45 Assistance Required				46 Cost	47	48	49	50
	Local Government %	State or Regional %	National or Federal %	Specific Assistance Wanted	Government Regulation and Delay Likert	Current and past benefits Likert	Dis-advantage Likert	Service or Assistance Wanted from Major Institution	Estimated Future Value Likert
Adelaide	8.07	26.68	28.24		1.67	1.73	1.33		1.84
Brisbane	4.35	21.74	17.39		2.02	1.52	1.09		2.98
Canberra	22.22	22.22	38.89		1.83	2.39	1.81		3.14
Melbourne	0.00	39.29	42.86		2.50	2.46	0.96		3.73
Sydney	26.67	46.67	40.00		2.00	2.33	2.66		1.87
Australia	12.26	31.32	33.48		2.00	2.09	1.57		2.71
Christchurch	11.11	25.00	25.00		2.03	2.61	1.28		3.38
Australian + New Zealand	11.69	28.16	29.24		2.02	2.35	1.43		3.05

Appendix 14: Slide from Professor Blandy Presentation

Spending on R&D in General (GERD), by Business (BERD), by Government (GOVERD) and by Higher Education (HERD) as percentages of GDP, various countries, and as percentages of Gross State Product, various States, 1998/99 **Economic Outlook EIA August 2002**

Slide 16 (Blandy, 2002)

GERD Country/State	%	BERD Country/State	%	GOVERD Country/State	%	HERD Country/State	%
Finland	2.90	Finland	1.94	**S Australia**	**0.69**	**S Australia**	**0.63**
US	2.74	US	1.94	Finland	0.38	Finland	0.56
Germany	2.29	Germany	1.57	Queensland	0.36	Australia	0.44
S Australia	**1.93**	Denmark	1.32	Australia	0.35	Germany	0.41
Denmark	1.92	UK	1.20	Germany	0.34	Denmark	0.41
UK	1.83	Canada	1.03	Victoria	0.31	Queensland	0.41
Victoria	1.71	Victoria	0.95	Denmark	0.29	US	0.39
Canada	1.64	W Australia	0.70	UK*	0.28	UK*	0.38
Australia	1.49	Australia	0.68	W Australia	0.25	NSW	0.38
W Australia	1.37	NSW	0.63	NSW	0.23	Victoria	0.37
NSW	1.25	**S Australia**	**0.62**	Canada	0.22	Canada	0.36
Queensland	1.23	Italy	0.55	US	0.22	W Australia	0.36
Italy	1.02	Queensland	0.4	Italy	0.22	Italy	0.26

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