A Valuation Process for Intellectual Property in a Technology Park Environment

By

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IN APPRECIATION

I humbly dedicate this thesis to the memory of my late wife Maureen, without whose inspiration, support and help it would never have happened.

"You were the wind beneath my wings"

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Abstract

A Valuation Process for Intellectual Property in a Technology Park Environment

With the rapid development of the global economy, intellectual capital has become a critical driver of a business's sustainability. The essential difference between companies operating in the 'old' and the 'new' economy is that, where value in the past was created within industrial sectors such as manufacturing, education, retail, wholesale and financial services, value in the future will be created primarily from the application of knowledge. Increasingly, the main assets of 'smart' companies will be in the form of intellectual, and not physical, capital. Technology development is a logical product of intellectual capital. Thus, in the new economic paradigm, companies perceive technology developments as necessary commercial activities to underpin their competitive standings, and provide a platform for economic growth, profitability and shareholder value.

However, the development of commercially viable intellectual capital projects also requires substantial investments in intellectual property, often without certainties of success. Since valuation techniques and processes are crucial for business investments, this paper evaluates the various methods that are currently used to value intellectual capital and intellectual property, and finds that, in view of substantial inadequacies, there has arisen an imperative need to develop a new process for valuing these.

The industries that were selected for this study based on their significance to the development of the Australian knowledge economy were the Biotechnology, Information Technology and Energy and Environment.

The motivation for this research was to provide an empirical and quantitative contribution to the understanding of intellectual capital and nascent technologies valuation. The formulation of the models was based on a new branch of research, referred to as value-driver research, which has emerged in response to criticisms of the traditional valuation methodologies.

Thus, the methodology adopted in this study was to identify, evaluate and analyse the key factors, from a valuation perspective, that drive the value chain of nascent technologies throughout the development process. There steps involved in the research process that led to the development of the valuation process models were as follows:

(i) Consistent with current academic research which prescribes the need for new valuation models for intellectual capital, the research identified the underlying factors that create and drive value specific to each of the technologies being looked at in this study by subjecting specific case studies pertaining to them to analysis, using case- study analysis software.

(ii) A questionnaire containing 40 questions were sent to 300 companies which sought to establish if the value drivers identified from the case study analysis were pervasively present in each of the industries in the study, or otherwise.

(iii) Subjected the respondents' data to statistical analysis to identify pervasive value drivers.

(iv) Based on the statistical analysis, the research estimated a logistic regression model for each of the industries based on their individual value drivers. The objective of using logit regression modeling techniques was to assure the validity and rigour of the analysis. By doing this, the specified logit equations helped in explaining whether the set of independent variables (i.e. value-drivers) were statistically significant in collectively determining the value of firms in each sector. The objective of this regression manipulation was to statistically specify the value-drivers and determine the pervasiveness of these variables on the dependent variable according to the scores given by the respondents to the questionnaire.

The thesis succeeded in developing robust, flexible models of a linear multi-beta type, using the method of ordinary least squares (OLS) for estimating the value of intellectual capital, and was given the title **'Australian Multi-Factor Technology Valuation Model'**, which met a major objective of the research to provide a new and appropriate means of measuring the value of intellectual capital of the firm.

The final models were tested against empirical data, but the results appeared to at odds with the findings from the survey insofar as the number of value drivers that aggregate to total value for each industry was concerned. However, the results of the analysis of empirical data related to a specific period of time, and for a specific population. Additionally, given the other limitations of research, this was this was quite a plausible outcome.

Finally, the various implications arising from the study were discussed. These included implications for valuation of intangible assets, implications for strategic management, implication for public policy, and implications for equity investments. In the concluding section, suggestions for future research were also stated.

Chapter 1. Introduction

1.1 The Knowledge Economy

This paper is to conduct research on the valuation approaches used by managers in technological-intensive companies for valuing their technologies specifically within the confines of a technology park, and generally, in other environments. Companies perceive technology developments as necessary commercial activities to underpin their competitive standings, and provide a platform for economic growth, profitability and shareholder value. There are several examples, Microsoft Inc. being one of the best of these. The technologies developed by the computing, telecommunications, consumer electronics, pharmaceutical and electronic media companies, among others, change the way business is conducted and substantially change our home live as well. In the IT industry there is a disproportionate number of small companies whose revenues have grown by high comparative levels over the past decade. Recently in America successful start-up firms in the IT industry such as Compaq, Oracle and Sun Microsystems have shown higher growth relative to the general market. However, such business developments also require substantial investments in intellectual property, often without certainties of success. Since valuation techniques and processes are crucial for business investments, this paper will evaluate the various methods that are currently used and incorporate them, where appropriate, into the development of a valuation process for new and evolving technologies.

The industries selected for this study based on their significance to the development of the Australian knowledge economy[1] are:

- Biotechnology
- Information Technology
- Energy and Environment

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[1] Information Industries Action Agenda – Dept. of Communications, Information Technology and the Arts.

1.1.1 Biotechnology

Biotechnology is viewed by several countries as a key to the marketplace of the 21st century. This view was supported by John Gibbons, White House science adviser[2], on the basis of the Commerce Department's prediction that sales of biotech-derived products will grow between 15% and 20% annually through 1997 and beyond[3]. In the U.S. alone, total revenues for the biotechnology industry are currently estimated at between $U.S. 4 –5 billion. But according to the Commerce Department, that figure would have grown to $40 billion worldwide by the year 2000. Other estimates put it over $U.S. 50 billion, and some as high as $U.S. 100 billion [4]. It is little wonder that James McCamant, editor of the *Medical Technology Stock Letter,* stated that for investing in the future, biotech is '*it*', because it could be much bigger than anyone expects (Georgiou 1994). Yet, much of the technology, of which a great deal of development work is done at technology parks, is risky, with no certainty of producing future cash flows. In such a situation, valuation of these technologies, to attract venture capital, is critically important to make potential into reality.

1.1.2 Information Technology

Information Technology has emerged as a major form of intellectual property. Microsoft's Windows, Oracle Corporation's Financial Databases, SAP's Accounting Packages, provide clear evidence that software development, as a major form of knowledge asset, can yield substantial profits and cash flows to the owners of financial capital. The economic impact of information technology is substantial, and cannot be underestimated. For example, while information technology firms make up only 8% of the America's industries, they have contributed to over a third of the recent economic growth5. U.S. government statistics support this, and indicates that

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[2] Quoted in Office of Technology Assessment (OTA) report, "Biotechnology in a Global Environment" Forward

[3] Commerce, "Outlook" op cit., p. 83

[4] Figures from Commerce, "Emerging" op. Cit.

[5] Ira Magaziner, Business Wire, 5/12/98

one-third of the overall real growth in the country was attributed to IT, and IT will continue to be the 'engine of continued economic growth' for decades to come[6].

The business of IT, both actual and potential, is huge. Total spending on IT in 1996 in the U.S. was approximately $500 billion, and more than $1 trillion worldwide[7].

But the costs and risks associated with developing software are similar to those involved with R&D in energy and environment, and biotechnology. The risks are high, with no guarantees of profits or cash flows, which provide major impediments to investments. Thus valuation of such technologies at the R&D stage in technology parks, which reduce risks for the venture capitalists and provide a better framework for financial decision making is considered vitally important for success.

1.1.3 Energy and Environment

Countries are judged on their economic success on the basis of the degree consumption of produced goods and services achieved by its citizens. Thus, it is policy thrust of most countries to increase the well being of its people by achieving economic growth. Indeed economic growth is seen as the only way to eradicate poverty. But there is considerable doubt if economic growth can be sustained continuously, without damaging and degrading the environment. There are conflicting views on the desirability and effects of continuous growth, but environmental issues connected with economic growth have become both politically and economically sensitive. The United Nations Conference on the Human Environment 1972 was important because it established a link between concerns for the natural environment to the problem of economic development in lesser-developed countries (Common 1998). The issue then is to achieve economic growth to increase consumption and alleviate poverty, consistent with maintaining and conserving the environment. Such a concept, *Sustainable Development*, recognises, and even encourages, according to the Brundtland Report (Common 1998), economic growth in developing countries. But, says the report, developing countries must play a large role and reap large benefits,

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[6] Ira Magaziner, Senior Adviser to the President, CMP Tech Web, 5/12/98
[7] Paul A. Strassman, Method Software, Scientific American, 7/97

while industrialised countries must use less material and energy in their production activities.

R&D activities, therefore, is vitally necessary to underpin innovations consistent with sustainable growth. Clearly, firms have to re-engineer the manner in which they carry out their production activities, but it is both difficult and expensive for many to change over from tried and tested systems. Much of these R&D activities are carried out in research parks, and appropriate valuation of these technologies is important to attract venture capital.

1.2 Significance of Technology

With the rapid development of the global economy, intellectual capital has become a critical driver of a business's sustainability. The essential difference between companies operating in the 'old' and the 'new' economy is that, where value in the past was created within industrial sectors such as manufacturing, education, retail, wholesale and financial services, value in the future will be created primarily from the application of knowledge. Increasingly, the main assets of 'smart' companies will be in the form of intellectual, and not physical capital. Technology development is a logical product of intellectual capital.

The implications are clear, and have been adequately enunciated by several eminent writers in recent years. In the 21st century, comparative advantage is likely to emerge as a function of technology and skills, and human ingenuity will play a much bigger role. This is in contrast to the comparative advantage that nations derived in the past from natural resource endowments and capital-labour ratios (Houghton 2000).

According to Houghton (2000), the next wave of economic growth is going to come from knowledge-based businesses and can be characterised by the role of knowledge as a factor of production, and its impact on skills, learning, organization and innovation.

Such developments appear to be powered by so called "entrepreneurial clusters", i.e. R&D-intensive, concentrated areas which are at the forefront of IT and other innovations such as the Silicon Valley in America, and Thames Valley and Cambridge in the UK (The Economist, 1997b). They reflect the development of high-tech firms with linkages between the finance sector, a strong entrepreneurial culture, corporate research laboratories and universities that produce synergistic benefits.

Technology, and more precisely, high technology provide the means for survival for both a country and a corporation (Chacko 1988). Governments have not been blind to this fact, and many such as those of the U.S and Japan have encouraged and promoted the development of technology within their own countries. One such form of their commitment is to promote "entrepreneurial clusters", where technology is allowed to incubate and develop under a protective and nurturing environment. While the benefits of technology commercialization can produce huge financial returns, if successful, the process itself is both complex and costly. It is, however, the valuation aspects of these technologies, which are critically important from a commercial point of view, that this thesis will be examining and evaluating. And finally, based upon critical evaluations, proposals will be made for refining and improving one or more existing model(s) for use in judging the value of various technologies being developed in technology parks.

The significance of this study will be to identify the critical underlying value drivers for nascent technologies which are the output of the intellectual capital of a firm, to enable management to evaluate the viability of the project at different stages during the development process, and to develop a valuation process model incorporating these factors in the context of a research and development environment in the three critical industries identified in the foregoing paragraphs.

1.3 Research Objectives

The research objectives of this investigation is described below.

1.3.1 Definition of the Technology Value Chain

It is well understood that capitalism is undergoing revolutionary change from mass production system where the principal source of value was human labour to a new era of innovation induced production and where the principal component of value creation, productivity and economic growth is knowledge (Houghton and Sheehan 2000).

The motivation for this research is to provide an empirical and quantitative contribution to the understanding of intellectual capital, and nascent technologies, valuation. It will provide knowledge, insights and recommendations for a working valuation model to venture capitalists entrepreneurs, consultants and investors in risk management. This model will be based on a new branch of research, which has emerged in response to criticisms of the traditional valuation methodologies. A full discussion will follow in Chapter 2 Literature Review, and Chapter 3 Methodology.

1.3.2 Develop a Valuation Model

The chances of commercial success of nascent technologies, which are the output of the intellectual capital, are fraught with danger. In such an environment, the development of a valuation model in this research will provide a quantitative platform or benchmark for attracting venture capital which will reduce both uncertainties and dangers that new technologies encounter for investors. Following the analysis of case studies and postal questionnaires, (Chapters 3 and 4), logit models will be developed for valuing firms in the three high technology sectors and the outcome of the analysis is expected to highlight several pervasive value drivers for each of the three high technology sectors under investigation. From this analysis, the research will proceed to the development of a valuation process model using the results of the logit analysis.

The quantitative approach involves using the identified pervasive value drivers from the logit study to develop an econometric valuation model for intellectual capital. It should be noted that the use of underlying value drivers as a means for estimating the value of intellectual capital is a challenging endeavour, and is also a relatively new area of research (Helfert 2000).

1.4 Literature Review

The information for this study will come from primary and secondary sources through case study interviews, secondary literature research, and a survey of 300 companies through a medium of a postal questionnaire. Chapter 2 consists of an extensive literature review on traditional, current, and emerging valuation techniques and models and identifies a critical knowledge gap: the absence of methodologies and processes for the valuation of intellectual capital of knowledge-based firms. This provides the motive and justification for this research, which is to develop a valuation model of intellectual capital of firms, and contribute to knowledge in the field of valuations of firms in the new economic paradigm.

1.4.1 Intellectual Property Valuation

Valuation is the act of attaching a monetary value to a useful thing of quality. In terms of the business environment, valuation is important because it is the basis upon which rational investments are made in order to secure, among other things, future cash flows. It is therefore the basis of wealth creation. The valuation of intellectual property is particularly important because it has percolated through every aspect of life, and in a knowledge economy, its importance as a driver of profitability and wealth is unquestioned.

Because of the vexatious nature of valuing Intellectual Property, the models used for valuation purposes revolve around the traditional ones like discounted cash flows and the adjusted present value. However, such models are inadequate and inappropriate, as the following sections will describe.

A considerable body of research exists on the valuation of technologies. Most processes are a mixture of traditional and hybrid types, and other context specific models are institutionalised in a system with procedures and manuals (Copeland, 1995). But the formal method of discounted cash flow analysis (DCF) has emerged as best practice for valuing corporate assets

In knowledge-based firms, where much of the assets is intangible, and in the form of knowledge, skills and expertise, questions have arisen whether traditional financial or accounting methods are able to capture the value of the intellectual capital of the firm. In Chapter 2 Literature Review, a full discussion on these issues will be presented.

1.4.2 Models

The following section briefly describe the formal valuation methods for valuing intellectual capital, while chapter 2, literature review, examines each one in detail

1.4.3 Introduction

Valuation is a fundamental necessity for business investments to occur. Thus we need tools to determine what such investments are worth in terms of wealth creation. Such tools become particularly important for the 'new economy', in which firms are required to make major investments in intellectual property projects, primarily, to remain in business, and furthermore, to compete effectively. Ittner and Larcker (1997) stated that 'if you use the wrong measure, or if it doesn't map to economic performance, not only have you wasted a lot of money...but you've also potentially made disastrous... decisions'. It is quite obvious that without appropriate valuation tools, capital allocations could not take place in an environment in which ideas could not be developed into effective, income producing products and services, and ensure a continuing stream of cash flow in the future.

There exist today numerous models, techniques and tools for valuing technologies, and some of the more relevant and important ones are presented below.

1.4.4 Discounted Cash Flow (DCF) Method

As stated earlier, most companies today use the discounted cash flow valuation technique for valuing technologies. This approach represents discounting the future cash flows arising from a firm's assets by its cost of capital and deducting initial outlays, thus yielding its Net Present Value. But a number of severe limitations are evident in this approach (Chew 1977), and these will be discussed at length in chapter 2.

1.4.5 The Adjusted Present Value (APV) Method

The APV method is an extension of the DCF method in that it concentrates on value additivity. Managers can use APV to break up a problem into pieces that make sense from the point of view of value adding on specific projects.

APV is better equipped to handle complexities of projects, because it allows such projects to be split into pieces, for valuations to be made on each piece, and then for all the pieces to be added back (Myers 1984). However, the APV model suffers from the same inherent inadequacies as the DCF model, which will be discussed in chapter 2, literature review.

1.4.6 Option Pricing

The question of opportunities is another problem encountered with valuation issues. Opportunities may be thought of as possible future operations. This opportunity may be thought of as an option, which gives their owner the right, but not the obligation, to make an investment decision at a later date, at a predetermined price (Copeland, Koller and Murrin, 1991).

While option pricing is flexible in that a rich set of flexibility options involved in business decisions can be accounted for, the disadvantage of using this model is that it is highly complex, and still in the process of development. Instead of using the current stock price (Black-Scholes model) to value the entire opportunity of a new technology in the options pricing approach, Damodaran (Fox 1998) uses the expected cash inflows from introducing the product now, and the strike or exercise price of the stock is replaced with the present value of the costs of developing and introducing the product now.

Generally, the problems lie with the development of a body of accepted variance values, not only for the particular type of intellectual property, but the particular industry as well (Dixit & Pindyck 1995). The study of various scenarios producing various cash flows would justify the use of a variance. Unfortunately, this is so subjective that it allows for a range of viewpoints and interpretations. As a result, option pricing has not yet been widely used as a tool for valuing opportunities. (Smith, 1997)

1.4.7 The Capital Asset Pricing Model (CAPM)

The value of a technology may be stated to be the present value of its earnings over all future periods (Chew 1997). Since considerable risks are involved in estimating future earnings, the CAPM may be used as a valuation tool for assessing risk/returns relationships. The model is based on the theory of the relationship between risk and return. In its simplest interpretation it states that the expected risk premium on any security equals its beta times the market risk premium (Brigham & Houston 1998; Damodaran 1994).

While CAPM has considerable intuitive appeal (Brigham 1998), it has long been recognised that the model suffers some strong limitations, which has raised concerns about its validity. A recent study by Fama and French (1992) found no historical relationship between stocks' return and their market betas, confirming the view held by a number of academics, stock market analysts and researchers. Thus, although the CAPM represents considerable progress in asset pricing theory, there are deficiencies, which must be addressed before it becomes a reliable tool for valuation purposes.

1.5 Limitations of Existing Literature

The identified limitations of existing literature are that there is no literature for valuing nascent technologies in research parks. Further, the models used to determine value for nascent intellectual capital are inappropriate, since they were developed for a different class of assets. In situations where such a realisation is in existence, the processes used are ad hoc and unsystematic. In all these circumstances, the uncertainty of accurate valuations would increase risks and impede investments in firms investing in new technologies. These limitations will be discussed at length in chapter 2, literature review.

Yet organisations are increasingly beginning to compete on the basis of their intellectual property. But to remain competitive, firms have to make investments in intellectual capital. However, as stated earlier, investments in intellectual capital are not underpinned with sufficiently good models which increases the risks and uncertainties, impeding investments both in the business world, and more importantly, in technology parks where technology is expected to develop in a protective environment.

1.6 Methodology and Techniques

The methodology adopted in this study is to identify, evaluate and analyse the key factors, from a valuation perspective, that drive the value chain of nascent technologies throughout the development process. There steps involved in the research process are briefly described as follows:

(i) Consistent with current academic research which prescribe the need for new valuation models for intellectual capital (Heller 1994, Mavrinac 1996, Lev 1996, Helfer 2000), identify the underlying factors that create and drive value specific to each of the technologies being looked at in this study by subjecting specific case studies pertaining to them to analysis, using a case-study analysis software. The description of the software and the justification for its selection will be stated in Chapter 3, Methodology. The case studies (Chapter 4) will be written from interviews conducted with a firm operating in each of the industries selected for the study.

(ii) A questionnaire containing approximately 40 questions will be sent to 300 companies which will seek to establish if the value drivers identified from the case study analysis are pervasive or otherwise (Chapter 3)

(iii) Subject the respondents' data to statistical analysis to identify pervasive value drivers (Chapter 5)

(iv) Estimate a logistic regression model for each of the industries based on their individual value drivers (Chapter 5)

(v) Based on the results arrived at in Chapter 5, develop a valuation process model(s) for valuing intellectual capital of high technology firms, and

(vi) Test the model(s) developed for each of the industries against market data relevant to that industry.

1.6.1 Case Study and Literature Review

The primary source of information on the factors will come from current literature, and case studies drawn from companies in each of the three selected industries based in technology parks. The case studies will be subjected to analysis using case study analysis software. This will be followed by a general survey, using the medium of a postal questionnaire, of 300 hundred companies, to test the validity of the data from the case studies. The final selection of the factors for model building will be based on their pervasiveness on the valuation of the technology at the pre-commercialisation, or nascent, stage of development, and this will be discussed in detail in Chapter 3 on the methodology of the thesis.

1.6.2 Technical Review

Statistical testing will be done on the factors to determine their significance and to establish whether they should be included in the valuation process model based on the relationships established from the case study, survey and literature review conducted. The details of the statistics, the results, and the various tests to eliminate errors will be discussed in Chapter 3 (methodology) and Chapter 5 (results).

1.6.3 Building the Valuation Process Model

The study will incorporate these factors into a generic valuation framework (model) that best addresses the structure of valuation for nascent technologies. In Chapters 5 and 6, a comparative analysis will carried out using the same process model but with different variables specific to each industry to highlight characteristics and features that might be generic, and others that are industry-specific, to promote understanding of the complexity of and variations in technology valuation.

1.6.4 Data

The data required is initially obtained from materials provided by established Research Park. A selection will be made of three companies, from different industries, for an in-depth study into the various aspects of technology valuation pertinent to the industry. Empirical data will be obtained from a postal questionnaire covering 300 companies. Further, the time series data covering eleven years which will be used for the multi-variate valuation models for the three sectors under investigation in this research, will be obtained from several sources, predominantly from the Australian Bureau of Statistics, Australian Stock Exchange, and the Reserve Bank of Australia.

1.6.5 Data Required

Data required for determining the valuation process in a research and development environment include information relating to patents and their protection, R & D expenditures, quality of management, marketing skills and options, industry benchmarks and costs. A case study interview questionnaire (appendix 1) will be constructed with the intention of uncovering the underlying value drivers, which will be tested for significance by comparing them to the results of a general survey of 300 companies.

1.6.6 Data Collection and Analysis

This will be done in two stages, being at the exploratory research stage, and case studies. A total of three companies will be selected for the case study. The data will be analysed using NVIVO and Microsoft's EXCEL software, and SPSS, which is a statistical package.

As stated earlier, in order to test the validity of the results, a survey covering 300 companies will be carried out using the medium of a postal questionnaire. The results will be analysed using a statistical software (described in Chapters 3 and 5) to establish the pervasiveness and significance of the value drivers in each of the three industries selected for the study.

It is here that this research is aimed at making its major contribution to knowledge. By analysing variables in three technologies that contribute to value, then developing a process model to provide a basis of valuation, it is hoped some of the inadequacies and gaps inherent in current knowledge will be addressed, thereby increasing the confidence by which investments can be made in intellectual property.

1.7 Conclusion

This Chapter introduced the general concepts, an outline of the literature, and the framework for this research. It identified the critical knowledge gap in valuation techniques and methodologies which provides the justification and motivation of this research. In the next Chapter, there is a detailed examination of the literature pertaining to valuation methods that are currently in use for valuing assets. This is followed by an evaluation of these methods. The purpose of this critical review is to assess the validity, effectiveness, and relevance of the current methods for the purposes of valuing intellectual properties, which will provide the justification for the development of models of valuation for intellectual assets in three critical industries.

Chapter 2. Literature Review

2.1 Introduction

In Chapter 1, a brief introduction was made to the literature in the area of financial valuation, particularly that pertaining to the difficult and complex subject of valuation of intellectual capital. It was stated that, while there was sufficient literature on valuation methodologies, they were not appropriate to the valuation of intellectual capital and intellectual assets. This Chapter examines, in detail, the literature pertaining to valuation methods that are currently in use for valuing assets, and makes an evaluation of these methods, in order to assess their validity, effectiveness, and relevance for the purposes of valuing intellectual properties.

2.1.1 Definition

It is as well to commence with an explanation of the phrase 'intellectual property' and comment on its relationship with intellectual capital, intellectual assets, and intellectual resources. The current literature seems to assume an oneness of the terms 'intellectual property', 'intellectual asset', 'intellectual capital' as if they were homogenous and interchangeable. In fact, very little literature is available which seeks to distinguish these terms in relation to their valuation, and indeed, the underlying value drivers, which is the focus of this research. Even the professional accounting bodies have failed to provide guidelines within the context of what should be recorded in the balance sheets of companies, in respect of intellectual capital.

The term 'intellectual property' refers to patents, trademarks, copyrights, and trade secrets or know-how (Smith and Parr, 2000). This classification arises out the unique characteristic, that owner(s) of such property, or an asset, can be protected by law from unauthorised use, or possession of them by others, whether for profit or not. Where tangible or financial assets are concerned there is little distinction between an asset and a property, because both are afforded the same protection of ownership by law. However, in the circumstances of intellectual assets and intellectual property, some distinction can be made. Quite simply, an intellectual asset is a bank of knowledge that is codified and defined, and includes plans, procedures, memos, sketches, drawings and computer programs. Any item on this list that are legally protected are called intellectual property, and may include patents, trademarks, copyrights, and trade secrets (Sullivan 1998, Smith and Parr 2000). Most firms would seek to legally protect all or part of their intellectual assets, which would convert them to intellectual properties. Intellectual capital, on the other hand, is the knowledge capability of a firm to produce assets that can become profitable. Sullivan (1998) define intellectual capital as 'simply, knowledge that can be converted into profits. The link and relationship is clear: profitable intellectual assets cannot be created unless there are the skills, knowledge, and managerial capability present in an organisation. Therefore, what is important is that companies direct their efforts to identifying, creating and nurturing the intellectual capital base of the firm that are now regarded as critical drivers of profitability and value.

Another definition of intellectual capital can be found in the contribution of Sullivan and Edvinsson[8], who described it as *'knowledge that can be converted to value'*. In support of this definition they stated that

Intellectual capital is a topic of increasing interest to firms that derive their profits from innovation and knowledge-intensive services. In many cases, these 'knowledge firms' find that the market place values them at a price far higher than their balance sheets warrant. What is the true value of company like Microsoft? It's more that the tangible assets; the company's value is in its intangible intellectual capital as well as its ability to convert that into revenues.

In essence, intellectual capital is the knowledge capability of an organisation to convert knowledge, skills and expertise into profitable intellectual assets, and include inventions, technical know-how, design approaches, computer software and programs. When these assets become protected by patents, copyrights, trademarks, and trade secrets, they assume the character of an intellectual property.

[8] Patrick H. Sullivan and Leif Edvinsson, 'Developing an Intellectual Capital Management Capability at Skandia,' in Russell L. Parr and Patrick H. Sullivan, Technology Licensing: Corporate Strategies for Maximising Value (New York & Sons, 1996), p.249.

2.2 Implication for Valuation in this Study

The focus of this study is the valuation process of intellectual capital, which provides the foundation for the creation of intellectual assets. At a nascent stage of their development, intellectual assets are difficult, if not impossible, to value, mainly because their commercial viability cannot be determined by traditional methodologies. This is examined fully in the literature review that follows. Nevertheless, valuation at any stage of the development of an intellectual asset is important, not least because without data about an asset's value, no investments will be possible to convert commercial potential into profitable reality.

While the benefits of converting nascent technologies into commercial products and services can produce huge financial returns, if successful, the process itself is both complex and costly. It is, however, the valuation aspects of these technologies, which are critically important from a commercial point of view, that this thesis will be examining and evaluating. And finally, based upon critical evaluations, proposals will be made for refining and improving one or more existing model(s) for use in judging the value of various technologies being developed in technology parks.

As stated in Chapter 1, Introduction, the significance of this study will be to identify the critical underlying valuation factors for technological development to enable management to evaluate the viability of the project at different stages during the development process and to develop a valuation process model incorporating these.

Research on valuation based on critical underlying value drivers to replace the traditional methodologies and techniques follow severe criticism centered on their inability to capture the true value of the intellectual capital of firms. This is discussed in the following sections of this Chapter.

2.3 Importance of Intellectual Property to company value

Arthur (1996) states that diminishing returns hold sway in the traditional part of the economy – the processing industries-, while increasing returns reign in the newer part, which consist of the knowledge-based industries. New economy businesses have been achieving market capitalisation levels at a much faster pace than those in the old economy. Bontis (1996), states that different 'understandings', in the form of different management techniques, strategies and government regulations are needed for managing firms in the old and new economies. It is widely aserted that technology (which is an output of intellectual capital) is the fundamental factor that will sustain the current rate of growth, profitability and high share prices. Lehmann (1996) states that economic growth and competitiveness will be determined by the ability to create, own preserve and protect intellectual property. But the pace of technology development is fast, and companies cannot afford to use outdated and redundant intellectual properties in the face of ever increasing competition. Thus the role of technology innovation and development becomes increasingly important from a strategic viewpoint. De Long (1996) states that the valuation of companies as expressed in the share prices really reflect the underlying fundamentals, of which the major one is technology, and which is also the factor that is transforming the economy and generating a global economic boom.

Australia is no exception to the new economic paradigm where the economy's fortunes are closely tied to the speed of the transformation that companies are able to make from the old to the new economy. According to Tegart, Johnston and Sheehan (1998), knowledge and people are core resources in the knowledge-based economies and 'matching the education and skills of the workforce, and government policy are crucial for Australian industry to remain competitive in the global economy. The knowledge sector includes the necessary pool of skilled workers who have the ability to make continual contributions to the development of intellectual property.

But knowledge and intellectual capital are not easy to measure, and there are formidable obstacles to developing a perfect model for this purpose. Furthermore, there are no public markets that would establish meaningful values. In fact, Drucker (1993), argued that to calculate a meaningful 'return on knowledge' would be a near impossible task, presumably because it is so difficult to price the value of intellectual assets.

In spite of its undoubted importance, valuation techniques for intellectual capital remain inadequate (Dabek 1999). For those assets being developed within technology parks, the situation is even more unsatisfactory. It will seen in Chapter 4, Case Studies, that even large firms have no established framework for valuing their new technologies, but use 'guesstimates' and 'rules of thumb' for this purpose.

The objective of this research, then, is to provide objective processes of valuation of technologies that are in their early stages of development within the laboratories of La Trobe University's Research Park, which, with their commercialisation will, it is hoped, provide the platform for profitability and growth, and prosperity.

2.4 Current Valuation Methods

Current valuation models are discussed and evaluated in the following sections.

2.4.1 Valuation and Price

The question 'what is value?' is sometimes difficult to define, although it is a fairly basic question that an analyst might ask. There is a plethora of explanations provided in many economics and financial journals, and even Webster's Dictionary gives eight different definitions of value. However none of them is satisfactory from a financial decision making point of view. According to Rao (1992), value is really only economic value, and social, ethical, and moral values are not central to it. This means that value must have an identifiable nexus with profitability and wealth creation. Thus investments in new technologies must be viewed as activities connected with maintaining competitiveness by firms to create opportunities for future profits and shareholder wealth. It is in this context that this research aims to make a major contribution: to uncover the underlying drivers of value in three key industries in which value may be determined by their employment and utilisation of intellectual capital.

For an asset to have value, it must be seen to have two characteristics: Firstly, it must have the potential for providing benefits, and secondly, acquiring it must involve a cost to the owner of the asset. An example would be a manufacturing plant which, which would have been acquired for a cash value, and would possesses an economic value because it provides an opportunity for the owners to generate cash benefits by using it to make saleable goods. Even it the plant is obsolete, it might still possesses some economic benefits in the form of scrap value, or trade-in value. Thus, all intellectual capital may have some value, but this may not be significant. This research is concerned with establishing significant and pervasive value drivers in each of the three industries, with the objective of formulating a framework for valuing such intellectual capital.

Value is associated with, and connected to, sacrifice. In other words, obtaining benefits must involve some initial sacrifice, and the potential benefits must be seen to be directly related to the sacrifice. Benefits may be tangible or intangible, but tangible benefits have the advantage of being physical, easily identifiable, and generally, easily quantifiable. In valuing new technologies, this paper will be confined to measuring tangible benefits, provided by acquiring the asset, in the form of cash flow streams, or sale value, or value provided by any other way, for example, licensing the technology.

In terms of the acquisition of an asset, the word 'cost' has a special meaning. The true cost of anything is the most valuable alternative given up or 'sacrificed'. This is really the opportunity cost, and is the cost most relevant to financial decision making. The identification of opportunity cost arises out of the recognition that every act of choice involves an act of sacrifice. Benjamin Franklin stated:

"Remember that time is money. He that can earn ten shillings a day by his labour, and goes abroad, or sits idle one half of that day, tho' he spends but six pence during his diversion or idleness, ought not to reckon that the one expense; he has really spent or rather thrown away five shillings besides.[9]"

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[9] Benjamin Franklin's 'Advice to a Young Tradesman', Papers, vol.3, pp.306-308, first printed on July 21, 1748. Reprinted in 'The Political Thoughts of Benjamin Franklin, ed. R.L. Ketcham (Indianapolis:Bobbs-Merrill, 1965.

Opportunity costs are estimated by looking at alternatives that are available elsewhere. Further, they are related to value because opportunity costs are reflected by the use of appropriate discount rates in time-value calculations, which is one of the methods that will be used in valuing new technologies.

Thus 'valuation' means the direct outcome of methods and processes used to value an asset, while 'price' is about using the (valuation) outcome to reach an agreement for buying and selling. In other words, price is about the exchange of ownership of an asset for an agreed monetary value, while 'value' is an opinion(s) about an asset's intrinsic worth.

Razgaitis (1999) states:

"Pricing is about using the valuation findings to reach an agreement. Pricing is the internal and external communication of perceived value. Pricing is also the concrete answer to valuation, the specification in monetary or equivalent terms of what is offered for sale. Valuation as we shall see, tends to produce a range of numbers, either as a result of different methods used or as an expression of uncertainty in value; pricing is the proposed number. Yet another way of expressing the difference is this: Valuation is an opinion; pricing is a commitment."

2.4.2 Accounting Methods

While identifying intellectual assets within an organisation is difficult enough, measurement of them is even more arduous. The situation is not helped by the lack of accounting standards, or even guidelines, by which an organisation can measure and value identified intellectual assets, as the following section demonstrates. There are several accounting valuation methods available, but one that is the only permitted for financial reporting purposes is historical cost based. Unfortunately, this method fails to capture the value of intellectual capital on the basis of opportunities available to managers to proceed with the investment, sell it, delay its implementation, or seek new information before continuing to support it. Its basis is to count the cost of development, rather than compute its value through the input of knowledge, skills, techniques, which are the hallmarks of a knowledge-based firm.

According to Mohammed J. Abdolmohammadi and Lynette Greenlay[10] (1999), there are three accounting methods that should be adopted for the purpose of measuring and valuing intellectual capital.

The first method is termed the ROA method which uses the average pre-tax earnings of a company for three to five years. When divided by the average tangible assets of the company over the same period, it will yield the Return on Assets (ROA). It is then compared with the company's industry average to calculate the difference. If this difference is zero or negative, the company is seen not to have an excess intellectual capital over its industry average. However, if the difference between the company's ROA and its industry average is positive, then the company is assumed to have excess intellectual capital over its industry. This excess ROA is then multiplied by the company's average tangible assets to calculate an average annual excess earning. By dividing this excess earning by the company's average cost of capital, one is able to derive an estimate of the value of its intellectual capital.

This method is simple to use and the information needed for it is readily available in historical financial statements.

The second method, known as the Market Capitalization Method (MCM), reports the excess of a company's market capitalization over its stockholders' equity as its intellectual capital. Considering the effects of inflation or replacement costs would further rectify the value.

This method is reasonably simple to use, and produces fairly accurate results. However, to fine-tune this method, historical financial statements have to adjusted for the effects of inflation, or replacement costs. Using historical data may distort the measurement, particularly in industries with particularly large balances of old capital assets, such as mines and heavy engineering production plants.

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[10] The authors are based at Bentley College of the Cambridge Institute of Applied Research

The third method, known as DIC (Direct Intellectual Capital) method, is the most complex means of measuring intellectual capital. It results from the decomposition of intellectual capital into the market and intangible assets, which are then individually assessed. This, according to the authors, provides the most accurate method of valuing and measuring intellectual capital. However, the DIC method is very complex and expensive to implement and maintain because of the very large number of components that have to be identified and individually measured.

While the three methods are technically sound, they have little relevance for valuing new technologies, primarily because they rarely have a historical income streams, and secondly, because very few of the firms, developing new technologies within La Trobe's Research Park are quoted on the Stock Exchange. Thirdly, financial reporting standards would not permit the accounting for value using these techniques. If they were to be used, these methods would be ad hoc and lack standardisation, and could not be used for purposes of comparison between firms.

In latter sections of this Chapter, a discussion is presented about the full range of academic criticism in respect of using financial accounting methods for reporting valuation issues in knowledge based companies.

2.4.3 Financial Methods

The currently used financial methods are discussed and evaluated in the following sections.

2.4.4 Discounted Cash Flow (DCF) Method

In the late 1970s, discounted cash flow analysis (DCF) emerged as best practice for valuing corporate assets. And one particular version of DCF became the standard. According to that method, the value of a business equals its expected future cash flows discounted to present value at the weighted-average cost of capital (WACC).

Today, WACC based standard is not solely used as a valuation model. This is not to say that it no longer works—indeed, with today's improved computers and data, it probably works better than ever. But it is exactly those advances in computers and software, along with new theatrical insights, that make other methods even better. Since the 1970s, the cost of financial analysis has come down commensurately with the cost of computing—which is to say, breathtakingly. One effect of that drop in cost is that companies do a lot more analysis. Another effect is that it is now possible to use valuation methodologies that are better tailored to the major kinds of decisions that manager's face (Barwise, 1987).

The discounted cash flow of a technology can be arrived by the following formula:

$$NPV = CF_0 + \frac{CF_1}{(1+k)^1} + \frac{CF_2}{(1+k)^2} + \dots\dots\dots\dots + \frac{CF_T}{(1+k)^n}$$

(where NPV – the net present value; CF_t = the cash flow for period t, where t = 1, 2, …., T; and k = the discount rate)

A forecast is first made of the business cash flows that include revenues, expenses, and new investments, but which exclude cash flows associated with the financing aspects of projects, such as interest, principal payable on loan capital, and dividend payments on equity capital.

Secondly, the discount rate used for calculating the Net Present Value of the project is adjusted to reflect whatever value is created or destroyed by the financing program. This rate, the WACC, is also intended to pick up the value of interest tax shields that come from using an operation's debt capacity (Myers, 1984).

A number of limitations are clearly inherent in the DCF model. Chew (1997) states the model is less helpful in valuing businesses with substantial growth opportunities or intangible assets. Since development of a technology represents, in many ways, the opportunity, or option, to make investments at a later time, the DCF method is not, in his estimation, a helpful tool in valuing intangible assets. He also states that DCF is no help at all for pure research and development, and that the value of R&D is almost all option value, because the value of intangible assets is usually options value.

The calculation of an appropriate discount rate is also an issue that argues against using the DCF model in valuing technology. If a set of cash flows over time were calculated, there would be a discount rate that would yield the correct present value. However, establishing what the correct discount rate is very difficult indeed. The current use of a Weighted Average Cost of Capital (WACC) is regarded by Chew (1997) as nothing more than highly imperfect rule of thumb.

The most common valuation problem is valuing operations, or asset-in-place. Valuing nascent technologies would be an example of valuing an asset-in-place. Often managers need to estimate the value of an ongoing business or some part of one—a particular product, market, or line of business, or indeed, a new technology. Or they might be considering a new equipment purchase, a change in suppliers, or an acquisition. In each case, whether the operation in question is large or small, either it is a whole business or only part of one, or the corporation has already invested in the activity or is deciding now whether to do so. The question is, how much are the expected future cash flows worth, once the company has made all the major discretionary investments?

That is precisely the problem at which traditional DCF methods are aimed. A discounted-cash-flow analysis regards businesses as a series of risky cash flows stretching into the future. The analyst's task is first, to forecast expected future cash flows, period by period; and second, to discount the forecast to present value at the opportunity cost of funds. The opportunity cost is the return a company (or its owners) could expect to earn on an alternative investment entailing the same risk. Managers can get benchmarks for the appropriate opportunity cost by observing how similar risks are priced by capital markets, because such markets are part of investors' set of alternative opportunities (Myers, 1984).

Opportunity cost consists partly of time-value—the return on a nominally risk-free investment. This is the return you earn for being patient without bearing any risk. Opportunity cost also includes a risk premium—the extra return you can expect commensurate with the risk you are willing to bear. The cash flow forecasts and the opportunity cost are combined in the basic DFC relationship.

Today most companies execute discounted-cash-flow valuation using the following approach: First, they forecast business cash flows (such as revenues, expenses, and new investment), deliberately excluding cash flows associated with the financing program (such as interest, principal, and dividends). Second, they adjust the discount rate to pick up whatever value is created or destroyed by the financing program. WACC is by far the most intended to pick up the value of interest tax shields that come from using an operation's debt capacity (Myers, 1984).

The practical virtue of WACC is that it keeps calculations used in discounting to a minimum. The concept of averaging the various costs of capital available to the company is reasonably easy to understand, and the reason for its use in a DCF calculation it is quite sound. But WACC's virtue comes with a price. It is suitable only for the simplest and most static of capital structures. In other cases (that is, in most real situations), it needs to be adjusted extensively—not only for tax shields but also for issue costs, subsidies, hedges, exotic debt securities, and dynamic capital structures. Adjustments have to be made not only project by project but also period by periods within each project. Especially in its sophisticated, multilayered, adjusted-for-everything versions, 'the WACC is easy to misestimate. The more complicated in company's capital structure, tax position, or fund-raising strategy, the more likely it is that mistakes will be made.

2.4.5 Adjusted Present Value

Today's better alternative for valuing a business operation is to apply the basic DCF relationship to each of a business's various kinds of cash flow and then add up the present values. This approach is most often called adjusted present value, or APV. It was first suggested by Stewart Myers of MIT, who focused on two main categories of cash flows: "real" cash flows (such as revenues, cash operation cost, and capital expenditures) associated with the business operation; and "side effects" associated with its financing program (such as the values of interest tax shields, subsidised financing, issue costs, and hedges). More generally, APV relies on the principle of value additivity. That is, it's okay to split a project into pieces, value each piece, and then add them back up. (Myers, 1984). APV may be expressed by the following:

$$NPV^A = CF_0^{\ A} + \frac{CF_1^{\ A}}{(1+k)^1} + \frac{CF_2^{\ A}}{(1+k)^2} + \ldots\ldots\ldots\ldots + \frac{CF_T^{\ A}}{(1+k)^n}$$

$$NPV^B = CF_0^{\ B} + \frac{CF_1^{\ B}}{(1+k)^1} + \frac{CF_2^{\ B}}{(1+k)^2} + \ldots\ldots\ldots\ldots + \frac{CF_T^{\ B}}{(1+k)^n}$$

$$APV = NPV^A + NPV^B$$

(Where: APV = the adjusted present value; NPV^A & NPV^B = the net present value of investment components A & B; $CF_t^{\ i}$ = the cash flow for investment i in time period t, t = 1, 2, …., T; and k = the discount rate)

APV helps when one wants to know more than merely, Is NPV greater than zero? Because the basic idea behind APV is value additivity, one can use it to break a problem into pieces that make managerial sense. A good illustration can be found in a situation where an acquisition of one company by another takes place. Even after the deal has closed, it helps to know how much value is being created by cost reductions rather than operating synergies, new growth, or tax savings. Such an analysis is often not found in traditional DCF calculations.

Or consider an investment in a new plant. One may negotiate specific agreements with, for example, equipment suppliers, financiers, and government agencies. In both examples, different people will be in charge of realizing individual piece of value. APV is a natural way to get information about those pieces to managers—or for them to generate that information for themselves (Myers, 1984).

Executives are discovering that APV plays to the strength of now commonly used spreadsheet software: each piece of the analysis corresponds to a subsection of a spreadsheet. APV handles complexity with lots of subsections rather than complicated cell formulas. In contrast, WACC's historical advantage was precisely that it bundled all the pieces of an analysis together, so an analyst had to discount only once. Spreadsheets permit unbundling, a capability that can be powerfully informative. Yet traditional WACC analyses do not take advantage of it. Indeed, many managers use their powerful spreadsheet merely to generate dozens of bundled valuation analyses, rather than to produce unbundled analyses that would be managerially relevant.

WACC still had adherents, most of who argue that it works well enough when managers aim for a constant debt-to-capital ratio over the long run. Some go even further, saying that managers ought to aim for exactly that—and so therefore WACC is appropriate. But whether managers ought to behave thus is highly questionable; that they do not, in fact, follow this prescription is indisputable. To state that managers should maintain constant debt ratios because that policy fits the WACC model is unsuitable from the viewpoint of objective valuations.

While APV is very good at handling complexities of projects, and is superior to the traditional DCF model, it suffers from the same inadequacies in valuing technology as the DCF model. Where it draws the most criticism is in its use of WACC which, as stated above, has been described as nothing more than 'a highly imperfect rule of thumb'.

2.4.6 Equity Cash Flows

Claims that companies issue against the value of their operations and opportunities are the last major category of valuation problem. When a company participates in joint ventures, partnerships, or strategic alliances, or makes large investments using project financing, it shares ownership of the venture with other parties, sometimes many others. Managers need to understand not simply, the value of the venture as a whole but also the value of the company's interest in it. That understanding is essential to deciding whether or not to participate as well as how to structure the ownership claims and write good contracts (Black, 1998).

Suppose a company is considering investing in a joint venture to develop an office building. The building itself has a positive NPV—that is constructing it will create value. What's more, the lead developer is confident that lenders will provide the necessary debt financing. An investor is being asked to contribute funds in exchange for an equity interest in the venture. Should he invest? If all he has done is to value the building, he can't tell yet. It could be that his partner stands to capture all the value created so even though the building has a positive NPV, the investment does not. Alternatively, some ventures with negative NPVs are good investments because a partner or the project's lender makes the deal very attractive. Some partners are simply imprudent, but others---governments, for example---deliberately subsidise some projects (Copeland, 1995).

A straightforward way to value your company's equity is to estimate its share of expected future cash flows and then discount those flows at an opportunity cost that compensates the company for the risk it is bearing. This is often referred to as the equity cash flow (ECF) approach; it is also called flows to equity. It is, once again, a DCF methodology, but both the cash flows and the discount rate are different from those used either in APV or the WACC-based approach. The business cash flows must be adjusted for fixed financial claims (for example: interest and principle payments), and the discount rate must be adjusted for the risk associated with holding a financially leveraged claim (Rappaport, 1996).

Holding leverage properly is most important when leverage is high changing over time, or both. In those situations, lenders interests may diverge from those of shareholders, and different shareholders' interests may diverge from one another. Such divergence is especially common in transactions that produce or anticipate substantial changes in the business or its organisation—in mergers, acquisitions, and restructuring, for example.

Unfortunately, leverage is most difficult to treat properly precisely when it is high and changing. When leverage is high, equity is like a call option, owned by the shareholders, on the assets of the company. If the business is successful, managers acting in the best interests of the shareholders will "exercise the option" by paying lenders what they are owed. Shareholders get to keep the residual value. But if the business runs into serious trouble, it will be worth less than the loan amount, so the borrower will default. In that situation, the lenders will not be repaid in full; they will, however, keep the assets in satisfaction of their claim.

It is widely understood that highly leverage equity is like a call option because of the risk of default. Why not use an option-pricing approach to value the equity? Because the options involved are too complicated. Every time a payment (interest or principle) is due to lenders, the borrowers have to decide again whether or not to exercise the option. In effect, levered equity is a complex sequence of related options, including options on options. Simple option pricing models are not good enough, and complicated models are impractical. That is why it's worthwhile to have ECF as a third basic valuation tool.

It's important to state that an ECF valuation, no matter how highly refined, is not option pricing, and therefore will not give a 'correct' value for a levered equity claim. But ECF can be executed so that its biases all run in the same direction—toward a low estimate. So, although the answer will be wrong, the careful analyst knows that it will be low, not high, and why.

The key to using ECF is to begin the analysis at a point in the future beyond the period in which default risk is high. At that point, an analyst can establish a future value for the equity using conventional DCF methods. Then ECF works backward year by year to the present, carefully accounting for yearly cash flows and change in risk along the way, until it arrives at a present value. The procedure is quite straightforward when built into a spreadsheet, and if certain formulaic rules are adopted for moving from later to earlier years, ECF's biases contrive to underestimate the true equity value. The formulaic rules amount to an assumption that borrowers will not really walk away from the debt even when it is their best interests to do so. Obviously, this assumption deprives them of something valuable—in real life they might indeed walk away, so the real-life equity is more valuable than the contrived substitute.

An ECF analysis also shows how change in ownership structures affect cash flow and risk, year by year, for the equity holders. Understanding how a program of change affects the company's owners helps to predict their behaviour—for example, how certain shareholders might vote on a proposed merger, restructuring, or recapitalisation of the venture. Such insight is available only form ECF or its variations (Brailsford et al., 1998).

Analysts have often asked the question why DCF and not ECF is used for valuation purposes. Some evaluate equity claims by first valuing the entire business (with WACC-based DCF) and then subtracting the value of any debt claims and other partners' equity interests. This approach requires managers to presume they know the true value of those other claims. In practice, they don't know those values unless they apply ECF to estimate them. Another common approach is to apply a price-earning multiple to the company's share of the venture's net income. That has the virtue of simplicity. But finding or creating the right multiple is tricky, to say the least. Skillfully chosen price-earning ratios may indeed yield reasonable values, but even then they don't contribute the other managerial insights that flow naturally from the structure of an ECF analysis (Brailsford et. al., 1998).

2.4.7 Valuing Opportunities: Option Pricing

Valuation is a fundamental necessity for business investments to occur (see Oh and Islam 2001; Oh and Islam forthcoming). Thus we need tools to determine what these investments are worth in terms of wealth creation. Such tools are particularly important for the 'new economy' or 'knowledge economy', in which firms are required to make major investments in intellectual property projects, particularly in those relating to new technologies, to compete effectively. Ittner and Larcker (1997) state that 'if you use the wrong measure, or if it doesn't map to economic performance, not only have you wasted a lot of money...but you've also potentially made disastrous... decisions'. It is quite obvious that without appropriate valuation tools, capital allocations could not take place in an environment in which ideas could not be developed into effective, income producing products and services, and ensure a continuing stream of cash flow into the future.

There are numerous models today with techniques and tools for valuing technologies but one that is particularly credible, meaningful and realistic is the Options Pricing Model. Its value lies is that it overcomes some of the commonly encountered problems associated with traditional models such as NPV.

2.5. Knowledge Economy: Opportunities and Options for Valuation

Valuation research in economics is extensive and increasing, and is complicated by the emergence of the knowledge economy. The study of knowledge as a key variable for determining value has been given significant attention in economics. Information and knowledge aspects of business have not received the same attention as the trilogy of capital, labour and resources – leading to a situation of uncertainty about the economic impact of information, as a key economic resource, for the exploitation of virtual business or e-commerce. The virtual world is one where many of the conventional constraints of physical economic processes (research and development R&D), manufacturing, distribution and marketing) no longer apply and firms, big or small, can compete with anyone in the world just as easily.

Contrary to the conventional economic theory of diminishing returns developed in the nineteenth century, Arthur (1996) advocates the law of increasing returns. The foundations that the law of increasing returns is based upon rely on manipulating and exploiting the information and virtual aspects of a business. According to Arthur, increasing returns 'are the tendency for that which is ahead to get further ahead, for that which loses advantage to lose further advantage.' This holds true for industries that have no constraints on resources, such as high technology and knowledge-based industries. A business consists of both the physical and the virtual and while the physical may be subject to constraints, the virtual is not.

Arthur (1996) defines the criteria for firms subject to increasing returns as those having made high investments in information systems in their operations. They are now using this information relatively cheaply. They are capable of locking in customers and networking by supplementing one firm's core strengths with those of another and creating a win-win situation for all. In equity valuation, the current market conditions call for a shift to new theories of the growth of firms. An assumption of the new growth theories should be the presupposition of the possibility of super normal profits in the hands of able management. The current trend of mega corporate mergers and acquisitions[11] is growing and will continue to be prevalent as strategic alliances continue to be struck to exploit e-commerce capabilities, including management and technical expertise. A parallel can be drawn between the present e-commerce firm and the neo-Schumpeter model of repeated innovation by a 'new theory' firm.

Schumpeter (1934) emphasised the important role played by the financial sector in economic growth. Schumpeter's theory of economic development promotes the causal relation between the financial and the real sectors. The benefits derived from the financial sector are the efficient intermediation between lenders and borrowers through capital mobilisation, risk management, project screening and monitoring and transaction cost reduction. These activities invariably contribute to efficient allocation of resources by addressing the problems of high transaction costs and information asymmetries, a situation reinforced by electronic banking on the Internet. Therefore, the financial sectors disseminate information about the real market factors influencing economic growth and ultimately stock prices as reflected by financial variables. Fama (1970, 1990, 1991) conducted an extensive study of the relation between stock market returns and fundamental economic activities in the United States. Several authors have (Oh and Islam 2001; Oh and Islam forthcoming) modelled the relation between asset prices and real economic activities using factors such as productivity, growth rate of gross national product, production rates, yield spread, inflation, unemployment and other real activity indicators. Most notably, the continued rapid growth of the knowledge economy has significant effects on the structure and functioning of financial economies of the firm, sector and aggregate level.

In the post industrial revolution era, the growth of national economies has been strong due to the increasing availability of material goods, services, and wealth as well as knowledge. The factors of economic growth also include capital stock, knowledge,

[11] Example of recent mergers and acquisitions include the AOL-Time Warner merger in the US creating the largest firm in the world in terms of market capitalisation.

science and technology, population, innovation, the supply of resources, better management practices, improved productivity, and other related economic factors. However, the accelerated rate of economic growth has modified the traditional structure and institutional basis of the economy. This has been accompanied by by-products of fundamental consequences such as globalisation, the emergence of the knowledge economy, and regional convergences and divergences of economic growth of different countries (Islam 2001; Sheehan and Tegart 1998). The important characteristics of a knowledge economy may be summarised as the increasing knowledge intensity of the economy, the rise of the online economy, the rising value of knowledge and market failures, and integrated international markets and globalisation (Sheehan and Tegart 1998). With the emergence of the knowledge economy and the changes in the growth rate and structure of the economy, several issues about its analysis and management, especially the relations between finance and real economic activities in the knowledge economy, have originated. Some of the relevant issues of e-commerce finance in the knowledge economy are summarised in the following sections (Oh and Islam 2001; Oh and Islam forthcoming).

Australia has recorded remarkable economic performance, experiencing a rise in trend growth (GDP per capita) in recent years. A rapidly changing economy in which, information and communications technology (ICT) plays an increasingly important role in restructuring economic activities resulting in strong non-inflationary growth, high stock market valuations, low unemployment are evidence of economic progress. The pervasive role of ICT applications span across a wide range of sectors in the economy has heralded in the era of the New Economy. The World Wide Web (WWW) is inextricably entangled in the structures of law, custom and e-commerce. An application of the Internet has grown exponentially over the past five years and is generally expected to continue this trend in the medium-term (Coppel 2000). The estimates for electronic transactions expect a five-fold growth over the next three to four years.

The recent global volatility in technology stocks has raised questions regarding the underlying value of market capitalisations that appear to defy all conventional financial evaluations and economic fundamentals.[12] The present market scenario for e-commerce stock valuation is unclear and at best is an inconsistent measurement of e-commerce equity investment according to traditional measures. The movements of stock prices since World War II were closely connected to the rate of economic growth and economists had no trouble in explaining the resulting stock returns by standard valuation models according to which stock prices are determined by market fundamentals. But the recent volatility of the technology stock prices are more troublesome and the question has been asked whether these stock prices can still be explained by fundamentals, or whether speculative bubbles and fads govern these prices.

The global market euphoria in e-commerce stocks raises the question of the underlying value of their market capitalisation, which appears contrary to conventional financial valuation wisdom. Are technology stocks really worth their market value or are the brokers 'noise-trading' (Black 1986) and over-hyping these shares to euphoric investors? An argument for the current valuation of technology related stocks is that information technology, which provides the impetus for the role of macroeconomic or real variables current market boom on a global scale, is a fundamental factor transforming the economy (De Long 1996). The stock market reflects this future growth of the economy because investors, optimistic about the new economy, factor this into their investment decisions. Economic growth in the post-industrial era is expected to occur at a faster rate and earnings growth would also be faster than before and this fundamentally justifies the current stock prices. It follows that the value of e-commerce stocks is currently valued based on the potential outcomes and economic impacts of e-commerce, the forces underlying its development. This paper predominantly considers non-standard balance sheet or income statement information as inputs to develop a valuation model that overcomes the limitations of traditional valuation methods.

Opportunities to make investments are commonly encountered with the ensuing valuation problem, and should be thought of as possible future operations. A decision on how much to spend on research and development (an investment decision problem

[12] Alan Greenspan's speech at the Economic Club of New York, January 2000.

in the knowledge economy), now or in future, or the kind of R & D expenditure that the firm should be making, are decisions involving the valuation of opportunities. The decision to make spending commitments now creates, not cash flow from operations, but the opportunity to invest again later, depending on how things look. For example, marketing expenditures that appear to have the same characteristics. Spending to create a new or stronger brand probably has immediate payoff. But it also creates opportunities for brand extensions later. The opportunity may or may not be exploited ultimately, but it is valuable nonetheless (Lueharman 1998). Companies with new technologies, product development ideas, a defensible position in fast-growing markets, or access to potential new markets are considered to own valuable opportunities. For some companies, opportunities are the most valuable things they own because they provide possible avenues for future cash flows.

The question then arises as 'how do corporations typically evaluate opportunities?'. A common approach is not to value them formally until they mature to the point where an investment decision can no longer be deferred. At that time, they join the queue of other investments under consideration for funding. This approach invites criticism as being shortsighted because it leads companies to undervalue the future and hence, to under-invest.

Reality appears to be more complicated and depends a great deal on how managers are evaluated and rewarded. (Kester 1984). The absence of a formal valuation process often gives rise to personal, informal procedures that can produce incongruent decisions. Managers with political clout within an organisation may promote and defend the opportunities that they regard as valuable, often resulting in over-investment in poor opportunities and under-investment in good ones.

Some companies use a formal DCF-based approval process, but evaluate strategic projects with special rules. One such rule assigns strategic projects a lower hurdle rate than that assigned to routine investments to compensate for DCF's tendency to undervalue strategic options. Unfortunately, in many cases the DCF's model's negative bias is not merely overcome, but overwhelmed by such an adjustment. Once again, over-investment can occur in practice, where theory would have managers worry about under-investment. Another special rule evaluates strategic opportunities off-line, outside the routine DCF system. For better or worse, experienced executives make judgment calls based on heuristics. Sometimes that works well, but the best managers back up their judgement with sound analyses where possible.

In general, the right to start, stop, or modify a business activity at some future time is different from the right to operate it now. A specific decision - whether or not to exploit the opportunity – has yet to be made, can be deferred. The right to make the decision optimally - that is, to do what is best when the time comes - is valuable. A sound valuation of business opportunity captures its contingent nature: "If R&D proves that the concept is valid, we'll go ahead and invest." The unstated implication is that "if it doesn't, we won't."(Hull 1993).

2.6 Option Pricing and Option Pricing Models

The crucial decision to invest or not will be made after some uncertainty is resolved or when time runs out. In financial terms, an opportunity is analogous to an option. An option provides the right, but not the obligation, to buy or sell something at a specific price on or before some future date. A call option on a share of stock gives an investor the right to buy that share say for $100 at any time within next year. If the share is currently worth $110, the option clearly is valuable. What if the stock is worth only $90? The option still is valuable because it won't expire for a year, and if the stock price rises in the next few months, it may well exceed $100 before the year passes. Corporate opportunities have the same feature: "If R&D prove that the concept is valid" is analogous to "if stock price rises in the next few months". Similarly, "we'll go ahead and invest" is analogous to "we'll exercise the option." (Hull 1993).

An option is a contract giving its owners the right to buy or sell an underlying asset at a fixed price on or before a given date (Ross 1988). As stated earlier, options are a unique type of financial contract because they give the buyer the right, but not the obligation, to do something. The buyer uses the option only if it is a smart thing to do, that is, there is financial value in doing it. If there is no value, or little value in exercising the option, then it can be discarded.

The most common type of option is a call option, which gives the owner the right to buy an asset at a fixed price during a particular time period. This is analogous to exercising the option to make the investments in a new technology after due consideration of all factors about the project. The price of a call option has been described as a function of five variables (Black and Scholes 1973). These are:

- **Current share price**. The higher the current share price, the higher the value of the lower (and upper) bound of the option price. Thus, the option's price will increase as the share price increases. This relationship can also be appreciated by recognising that as the share price increases, so does the expected payoff of the option.
- **The exercise (or striking) price**. The higher the outlay to acquire the underlying share at the time of exercise of the option, the less the option is worth, which means that the call option price would be a decreasing function of the exercise price.
- **The risk-free rate of return**. As the risk-free rate rises, the present value of the exercise price falls and the option becomes more valuable. Therefore, a call option price is an increasing function of the risk-free rate of return.
- **The time to maturity**. Increasing the time to maturity also increases the price of an option. The further into the future is the payout of the exercise price, the lower is its present value. Like an increase in the risk-free rate, the effect is an increase in the lower boundary for the price of the option.
- **The variance of the share price**. The price of an option is an increasing function of the variance of the underlying share price. At first, this relationship may seem to contradict a standard assumption that investors are risk averse and, therefore, would pay a lower, rather than higher price for greater variance. When an investor holds a share he/she is concerned about both good and bad share price outcomes, as payoffs are received from the entire probability distribution of possible share prices. If, however, an investor holds a call option on the share, a payoff is received only if the current share price exceeds the exercise price. Thus, only the probability of the current share price being greater than the striking price is of interest. If the variance of the share price increases, the probability of the current share price being greater than the exercise price increases, and therefore the option becomes more valuable.

Thus, an increase in variance of the share price increases the possible positive payoff without affecting the size of possible losses from the option, and would, therefore, lead to an increase in the options' price (Bishop 1988).

Black et al. (1973) derived a formula for pricing call options, which is referred to as the Black-Scholes Options Pricing Model, in which they asserted that the price of an option is a function of the five variables stated above.

$$C_0 = S_0N(d_1) - Ee^{-rft}N(d_2)$$

$$d_1 = [\ln(S_0/E) + (r_f + 1/2\sigma^2)t]/\sqrt{\sigma^2 t}$$

$$\boldsymbol{D_2 = D_1 - \sqrt{\sigma^2 T}}$$

where

$N(d)$ = Probability that a standardised normally distributed random variable will be less than or equal to d

σ^2 = Variance (per year) of the continuous return on the stock

t = Time (in years) to expiration date

r_f = Continuous risk-free rate of return (annualised)

The formula is complicated, but is regarded as one of the most practical (Ross 1988). The attraction of the formula is that four of the parameters are observable: the current share price, the exercise price, the risk-free rate of return, and the time to maturity. Only one of the parameters must be estimated, namely, the variance of the share price. This aspect of the Pricing Model makes it practical for managers to use it to price various business opportunities, including capital projects.

2.7 Options Pricing Models and a Firm's Investment Decisions

When considering the investment opportunities available to the firm, managers should pay attention to the options, which are included within these opportunities. These include future investment opportunities, which are *real options* for the firm and options to invest, expand and/or abandon existing projects.

The investment opportunities available to a firm may include opportunities to invest in real assets under potentially favorable conditions at some future point in time. These opportunities are called *real options*, and are analogous to a call option where the underlying asset is the project. Therefore, the present value of a project on which the firm has an option is analogous to the variable 'current share price' in Black-Scholes. Similarly, the 'expected (striking price)' is analogous to the outlay required to undertake the project; 'the time to maturity' is analogous to the time left before the decision to invest in the project must be made; and the 'variation of the share price' is analogous to the uncertainty associated with the project.

Luehrman has published a series of papers in the *Harvard Business Review* (1998) which supports the view that investments in new technology projects should be seen as a decision-making strategy from the perspective of taking and exercising options. In one of the articles in the series, he illustrates how such options relate to the Black-Scholes Model. This supported the earlier example provided by Dixit and Pindyck (1995) that investment opportunities were really analogous to call options, and should be valued as such.

These investment opportunities are discretionary, and whether or not they are undertaken depends upon uncertain future conditions. Bishop et al (1993) have identified *real options* found in investment opportunities which can easily be applied for new technology projects and include:

- The option to wait before investing. This is a call option on the investment project. The underlying goal is to recognise that having an option to an investment project in technology in high-volatility situations is an opportunity to spend a little and learn a little, deferring decisions of major investments until there is much higher certainty of success (Razgaitis 1999).
- The option to make follow-on investments if the immediate investment project succeeds.
- The option to abandon the investment project. This overcomes the problem with a DCF approach which assumes that all investment money will be spent, regardless of intermediate outcomes. In reality what actually happens is that an investor in a technology project can terminate a project early if it looks as if

the risks are going to be higher than anticipated, thereby saving some or much of the investment that would have been committed and lost.

2.8 Evaluation of the Option Pricing Model

The key to valuing a corporate investment opportunity as an option is the ability to discern a simple parallel between project characteristics and option characteristics. The potential investment to be made corresponds to an option's exercise price. The operating assets the company would own, assuming it made the investment, are like stock one would own, exercising a call option. As stated earlier, the length of time the company can wait before it has to decide is like the call option's time to expiration. Uncertainty about the future value of the operating assets is captured by the variance of returns on them; this analogous to the variation of stock returns for call options. The analytical method here is to perform this mapping between the real project and a simple option, such as European call option. (A European call can be exercised only on the expiration date, making it the simplest of all options.) If the simple option captures the contingent nature of the project, then by pricing the option we gain some additional, albeit imperfect, insight into the value of the project (Slywotzky 1996).

To illustrate, suppose a company is considering whether to invest \$1 million to modify an existing product for an emerging market. A DCF analysis of the expected cash flows shows them to be worth only about \$ 900,000. However, the market is volatile, so that value is unlikely to change. A combination of patents and know-how will protect the company's opportunity to make this investment for at least two more years. After that, the opportunity may be gone. Viewed conservatively, this proposal's NPV is negative \$100,000. But the opportunity to wait a couple of years to see whet happens is valuable. In effect, the company owns a two-year call option with an exercise price of \$1 million on underlying assets worth \$900,000. We need only two more pieces of information to value this business opportunity as a European call option: the risk-free rate of return (this is the same as the time value of money—suppose at 7%); and some measure of how risky the cash flows are. For the later, suppose the annual change in the value of these cash flows have a standard deviation of 30% per year, a moderate figure for business cash floes. Now a simple option-pricing model, such as the Black-Scholes model, gives the value of this call as about $160,000 (Black et al. 1973).

This illustrates the point that the value of the opportunity is positive, not negative. That is always true as long as time and uncertainty remain. The company should not invest that $1 million now—to do so would be to waste $100,000—but neither should it forget about ever investing. In fact, the odds are pretty good that it will want to invest two years from now. In the meantime, the product or country manager monitors developments. He or she focuses not only on NPV but also on the proper timing of an investment. Alternatively, if the company doesn't want to invest and doesn't want to wait and see, it can think about how to capture the value of the opportunity now. The option value gives it an idea of what someone might pay now for a license to introduce the new product. In the same way, the option value can help a company think about how much to pay to acquire such a license or to acquire a small business whose most interesting asset is such an opportunity.

So an option is valuable and its value clearly depends on the value of the underlying asset: the stock. Yet owning the option is not the same as owning the stock. Not surprisingly, one must be valued differently than the other. In considering opportunities, cash, time value, and risk all still matter, but each of those factors enters the analysis in two ways. Two types of cash flows matter: cash from the business and the cash required to enter it, should one choose to do so. Time matters in two ways: the timing of the eventual flows and how long the decision to invest may be deferred. Similarly, risk matters in two ways: the riskiness of the business, assuming that one invest in it, and the risk that circumstances will change (for better or for worse) before you have to decide. Even simple option-pricing models must contain at least five or six variables to capture information about cash, time, and risk and construct it to handle the contingencies that managers face as the business evolves.

The implication for valuation is that the options approach handles simple contingencies better than standard DCF models, and thus, it has been regarded as a promising approach to valuing business opportunities since the mid-1970s. However, real businesses are much more complicated than simple pure puts and calls. A combination of factors—big, active competitors, uncertainties that do not fit neat probability distributions, and the sheer number relevant variables—makes it impractical to analyse real opportunities formally. As a result, option pricing has not yet been widely used as a tool for valuing opportunities. It is also for this reason that it has not been widely used for valuing intellectual capital.

However, a number of characteristics about this model are noticeable. Firstly, an investor's risk aversion does not affect value, and the formula can be used by anyone, regardless of his or her willingness to bear risk. Secondly, the formula does not depend on the expected return on the stock. Investors with different assessments of the stock's expected return will nevertheless agree on the stock price, and that price already balances different investors' divergent views.

Nevertheless, there are criticisms that can be made against using Option Pricing Models for valuing new technologies. One problem in applying net present value analysis to real options is that the possible cash flows, and associated probabilities, are difficult and complex to specify. Bishop et al (1993) states that the financial manager must recognise the value of the options created by the initial project and not reject it simply because it is a negative net present value project by itself. The decision to undertake the project requires that management considers the NPV of both the initial project and the options it creates.

Some of the criticisms of the Black-Scholes Model appear to be sourced in the underlying assumptions, which appear to be severe (Curran 1988). They are:

- There is a risk-free rate known and invariant over the life of the option
- There are no transaction costs and no taxes
- The market functions continuously
- The stock pays no dividends
- The option cannot be exercised until maturity (European option)
- The stock price is 'lognormally' distributed (the stock prices are a lognormal distribution that represents a continuous function of time)
- Short sales of the stock can be transacted without restrictions

Thus, the Black-Scholes Model must be viewed only as a conceptual framework, and must be modified in practice. Curran (1988) observed that the calculus of the hedge ratio justifying the risk-free rate on the combined portfolio implies that the position will be altered continuously because of changes in underlying variables. Real-world transaction costs involved in altering the portfolio daily, if not continuously, would be prohibitive. As stated earlier, transaction costs, of course, are assumed away in the model.

Secondly, the distribution of stock prices often exhibits discontinuities (jumps). A continuous function, even as an approximation, may be inaccurate. Thirdly, the model does not allow for dividends and taxes; and fourthly, the European option differs from the American option: the latter can be exercised anytime before the expiration of the maturity date. Therefore, while none of these problems are insurmountable, they weaken the model as an applied tool.

Bishop (1993) also states that there are several problems in applying existing option pricing models, such as the Black-Scholes model, to real options. The present value of the project, the required outlay and the time left before the investment decision must be made, may not be certain for real options. The required outlay and the time left before the investment decision must be made will vary according to the actions of the firm's competitors. Real options may not be proprietary; that is, the firm may not be the only one able to exercise the option, such as the development of microcomputers.

According to Curran (1988) one problem, in particular, is difficult to overcome. Using past measures of variability as representative of future variability can yield a value for a call option not indicative of the future. When the value is compared with the market price of the option and the two differ, the question arises if the model is wrong or the variance has changed. Past data may not be relevant. Alternatively, even though past data may be indicative of the future, the options market may be inefficient. Finally, the options market may be efficient and the variance may be correct but the model is an incorrect explanation of how options are priced.

2.9 Modified Option Pricing Models

In respect of the criticisms related to the assumptions underlying option pricing models, they are sufficient conditions to make them (the models) credible. If they do not hold, a variation sometimes does.

For example, Damodaran (Fox 1998) uses the expected cash inflows from introducing the product now, and the strike or exercise price of the stock is replaced with the present value of the costs of developing and introducing the product now as represented by the following equation:

$$V = Se^{-yt}N(d1) - Ke^{-rt}N(d2)$$

$$d_1 = \frac{ln(S/K) + t(r - y + \sigma/2)}{\sigma\sqrt{t}}$$

$$d2 = d1 - \sqrt{\sigma t}$$

(where: S = the present value of expected income from introducing the product now; K = the present value of costs of developing and introducing the product now; t = 1/years of market viability or patent life; and r = risk-less rate corresponding to the patent life or "y").

Other modifications to the original Black-Scholes model include the replacement of the time to expiration of the option with the market life of the patent, a factor representing (1/patent life) is included and the risk-less rate that corresponds to the patent life is used.

Long-lived opportunities in volatile business environments are so poorly handled by DCF valuation methods that an option-pricing analysis does not have to be very sophisticated to produce worthwhile insights. A pragmatic way to use option pricing is as a supplement, not a replacement, for the valuation methodology already in use. The extra insight may be enough to change, or least seriously challenge, decisions implied traditional DFC analyses.

There is yet another way to think about the analytical strategy. Values for fairly illiquid or one-of-a-kind assets (real estate, for example) are often benchmarked against values of assets or transactions regarded as comparable but not identical. Many excellent business opportunities are one-of-a-kind, and many are illiquid. Lacking a comparable benchmark for the example above (modifying our product to enter an emerging market), the company synthesized one by setting up a simple European call option. By pricing the synthetic opportunity (the call option), it gained additional insight in the real opportunity (the company doesn't expect the synthetic or the resulting estimate of value to be perfect). (Luehrman, 1998b).

What business managers and investors in risky investments require is an easy to learn tool that can be used over and over to synthesize and evaluate simple options. Furthermore, because the goal is complement, not replace, existing methods, managers would like a tool that can share inputs with DCF analysis, or perhaps use DCF outputs as inputs. Black-Scholes will be the first choice because it is the first and still the one of the simplest models. Arguably not the easiest to learn, it is perhaps the most versatile of the simpler models. An intuitive mapping between Black-Scholes variables and project characteristics is usually feasible. And even though the model contains five variables, there is an intuitive way to combine these five into two parameters, each with a logical, managerial interpretation. This intuitive process lets a manager create a two-dimensional map, which is much easier than creating one with five variables. Finally, the Black-Scholes model is widely available in commercial software, which means that if a manager can synthesize the comparable option, a computer can price it quite easily. The crucial skills for the generalists are to know how to recognize real options and how to synthesize simple ones, not how to set up or solve complex models.

Interest in option pricing has picked up in recent years as more powerful computers have aided sophisticated model building. Nevertheless, models remain the domains of specialists. Generalists will get more out of option pricing by taking a different approach. Whereas technical experts go searching for objective truth—they want the "right" answer—generalists have a business to manage and simply want to do better job of it. So an option-based analysis of value need not be perfect in order to improve decision making regarding new technologies.

Thus, while option pricing models, particularly the Black-Scholes model has been used primarily to value stock options, the concept can be extended to other investments such as that in a new technology project. However, modifications will be necessary in order to make it workable. In spite of the problems associated with option pricing models, they provide a sound conceptual framework for application to valuation problems in respect of intellectual capital than other financial models such as DCF and APV. But as stated in the foregoing paragraphs, this approach has not gained widespread recognition for valuing intellectual capital.

2.9.1 The Capital Asset Pricing Model (CAPM)

The value of a technology may be stated to be the present value of its earnings over all future periods (Chew 1997). Since considerable risks are involved in estimating future earnings, the CAPM may be used as a valuation tool for assessing risk/returns relationships. The model is based on the theory of the relationship between risk and return. In its simplest interpretation it states that the expected risk premium on any security equals its beta times the market risk premium (Myers 1999). In other words, the expected rates of return demanded by investors depend on two things (a) the risk free rate being the compensation for the time value of money, and (b) the risk premium, which depends on beta and the market risk premium. The relationships are represented by the equation below:

$$\text{Required rate of return} = K_{rf} + (K_m - K_{rf})\beta$$

(where: K_{rf} = the risk-free rate; K_m = the average market security return; and β = the systematic risk of the project)

While CAPM has considerable intuitive appeal (Brigham 1998), it has long been recognised that the model suffers some strong limitations, which has raised concerns about its validity. A recent study by Fama and French (1992) found no historical relationship between stocks' return and their market betas, confirming the view held by a number of academics, stock market analysts and researchers. Thus, although the

CAPM represents considerable progress in asset pricing theory, there are deficiencies, which must be addressed before it becomes a reliable tool for valuation purposes.

These are the various models that are currently being used as being appropriate models for valuing IP in technology parks. Clearly, the Options Pricing Model (Damodaran Modified) is the most appropriate, given its ability to predict the positive effects of market and technological changes in the future. This is in clear contrast to the use of the standard NPV method because it lacks the element that substantially affects the value of intellectual property, ie. the power of management to exploit opportunity. Accordingly, this method is preferred over standard DCF techniques for valuing intellectual capital.

2.10 Risks in Technology Valuation

Risk is present in almost all decisions. It is centrally important in valuing technology to understand, assess, and incorporate it as accurately as possible. Whether eliminating, or even avoiding it, is very doubtful given the very nature of technology, the objective should be to properly assess it, then deciding if the risk is worth bearing.

If a discounted cash flow model is used, it is important to measure the risk characterising future cash flows, before an appropriate risk-adjusted is applied to convert future cash flows into their present values.

I define risk as 'an adverse variance from the expected'. There is a plethora of definitions of the word in various dictionaries, journals, and books, but in essence it is the likelihood that the real outcome will be less favourable than the most likely one.

David Hertz states [13]:

To understand uncertainty and risk is to understand the key business problem – and the key business opportunity.

[13] In Rao. R.K.S.. Financial Management: concepts and applications, 2nd Ed., New York: Maxwell Macmillan, 1992.

From a technology valuation standpoint, it is important to distinguish between uncertainty and risk. According to Rao (1992), uncertainty exists when a decision-maker knows all the possible outcomes of a certain act, but for one reason or another, cannot assign probabilities to the various outcomes. Risk, on the other hand exists when the decision-maker knows not only the various outcomes, but also the probability associated with each one. In other words, the difference between the two is that risk is a quantifiable uncertainty.

In respect of technology valuation, four different categories of risk can be identified:

2.10.1 Operational Risks

In respect of valuation, Razgaitis (1999) identifies four different categories of operating risks:

2.10.1.1 Marketing Risks

Good technology does not necessarily guarantee commercial viability. What the market will demand and the quantity customers will purchase is often difficult to predict. The performance of the product in the market is subject to a multiplicity of marketing risks, not least changing customer tastes and competitors' actions. Such risks proved the death knell for products such Sony's Betamax, and Dupont's Corfam, in spite of the extensive marketing research that was carried out to establish those products' commercial viability.

2.10.1.2 Research and Development Risks

The quality of R & D is a major risk factor that is found in the development and deployment of technology. Good ideas do not necessarily ensure commercial success because one can never predict and anticipate the problems that may arise in the actual process of 'prototyping' the technology. R & D is an expensive and time-consuming process, and while the technology may be workable, costs may make it commercially unviable.

2.10.1.3 Manufacturability Risks

This refers to the ability to induce a production environment that will allow the final processes from the R & D efforts to be manufactured cost effectively. Passing the R & D stage does not necessarily translate to success at the manufacturing stage. The costs of capital equipment, different production modes, and the quality of production personnel are some of the factors that can cause a potentially good technology to fail.

2.10.1.4 Competitive Risks

It is difficult to estimate the actions of competitors while a technology is being developed for production. The long time lag it often takes from the 'idea' stage to full commercialisation of a technology provides an opportunity to competitors to accelerate their own efforts to introduce new products, or replace those products that are facing a declining life cycle. Companies cannot be assumed to be silent spectators to competitor actions on new product and services development. Even if a firm introduced new and improved products ahead of its competitors, it does not guarantee commercial success. This is because firms can easily learn from the mistakes of competitors and avoid making costly errors that pioneering often entails.

This aspect of valuation is so important that whatever valuation methodology is used, it must include the calculation of risk. Interestingly, accounting methods make no attempt to incorporate risk in reporting procedures, while financial methods incorporate it in DCF, and the CAPM techniques of valuation. However, since risks assume a high profile in knowledge-based companies' financial decision making, they must feature prominently in valuation models to value the intellectual capital of the firm.

2.11 The Need for a New Valuation Methodology

From the foregoing discussions dealing with established valuation methodologies, it can be clearly asserted that they are inappropriate for the valuation of intellectual capital of companies, whose major business focus must be to develop new technologies in order to remain profitable and competitive. This view has led to the development of a new area of research, which is to determine and understand factors that lead to value being created: value drivers in knowledge based companies (Helfert 2000).

The ability to manage knowledge efficiently and effectively will provide a competitive edge in today's knowledge economy (Razgaitis 1999). In this respect, the concept of good management in the knowledge-based sector includes the ability to understand and appreciate the value of the business, and manage the critical underlying factors that affect value (Sullivan 2000). The motivation of this paper is the need for identification and a theoretical and systematic evaluation of the value-drivers that are important to the valuation of nascent technologies in the three industries identified in Chapter 1.

As stated earlier, the application of currently available economic and accounting models to the valuation of intellectual assets has revealed fundamental inadequacies (Drucker 1993; Dabek 1999; Razgaitis 1999). But accuracy of valuation is a fundamental necessity for business investments to occur because such investments are likely to provide a platform for growth, profitability and competitiveness (Lehmann 1996). The traditional source of funding for innovative ventures has been private equity. This situation has made the availability of market information on the value of intellectual assets less forthcoming due to the private nature of most knowledge-based transactions. This limits the traditional role played by private equity firms in funding innovative endeavours, posing numerous risks and uncertainties. The motivation of this paper is therefore an attempt to address the intricacy of valuing intellectual capital by identifying the critical underlying value-drivers of intellectual assets and establishing their relationships to value creation.

In their exploratory investigation into knowledge companies, Eccles and Mavrinac (1995) found that factors that mattered for sell-side investment analysts and portfolio managers from an investment viewpoint were:

- Earnings and cash flows
- Market growth
- Industry and segment performance
- Market share
- Costs
- Capital expenditure on new projects
- Research and Development expenditure
- New product development

In earlier research, Akiva and Morikawa (1990) found that non-financial factors that strongly influenced investment decisions were:

- Quality of management
- Quality of products and services
- Strength of market position
- Quality of new product development
- Customer satisfaction
- Strength of corporate culture regarding innovation and R & D

Adding weight to this view of what drives value, Ikujiro Nonaka (1991) stated that what make firms successful in the knowledge economy are:

- Innovation of ideas, products and services
- Creation of new knowledge through research and development
- Meet the needs of customers
- Create new markets
- Manage the creation of new knowledge

In recent research, Sullivan (2000), stated that knowledge intensive companies reported the following to add value to their companies:

- Reduced costs from innovation
- Blocked competition

- Barriers to entry by potential competitors
- Customer loyalty
- Protection from innovation
- Litigation avoidance
- Revenue growth from market strength

Broadly, all these factors can be categorised into the following headings:

- Prospects of success at commercialisation
- Legal considerations in respect of protection of intellectual capital
- Market success factors
- Innovation and innovation management
- Competition considerations
- Financial factors, including profitability and cash flows
- Risk management
- Economic factors
- Government support and policies
- Productivity

It is clear to see that that valuation of intellectual capital arising from traditional measures and methodologies do not incorporate many of the underlying value drivers that have been identified in foregoing literature, and accordingly, has been the subject of much criticism in recent years. There is compelling evidence that shareholders place strong reliance on a broad range of non-financial factors, beyond the quantitative data reported in a firm's annual reports (Mavrinac 1996). Information in relation to investments in employee development, process quality, and corporate innovation will provide the foundation for tomorrow's financial performance, but currently, there is no mandatory reporting mechanism present for this to occur, nor are there any established valuation methodologies for this to occur.

It is quite clear that in knowledge economies, investors want more than traditional financial data for making economic decisions about firms (Ittner 1995; Cheney et. al. 1991). Non-financial measures of quality and strategic achievement have a profound effect on investment and valuation (Heller 1994). This call for new and improved financial reporting and valuation of intellectual capital in knowledge-based companies has come from both public and public organisations (Lev 1996, Mavrinac 1996, Kaplan & Norton 1997).

A leading critic of current standards of financial reporting, Mavrinac (1996) stated that criticisms have arisen from the following:

- The inability of current financial mechanisms to capture or communicate the value of strategy, processes and such intangibles assets as knowledge, innovation, and customer loyalty.
- Traditional focus on what is historic and tangible has a profound and depressing impact not only on companies' valuations but also on the nation's growth, productivity, employment levels, and wage rates.
- 'Rule-bound' systems are outdated, inaccurate, and increasingly irrelevant in today's service-oriented and knowledge-based economies.

Research by Lev (1996) found that 40% of the market valuation of the median corporation was missing from its balance sheet. For high tech companies, this was found to be more than 50%. Another research into 250 companies shows that a typical institutional investor devotes substantial attention to non-financial performance issues. Approximately 35% of the investment decision is driven by the investors' evaluation of non-financial data, for example the quality of a firm's intellectual capital.

Clearly, this shows that while established financial indicators of value are still important to investors, technological changes and 'knowledge work' have changed the investors' preference for measuring value. Future financial performance is often better predicted by non-financial indicators than by financial indicators.

Therefore, financial managers must understand the value of non-quantitative data, particularly that relating to intellectual capital of the firm, and its likely impact on the value of the firm. In the absence of professional accounting bodies' reporting guidelines, the firm should develop a framework for reporting on non-quantitative data for satisfying investors' needs. Bill Gates Chairman of Microsoft corporation observed 'Our primary assets, which are our software and our software development skills, do not show up on our balance sheet at all. This is probably not very enlightening from a pure accounting point of view'[14].

The recognition for developing new valuation methodologies based on underlying value-drivers, has led to a flurry of academic research. In brief, all these papers suggest that valuations of knowledge firms using accounting and economic methodologies are inappropriate and that other underlying indicators can be used productively as leading indicators of true valuation and of future financial performance. Further, understanding these indicators can enhance both managerial understanding and control of the firm's value-creation process (Kaplan and Norton 1993, Kron 1994, Vitale et al 1994, Atkinson and Waterhouse 1996).

This approach has continued to gain increasing recognition in recent years as a major development in valuation methodologies, and is based on the hypothesis that there are key elements that stand out as significant in the creation of value of knowledge assets (Helfert 2000). These key drivers, among others, may be financial profitability, growth potential, management ability, competitive advantage, all of which affects the expectations about the future success and cash flow generating potential of the company arising from its intellectual capital.

In the circumstances that there is a need to develop a new valuation methodology based on underlying value drivers, it needs to be stated that such a methodology will be neither accounting nor financial in nature. Helfert (2000) hails it as a new branch of valuation, while Sullivan (2000) refers to it as means of quantifying the intellectual capital of a firm.

2.12 Conclusion

As companies adopt valuation techniques made more powerful or accessible by desktop computers, the good news is that the tools a generalists needs are not very

[14] Bill Gates, 1999, *Business Strategy Review*, 2, pp 11-19.

hard to learn. The time and effort necessary before the techniques pay off naturally will depend on a company's situation and its current finance capabilities.

Benefits will be high for companies that expect to invest heavily in developing cutting-edge technology in the near future. For them, the suboptimal execution of a large, multiyear investment program will be costly. Consider, for example, an industry such as telecommunications, in which capital intensity is coupled with rapid growth and technological change. Success requires a sequence of good investments, and getting even one of them wrong can be very expensive. Or consider industries with only few significant players that compete head-on in nearly all aspects of their businesses (Amram, 999). Companies able to take swift advantage of a competitor's mistakes should expect the benefits of insightful analyses—and the penalties for poor analyses—to be particularly high. Similarly, any company working now to exploit a first-mover advantage is highly on the success of early investments.

An active approach to developing new valuation capabilities—that is deciding where you want your company to go and how to get there—should allow managers to develop those capabilities faster than a passive, laissez-faire approach, and it ought to yield more focused and powerful results. Of course, it also probably more expensive. However, the question is not whether it's cheaper to let nature take its course, but whether the more powerful corporate capability will pay for itself. That is, how much is that capability worth?

Much will depend on the willingness of managers to undertake intellectual capital projects to develop the intellectual assets and technologies in order to remain competitive. Nevertheless this willingness is not enough. They need to evaluate continuous investments in knowledge, and find the necessary funds to finance these developments. In this context, a correct procedure for valuation of nascent technologies will be required, without which venture capitalists will not undertake the high risks associated with financing capital expenditures on intellectual assets.

This Chapter examined and evaluated the various methods and techniques available to value intellectual capital. It was found that, while these methods had much merit for valuing financial assets like stocks, they were, in fact, inadequate and inappropriate for valuing intellectual capital.

The following Chapter contains the methodology for the conduct of this research. It describes the case study methodology, in which three case studies are subjected to analysis by means of analytical software, followed by a general questionnaire survey of three hundred companies. The methodology has been designed to discover the underlying drivers of value in each of the three industries in which intellectual capital is critical to profitability and wealth creation. Eventually, these pervasive value drivers will be used to model valuation processes, and is described in Chapter 5 of this study.

Chapter 3. Research Methodologies

3.1 Introduction

As stated in Chapter 1, Introduction, and Chapter 2, Literature Review, the objective of this research project is, firstly, to identify the factors that give rise to value in nascent intellectual capital investments, and secondly, to build a valuation model based on these factors for valuing intellectual assets. In this Chapter, the methodologies to be employed in this research will be discussed in detail.

3.2 General Discussion

The research approach adopted in this study is based upon the case study methodology. The definition of case study is "an empirical inquiry that investigates a contemporary phenomenon within its real life context when the boundaries between the phenomenon and its context are unclear, and where multiple sources of evidence are used" (Yin 1989).

Following the analysis of the case studies, a postal survey of 300 companies will be carried out to test the results of the case study, and establish, by statistical analysis, the pervasive value drivers in each of the three industries that are the subject of this research.

3.2.1 Choice of Case Study Method for this Research

The selection of the case study method was based on its suitability both to the purpose of the investigation and to the nature of the data to be collected and analysed. Firstly, the purpose of the investigation was to produce a rich description that would cover the variety of issues arising from the theoretical component of this thesis, and so enhance the understanding of what gives rise to value in nascent technologies. Specifically, the purpose was to create a model for valuation of intellectual capital projects based on factors that create value. The case study approach examines a single social phenomenon or single unit of analysis (Singleton, Straits and Straits 1993) in order to give meaning based on both the tacit and explicit knowledge of those who experience that phenomenon (Eisenhardt 1989). Three types of case studies can be distinguished: descriptive, explanatory and exploratory. The descriptive case study approach produces a rich description of a phenomenon in its context. The exploratory case study builds theory, and is therefore, suitable in situations where there is inadequate theoretical basis. An explanatory case study approach is suitable where cause-effect explanations are sought. This thesis incorporates all three types of approaches, and is discussed in the following sections.

Yin (1993) states that the case study method is appropriate when the data is integral to the context in which it occurs. Therefore, the case study method was chosen as appropriate to the purpose and nature of this investigation.

This research uses extensively Yin's (1989) work on the framework for the design and conduct of field research. The objectives of this case study research are to identify, evaluate and analyse the key factors that drive the value chain of nascent technologies throughout the development process, and provide a basis of valuation for a firm's intellectual property. The case study protocol that will serve as a logistical procedure guide in this research is described as follows:

The primary source of information on the factors will come from current literature, and case studies drawn from companies in each of the three selected industries based in technology parks. This will be followed by a postal survey of 100 companies operating in the same (three) industries, which also focus on developing new technologies for the future, and which also suffer from the problem of their inability to value, correctly, the worth of their nascent projects using traditional valuation methods. The final selection of the factors will be based on their pervasiveness on the valuation of the technology at the various stages of development.

Statistical testing will be done on the factors to determine their significance, and to determine whether they should be included in the valuation process model based on the relationships established from the case study, survey and literature review conducted.

The study will incorporate these factors into a generic valuation framework (model) that best addresses the structure of valuation for nascent technologies. A comparative analysis will carried out using the same process model but with different variables specific to each industry to highlight characteristics and features that might be generic, and others that are industry-specific, to promote understanding of the complexity of and variations in technology valuation.

The data required is initially obtained from materials provided by established companies in the research-park. A selection will be made of three companies, from different industries, for an in-depth study into the various aspects of technology valuation pertinent to the industry.

As stated in Chapter 2 Literature Review, and in the following sections of this Chapter, data required for determining the valuation process in nascent technologies include the following:

- Information relating to patents and their protection
- R & D expenditure, quality of research
- Quality of management
- Marketing skills and options (both local and international)
- Industry benchmarks and costs
- Financial data (projected cash flows, costs and revenues, profitability)
- Economic Environment
- Government policies
- The risk environment

The process of data collection and analysis will be done in two stages, being at the exploratory research stage, and case studies, and a survey. A total of three companies will be selected for the case study. The criteria for the selection of these companies will be the largest individual company operating in the three different categories, with a track record for developing and commercialisation new technologies. The data will be analysed using NVIVO and Microsoft's EXCEL, and SPSS, a statistical package.

3.3 Overview of Research Method

In order to be effective in this research project, both qualitative and quantitative methods will be applied. It will be accomplished upon the completion of the following four phases:

1. Literature Review

This first phase involved an extensive review of the relevant literature on valuation of assets, intellectual capital, and modelling. Issues such as valuation techniques, tools and methods, and more specifically, those that are used in valuing new technologies were identified.

2. Interviews

This phase of the research will be exploratory in nature because it will seek to identify key issues in technology valuations, which will ensure that the subsequent research begins with an initial understanding of the research problem to be investigated (Zikmund 1991). Research is exploratory in nature when it is uses interviewing as a means of gathering the data (Sekaran 1992). These interviews will take place in La Trobe University's Research Park, and will be conducted with three companies operating in three different industries, but all of whom are in the process of developing new technologies. The interview process has been described in a following section in this Chapter.

3. Postal Questionnaire

To confirm and test the results of the analysis of the case studies, a postal questionnaire will be sent to 100 companies, divided into the three different industries which are the subject of this research. This phase of the research is descriptive, which, according to Maykut and Morehouse (1994), attempts to describe a situation, or which provides information about certain issues. The questionnaires are designed to provide corroborative data on a previous understanding of the nature of the research problem, and are therefore, descriptive. The questionnaires will be posted because the respondents are expected to be located over a wide geographical area.

The actual process of this phase of the research has been described in a following section in this Chapter.

4. Data Analysis

The data from the case studies will be analysed using NVIVO, a case study analytical tool. Following this, the postal questionnaires will be statistically analysed using Excel. Once the factors have been identified, they will be incorporated into a valuation model. Should some factors prove to be industry specific, they will be incorporated into an industry specific model.

5. Economic Model Development

In Chapter 5, a logit model(s) will be developed for valuing firms in the three high technology sectors and the outcome of the analysis will highlight several pervasive value drivers for each of the three high technology sectors under investigation. Following on from this phase, Chapter 6 will continue to develop the valuation process using the results of the logit analysis to build an econometric model for the valuation of intellectual capital. This section is elaborated in the following sections of this Chapter.

3.4 Theoretical Framework

A theoretical framework is defined as a logically developed, described, and elaborated network of associations among variables that have been identified through such processes as interviews, observations, and literature surveys (Sekaran 1992).

For this research thesis, the theoretical framework has been derived from current literature. The key issues that have been identified, or will be identified, in this research are from the literature review, interviews concerning three companies in La Trobe University's Research Park, and a survey of 100 firms involved in developing technologies to ensure a stream of future cash flows. The variables that are considered relevant and important to this research are the underlying factors in intellectual capital projects which create a source of value; and which in aggregation, can yield a basis of quantitative valuation, thereby facilitating such activities as venture capital investments for commercialisation, selling, or transferring to interested parties in arms length transactions.

It is expected that some of the variables positively create value, thereby providing an insight to managers on how to create a framework for creating value at the pre-commercialisation stage of nascent technologies. For example, it is expected that the patentability of new technologies will create a source of value, because it is abundantly clear that without legal protection, the new technology can be duplicated and/or copied with ease, thus eroding, or even eliminating, any value at its pre-commercialisation stage.

Furthermore, there may be factors which are important in some of the chosen industries, but not in others. This will be referred to as 'industry specific variable(s). In other words, this variable(s) may be absent or present in some nascent technologies without affecting value, while its presence or absence in other nascent technologies may be critical to its success.

However, the literature merely states that valuation of nascent technologies should use traditional valuation methods, while only implying that there may be factors that create value. But as discussed in the foregoing Chapter, the traditional valuation methods do not incorporate these factors. For example, Razgaitis (1999), provides an example of a technology transfer agreement in which some of these factors are specifically present, but no connection have been made between them and the value of the transfer. This indicates a gap in theoretical development in what is understand as the sources of value in intellectual capital projects. Therefore, it is important, firstly, to develop a framework for investigating the drivers and sources of value in nascent technologies, and then incorporate them in a valuation model.

The theoretical assertion that, factors of value in aggregation yield a better model for valuing nascent technologies than those that are typically employed, will be investigated, based upon data from literature, case studies, and a survey. Finally, these relevant factors will be incorporated into a valuation model. In conjunction with statistical analysis and synthesis, the results of the investigation will create a more accurate, appropriate, and relevant model, for valuing intellectual capital investments.

3.5 Designing the Case Studies

The design of this empirical research is the logical sequence that connects the empirical data to the study's initial research question, which ultimately connects it to the conclusions. It is therefore, an action plan for creating a path for the research question to reach its conclusion. The research question is identifying the set of factors that create value for a new technology, which then leads to the conclusion of creating a model for the generic valuation of such a technology. In between the commencement and the conclusion, there are a number of major steps, which includes the collection and analysis of relevant data. Nachmias (1992) stated that a research design is a plan of action that guides the investigator in the process of collecting, analysing and interpreting observations. It is a logical model of proof that allows the researchers to draw inferences concerning causal relations among the variables under investigation. The research design also defines the domain of generalisability, that is, whether the interpretations can be generalised to a large population or to different situations.

The research will be treated as a blueprint of action that deals with four problem: the questions to study, what data are relevant, what data to collect, and how to analyse the results. The purpose of the design will is such that it will find consistency between the evidence and the research question, that is, the evidence *will* address the research question.

According to Yin (1994) five components of a research design are especially important:

- A study's question
- Its proposition, if any
- Its unit(s) of analysis
- The logic linking the data to the propositions
- The criteria for interpreting the findings

3.5.1 Study Question

The case study strategy has been used to create a valuation model for nascent technologies. This is because, it is the most appropriate strategy for answering 'how', 'what' and 'why' questions (Yin 1994). Part of the research focuses on 'what' questions, such as 'what are the variables that create value', and is, therefore, *exploratory* in nature. However, a major part of this research is to develop a valuation model, that is, focusing on 'how', and in these situations, the case study method of an *explanatory* nature is regarded as the most appropriate strategy (Yin 1994).

3.5.2 Study Propositions

In the second component, a proposition directs attention to something that should be examined within the scope of the research. In the first part of the study, there is no proposition, thus the identification of factors that create value assumes the nature of an 'exploration'.

In the second part of the research, developing a model based on the 'exploratory' section of the research is, therefore, explanatory in nature.

The process of model building for valuing new technologies will depend on questions such as 'how and why do nascent technologies create value'. This, according to Yin (1994) is the second component of research design. He states that every exploration should have a purpose, and should also state the criteria by which an 'exploration' will be judged.

3.5.3 Unit of Analysis

This component is related to the basic problem of defining what the 'case' is. According to Yin (1994), a 'case' can be a person, or an event or an entity. As a general guide, the definition of the unit of analysis, and therefore the case is related to the manner in which the initial research questions have been defined. Yin (1994) further states that each unit of analysis calls for a slightly different research design and data collection strategy.

The unit of analysis in this research is a valuation process model which attempts to allow a broad range of users to value nascent technologies for a multiplicity of reasons, not least attracting venture capital and investment dollars. The research strategy is to use a multiple case study approach to anlayse the fundamental factors that create value, and then create a generic model for valuing such technologies. The three case studies will focus on companies operating in three different industries. A comparative analysis will be carried out to establish if a generic model will suffice for all three industries, or if industry specific factors dictate the creation of three different models. Such a strategy is consistent with the design propositions of Yin (1994) as stated in the foregoing paragraphs.

3.5.4 Linking Data to Propositions, and Criteria for Interpreting the Findings

These components represent the data analysis steps in case study research, and the research design should lay the foundations for this analysis.

Linking data to propositions can be done in a number of ways, but since the case study analytical software NVIVO will be used, this will be achieved by 'pattern matching', which is regarded as one of the best approaches (Campbell 1975). The pattern matching technique is a good way of relating the data to the propositions, particularly where the multiple case study strategy is used.

In respect of NVIVO, it is a software that provides qualitative solution for researchers. It provides an excellent tool for handling and interpreting complex qualitative data, and allows researchers to achieve the finest possible research. The software is a powerful and robust program, and is able to assist with high quality, rigorous qualitative analysis.

NVIVO is designed for researchers working with non-numerical data, (such as interviews) and offers different ways of achieving discovery and clarification.

The software takes qualitative inquiry beyond coding and retrieval. It is designed from the ground up to integrate coding with qualitative linking, shaping and modeling. It manages rich data in rich ways, with flexible Sets for grouping and Attributes for organizing ideas and information in tables that can be exported to statistics packages. These integrated tools support searching that is qualitative, not merely mechanical.

The software is regarded as one of the leading products for code-based qualitative analysis. It combines efficient management of Non-numerical Unstructured Data with powerful processes of Indexing Searching and Theorizing.

Designed for researchers making sense of complex data, the software offers a complete toolkit for rapid coding, thorough exploration and rigorous management and analysis. The software has a full command language for automating coding and searching, and a Command Assistant that formats the command. It powerfully supports a wide range of methods. Its command files make project set up very rapid, and link qualitative and quantitative data.

Documents are imported singly or in batches, in plain text with automatic formatting to the chosen unit of text. Coding on-screen, with new immediate access to the code system, it allows the researcher to monitor and manage the emergence of ideas. Coded material is displayed for reflection, revision of coding and coding-on to new categories. With searches of coding or text accessed by visual displays, it allows the user to test hypotheses if required, locate patterns or pursue a line of inquiry to a confident conclusion.

3.5.5 Criteria for Interpreting a Study's Findings

In respect of the fifth component, the criteria for interpreting a study's findings, descriptive statistics and regression analysis will be carried out to establish which factors give rise to value in nascent technologies.

3.6 Methodology and Tests of Quality

The research design is consistent with four tests which have been commonly used to establish the quality of any empirical social research. Because case studies are one form of such empirical research, the four tests also are relevant to case study research (Yin 1994). These tests have been summarised by Kidder (1986) and are:

- **Construct Validity**: establishing correct operational measures for the concepts being studied.

- **Internal Validity**: establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships.
- **External Validity**: establishing the domain to which a study's findings can be generalised.
- **Reliability**: demonstrating that the operations of a study such as the data collection procedures can be repeated, with the same results.

The methodology in this research is designed to satisfy all four criteria, and is much more complex than the standard 'validity' and 'reliability' notions which have been common in earlier case study design. Each item has been given special attention in order to give this research characteristics of rigour and quality.

3.6.1 Construct Validity

1. In the first test, the case studies will identify a range of factors that create value (related to one of the major objectives of the research), and then,
2. Demonstrate from the identified factors which specific ones create value.

In order to achieve this, more than one source of evidence will be used (interview, background literature on the chosen industries, and software analysis). The second step will be to establish a chain of evidence, followed by submission of a draft case study report for review by each of the key informants.

3.6.2 Internal Validity

This test has been given the greatest attention in recent literature (Campbell 1966, and Cook 1979). Firstly, internal validity is a concern for causal (or explanatory) part of the research, and the analysis will ensure that the rigours of internal validity are met, that is, the causal relationships of factors that create value are correctly analysed and explained. According to Yin (1994), this logic is not applicable to the exploratory part of the research, which are not concerned with making causal statements.

Secondly, where inferences are made in the in the case studies, the rules of internal validity will be observed. Basically, each case study may involve inferences where such inferences may be justified. Instances where this may occur is in the data collection process, particularly in the interview stage from which the case studies will be written up. Every attempt will be made to ensure that the inferences are correct, logical, and that the evidence is convergent.

3.6.3 External Validity

In respect of the third test, the research will seek to establish whether the study's findings are generalisable beyond the immediate case study. Yin (1994) states that the problem of external validity has been a major barrier to case study research, based on the belief that single case studies offer a poor basis for generalising. Where the research is based on statistical generalisation (as is done with survey research) criticisms may have some merit. However, as Yin (1994) points, case study research relies on analytical generalisation, rather than statistical, generalisation, and thus, the criticism carries no merit.

Further, this research is based on three, rather than one, case study. Thus, the criticism has even less merit. External validity in the form of analytical generalisation, where, as in this case, the research seeks to generalise a particular set of results to some broader goal (that of the identification of factors relating to valuation of Intellectual Capital), is according to Yin (1994) soundly based.

After the process of identification has been completed, the factors will be subjected to the rigours of statistical analysis to ensure a high level of validity.

3.6.4 Reliability

The objective of the test of reliability is to ensure that if a later investigator followed exactly the same procedures as in this research, and conducted the same case study all over again, they would arrive at the same findings and conclusions. The goal of reliability is to minimise the errors and biases in a study (Yin 1994). In order to achieve such reliability, the research will document all procedures. In this thesis, the general way of approaching the reliability problem is to maintain documentation of all procedures in such a manner that it will be easy for anyone to establish an audit trail of events, and repeat the exercise. As Yin (1994) points out, a good guideline for doing case studies is, therefore, to conduct the research so that an auditor could repeat the procedures, and arrive at the same results.

The protocol that will be characteristics of the case studies, will be those that Yin (1994) recommends. These are:

The questions will be relevant and appropriate, so that the answers will be capable of interpretation for their intended purpose

The questions for the case studies will be framed to elicit relevant and appropriate information for the case studies, bearing in mind that the specific information that may become relevant to a case study is not always predictable. Nevertheless, much effort will be exerted to framing the right questions from which data for the research can be extracted.

The questions will be such that the answers will not be capable of a biased interpretation by the researcher's ideologies and preconceptions

The researcher will attempt to assimilate large amounts of new information without bias. The exact words of the interviewees will be recorded, bearing in mind that the terminology sometimes reflects an important orientation, and every attempt will be made to understand the context from which the interviewees perceive the world.

This type of skill will also be applied for the inspection of documentary evidence, as well as where an interviewee recounts direct observations about real-life situations. Where it is necessary to 'read between the lines', ie, making inferences, corroborating evidence with other sources of information will be sought and recorded. Every attempt will be made to acquire any important insight that the interviewees may have in order to make the case studies relevant, logical, and free from the researcher's own misconceptions and biases.

The questions will reflect the researcher's firm grasp of the issues being studied. This is the case whether the case study mode is 'explanatory' or 'exploratory'. In this research, both modes are present, as has been described in the foregoing paragraphs. The questions will demonstrate, adequately, the purpose of the case studies in the first place (identification of factors that create value in nascent technologies). The questions will not be used merely for the purpose of recording data in a mechanical manner, but as a source of information for analysing and interpreting the data. Therefore, questions will be framed to demonstrate a grasp of issues being studied, and such a grasp focuses the relevant events and information to be sought, to manageable proportions

The researcher should be unbiased by preconceived notions, and be sensitive and responsive to contradictory evidence.
The study will be carried out without any attempt to substantiate a pre-conceived notion. In order to eliminate bias, the questions will demonstrate an understanding of the issues, and exercise discretion in the interview process. This in consistent with the recommendations of Becker (1958, 1967).

The case study will be sensitive and responsive to contradictory evidence. Where the evidence is less than compelling, the case studies and the follow-up analysis will reflect this. Alternative explanations will be explored, and if contrary findings can produce documentable rebuttals, the likelihood of bias will, it is hoped, be reduced, or at best, eliminated.

3.7 The Use of Multiple Case Studies

Multiple case studies have in their design, distinct advantages over single case study design. This research is based on three case studies, but as Yin (1994), Eckstein

(1975), and George (1979) point out, the use of single, versus multiple case studies, must be seen to be in the same methodological framework, in spite of the general belief that they should be considered to be different methodologies.

Here, the research is based upon valuation of nascent technologies, but valuation may depend on different factors in the different industries being studied. Thus, while each industry is be the subject of an individual case study, the study, as a whole, will use the multiple case study design.

Multiple case study research has distinct advantages in comparison with single case study research; this being that the evidence from research based on multiple case study design is certainly more compelling. Thus, the overall study is regarded as being more robust (Herriott 1983). Further, where resources are available, multiple case study design should be undertaken, as this improves the reliability and credibility of the study. This is because multiple cases must be considered as the same as multiple experiments - that is, to follow a 'replication' logic (Yin 1994).

Replication in multiple case studies is analogous to that used in multiple experiments (Hersen & Barlow 1976). Further, Yin (1994) states:

If one has access only to three cases of a rare, clinical syndrome in psychology or medical science, the appropriate research design is one in which the same results are predicted for each of the three cases, thereby producing evidence that the three cases did indeed involve the same syndrome. If similar results are obtained from all three cases, replication is said to have taken place. This replication logic is the same whether one is repeating certain critical experiments, is limited to a few cases due to expense or difficulty in performing a surgical preparation in animals, or is limited by the rarity of occurrence of a clinical syndrome. In each of these situations, an individual case or subject is considered akin to a single experiment, and the analysis must follow cross-experiment rather than *within*-experiment design and logic.

The logic underlying this research is that the case studies will uncover, by the use of a case study analytical software tool, factors that create value in nascent technologies in three different industries. While, it is predicted, that certain factors will be the same across all the three industries, there will also be differences, which will probably be, by their nature, industry specific.

If the analysis is consistent with this prediction, it will provide this research with compelling support for building a model for valuing each such industry specific technology.

3.8 Data Collection

Initially, data collection will take place from interviews with senior personnel from three different companies based in La Trobe's Research Park.

The interviews form the exploratory part of the research because it is intended to provide a better understanding of key concepts and to ensure that subsequent research will begin with initial understanding of the research problem to be investigated (Zikmund 1991). Research is exploratory in nature when, according to Sekaran (1992), interviewing is used as a means of gathering data. In order to explore the factors that create value for nascent technologies, interviews will be carried out with three companies in La Trobe University's Research Park, which are engaged in developing intellectual capital projects.

The participants will be sent an interview script prior to conducting the interviews. After completion (of the interviews), which will be carried out with senior managers of the company, the case studies will be written up, which will then be subjected to analysis using the NVIVO case analysis software.

Bearing in mind that value-driver research is relatively new, there is a dearth of guidelines to be followed in determining the value drivers of nascent technologies in individual industries. In this situation, the questions in the interview have been designed to be broadly based, and covers a multitude of functional management areas, and their operating environment factors. This *exploratory* approach is amply supported by Yin (1994), and Merton et al (1990), as being an appropriate research procedure where extant literature and other sources of data cannot be used to deduce the data needed for the further analysis.

Nevertheless, in order to keep the interviews disciplined and focused, reference was made to literature on intellectual capital to provide a general framework for the questions that would seek to uncover the critical underlying value drivers in nascent technologies. In Chapter 2 Literature Review, the term 'critical value drivers' was discussed in detail, and several academic suggestions about what constitute value drivers were also stated.

Accordingly, the interview scripts and questions will be designed to elicit complete information in each of these areas. The open-ended nature of questions will allow the interviews to uncover as much information as possible, and where necessary supplementary questions will be asked to complete the 'jigsaw'.

The interviews will then be used to write the case studies, which will then be analysed by NVIVO to establish the pervasive underlying value drivers in each of the three industries.

The interview will take several forms. As stated earlier, the case study interviews will consist of open-ended questions in which key respondents will be asked the facts of the matter in relation to their nascent technologies. This will be augmented with questions that will ask respondents for opinions on what gives nascent technologies commercial value. Furthermore, the respondents will be asked to propose their own insights into matters of valuation of nascent technologies, and the intellectual capital of organisations.

The interviews will assume three distinct characteristics. Firstly, respondents will be considered to be 'informants'. Here, the respondents will not only be used as a source of information, but, where possible, as a source of corroboratory evidence.

Secondly, the interviews will also take a *focused* approach as proposed by Merton (1990). The design of the interviews is such that they are expected to be reasonably short. This will help to elicit the most critical and reliable information from the respondents, since they won't feel the frustration of having to sit for an extended period of time. The style of interviewing will be conversational, while at the same time, the predetermined question set will be asked to elicit the necessary information for the conduct of this study.

The third characteristic of the interviews will be that of a *formal* survey. Such a survey has been designed as being supplementary to the case studies, and as part of the empirical study. Certain questions in the case study interviews will be the same as in the questionnaire that will be sent out to various companies following the conclusion of the interviews.

3.8.1 Assumptions

Two assumptions will be made in relation to the interviews:

- The responses to the questions given to the investigator by the interviewees are truthful, accurate, and sincere.
- The respondents are able to properly comprehend the questions and provide answers within the context intended by the investigator

3.8.2 Limitations of the Interviews Method

All three companies chosen for the interviews are based in La Trobe University's Research Park. This has been done for two reasons: One being time and resource constraints, and two, being the dearth of similar firms in similar developing environments. The choice of three companies operating in three distinct industries, but located within the confines of a centralised Research Park is relatively rare, and initial invitations to take part in a research study were refused.

The assumptions and the limitations do not reduce the rigour of the interviewing process which will be designed to guard against the common problems of bias, poor recall, and poor or inaccurate articulation.

3.8.3 Security and Non-disclosure Arrangements

Participants in the interview process will be informed that they are free to answer, or refuse to answer, any questions put to them by the researcher. Furthermore, they will be informed that they may also partly answer questions if specific details are highly confidential, or if the question is intrusive. In addition, because of the confidentiality agreement, the respondent will be accorded the right of not having the name of the company divulged, or identified, at any stage of the investigation. Finally, the data from the interview, including the results of the follow-up analysis, will be stored and secured in a locked cabinet at Victoria University, and access to this will be available only to the researcher and his supervisor(s).

3.9 Principles of Data Collection

Yin (1994) states that benefits from the interview process can be maximised if certain principles are followed:

3.9.1 Use of Multiple Sources of Evidence

As stated earlier, this research is based on multiple sources of evidence. While interviews will be the primary focus of data collection, these will be followed with a survey of companies operating in the three different industries. Yin (1994) recommends the use of multiple case studies, and multiple sources of evidence in similar studies. He states that the need to use multiple sources of evidence far exceeds that in other research strategies, such as experiments, surveys, or histories. For instance, experiments are largely limited to the measurement and recording of actual behaviour in the laboratory and generally do not include the systematic use of surveys or verbal information. Surveys tend to be the opposite, emphasising verbal information but not the measurement or recording of actual behaviour.

3.9.2 Surveys

The interviews at the Research Park will be followed by a questionnaire (appendix 2) which will be sent to 300 companies, which are engaged in developing news technologies in the same industries, as a means of investing in intellectual assets. The use of questionnaires is among the most widely used techniques for gathering data (Babbie 1995; Fox et. al 1988; Eisenhardt 1989). The major advantage of a postal survey is that it offers great anonymity (Thomson 1992), and is suitable for vast geographical coverage (Sekaran 1992). Furthermore, as suggested by Som (1996), if potential respondents are scattered over a wide geographical area, there is no choice but to use a questionnaire, as interviewing in these circumstances would be extremely expensive. Therefore, since this is a national survey, a postal survey is considered most appropriate for the purposes of this research.

As suggested by Dillon (1990), and Zikmund (1997), in order for respondents to comprehend questions asked, in the sense intended by the researcher, the questions must be simple and straightforward. Thus the surveys, with a list of questions that are easy and simple to understand will be sent to senior managers of different companies who are responsible for, or have a major influence over investments in nascent technologies. The questionnaire will be accompanied by a covering letter to explain the purpose of the research and the need for them to participate.

3.9.3 Limitations of Postal Questionnaires

The following are the limitations of postal questionnaires:

- Questionnaires are notorious for their low response rates (Kerlinger 1986, Sekaran 1992)
- There is a lack of opportunity to clarify issues if the respondent does not understand some questions (Cochran 1977)
- The response to a question may be influenced by the response to other questions (Gay & Diehl 1992)

In designing the questionnaire, every attempt will be made to eliminate the limitations, or at least, to minimise the impact of the limitations on the quality of the research. Furthermore, the exhaustive statistical analysis will minimise errors to the highest degree possible.

3.9.4 Postal Questionnaire Design

The results of the analysis of the case studies will be given in Chapter 4, and a detailed report will be provided. The questionnaire design will be based on the findings of the literature review and the interviews carried out at the Research Park. Its main objectives will be to identify and establish the following:

- Whether the pervasive value-drivers are the same, or similar, as for the three companies in the Research Park
- The factors that create value in nascent technologies
- Whether the pervasive factors are the same, or similar, within the three chosen industries
- Whether the established methods of valuation were appropriate to the valuation of nascent technologies

The questionnaire (appendix 2) will comprise the following sections:
Section A: Questions designed to acquire information about the company, the industry in which it operates and the kind of technology it is developing.

Section B: Questions designed to acquire information about the respondent's level of education, their position in the company, and/or job title.

Section C: Questions designed to acquire information about what, in their educated estimation and opinion, were factors that created value in nascent technologies. The participants will be asked to respond on a Likert Scale, ranging from 0 to 5, indicating the importance they attached to the various factors.

Section D: These will include questions which will elicit information about the respondent's opinion on established and traditional methods of valuation of nascent technologies. It is expected that the respondent will appreciate the importance of valuation, and more precisely, the importance of valuation from the standpoint of securing finance and investments for the commercialisation phase. Respondents will be asked to answer the questions on the Likert Scale, from 0 to 5, indicating their opinion about the suitability of using current methods to value nascent technologies.

3.9.5 The Likert Scale

In 1932, Rensis Likert developed the Likert Scales to measure the degree of agreement or disagreement with constructed statements. Likert scales are commonly used in business research in order to make valuable and meaningful conclusions (Sekaran 1992), because they allow participants to respond with degrees of agreement or disagreement (Kerlinger 1986), or to indicate how they agree or disagree with a statement related to a certain issue (Zigmund 1991). Likert and similar scales have been used by many notable researchers in business like Moser and Kalton (1972), Brownell (1982), and Ghauri et al (1992).

3.9.6 Information Confidentiality

Protection of participants' confidentiality rights will, throughout this investigation, be given the highest priority. Accordingly, in order to maximise participation and create an environment of candour, the participants were assured of:

- Confidentiality and non-disclosure provisions of the research, and
- The availability, upon completion, of research findings to all participants, should they require it.

3.9.7 Multiple Sources of Evidence and Modification of Strategies

Yin (1994) also recommends modifying strategies to tailor them to a study's own requirement, because, in his opinion, such a modification of traditional strategies does not alter the fact that the case study inherently deals with a wide variety of evidence, whereas the other strategies do not.

In this research, no modification of existing strategy is envisaged, and the planned interview will be followed by a survey of approximately 100 companies operating in each of the three different industries as described in foregoing sections of this paper.

Yin (1994), and Patton (1990) further state that using multiple sources of evidence allows an investigator to develop 'convergent lines of inquiry', or triangulation, which is a process of establishing a fact, or a series of facts in a case study approach. This is true in spite of the fact that multiple sources of information are more expensive (Denzin 1978). The process addresses the potential problems of *construct validity* (which has been described in an earlier section of this Chapter), because the multiple sources of evidence essentially provide multiple measures of the same phenomenon. One analysis of case study methods found that those case studies using multiple sources of evidence were rated more highly, in terms of their overall quality, than those that relied only on single sources of information (Yin 1983).

3.9.8 Create a Case Study Database

The second principle is concerned with organising and documenting the data collected for the case studies. Yin (1994) states that there are two aspects of this:

(a) The data or evidentiary base, and,
(b) The report of the investigator, in whatever form it may take.

The data or documentary base for this study will consist of interview scripts, questionnaires, supporting documents provided by the respondents and interviewees (if available), and narratives.

The case study notes will consist of notes from the interviews, observations, or documentary analysis. A combination of handwritten notes, audio-tapes, and printed material will be organised and categorised to provide the best avenue for later identification (Patton 1980), access, and analysis.

Documents relevant to the investigation and collected during the course of the study will also be organised in the manner stated in the foregoing paragraph. The documents will be separated into primary and secondary files, depending on their degree of importance to the study. The main objective is to organise them so that they are ready for retrieval as and when they are required for inspection, and analysis.

The database will consist of materials derived from surveys, which will be conducted as part of the overall study. This data will also be organised and stored as stated in the foregoing paragraph, consistent with the recommendations of Miles and Huberman (1994).

The narratives which will be written to enhance the richness of the data, and collected during the data gathering stage, will be used extensively to give additional weight to the analysis and conclusions of the study. Yin (1994) recommends the frequent use of open-ended answers to the questions in the case-study protocol, and states that it is often used in a multiple-case study strategy. This is because each answer represents an attempt to integrate the available evidence, and to converge upon the facts of the matter or their tentative interpretation. Yin (1994) supports this view by stating that this process is an analytical one and is an integral part of the case study analysis; and that the main purpose of the open-ended answer is to document the connection between the specific pieces of evidence and various issues in the case study. He states, further, that the most important attribute of good answers is that they connect specific evidence to the pertinent case study issues.

The entire set of answers will then be considered part of the case study database, and it will then be used to compose the case studies (those that arise from the interviews), and the final report (those that arise from the questionnaires, if any).

3.9.9 Maintain a Chain of Evidence

Consistent with the recommendations of Yin (1994), this investigation will seek to increase the reliability of the information in the case studies by maintaining a chain of evidence. The principle is to allow an external observer to follow the derivation of any evidence from initial research questions to ultimate case study conclusions, or trace the steps from conclusions back to the initial research questions. The objective is to adequately address the methodological problem of determining construct validity (described above), thereby increasing the overall quality of the case.

The data collection process will be the most complex part of the study than any other. Yin (1994) states that in case-study research, data collection is more difficult and complex than the processes used in any other research strategy. This study has attempted to ensure flexibility, versatility and quality control, by using prescribed formal procedures so that the results reflect a concern for construct validity, and for reliability. This will ensure the best possible analytical outcome.

Following the analysis, a final valuation report will be produced, which will detail my findings, and give the investigator's own conclusions in respect of a valuation model, which is expected to be better than those currently used to value nascent technologies.

3.10 ANALYSIS OF DATA

The nature of data analyses underpinning this investigation is discussed in the following sections.

3.10.1 Case Studies and Surveys

In attempting to build a valuation model for nascent technologies in three different industries, the approach has been to write constructive case studies on three separate and independent companies operating in three different industries in La Trobe University's Research Park. As stated in the foregoing sections of this paper, the strategy is both *exploratory* and *explanatory*. The analysis of the case studies using an appropriate computer software tool (NVIVO) has revealed the various factors that drives and creates value for a new technology. This is the exploratory characteristic of this research. A survey of 300 companies, tested for statistical analysis, will allow the researcher to test the validity of the NVIVO analytical results. This has provided the foundation for the explanatory sequence of the research, which is to build a valuation model for nascent technologies in the three different industries.

3.10.2 General Strategies

The first strategy has been to follow the theoretical propositions that led to the case studies. It was stated that, while there were innumerable methods by which an asset's value could be determined, these were, however, inappropriate for the valuation of Intellectual Capital that was reflected in assets such as a firm's nascent technologies. It was followed with the proposition that building a valuation model based on identified value factors was possible. The original objectives and design of these case studies were based on these propositions, which reflected the research questions, reviews of literature, and new insights. In essence the propositions, among them to create a valuation model, have shaped the data collection plan (detailed in the foregoing sections of this paper), and the appropriate design of the research strategy.

The proposition is the theoretical and philosophical orientation guiding the case study analysis, and indeed, this research paper. This, clearly, has helped to focus the researcher's attention on relevant, clear, and accurate data, and ignore other data. Indeed, the clear objective of this research has helped to organise the case studies in a manner which allows an effective and efficient analysis of data, to provide answers to 'how' and 'why' questions, referred to above, as the *exploratory* and *explanatory* characteristics of this thesis.

The second general analytical strategy has been to develop a descriptive framework for organising the case study. Yin (1994) states that this may be a less preferable strategy than the one described above, but nevertheless, can be quite effective when causal links have to be established. There is no recommendation or, indeed, prescription by him that the two strategies are mutually exclusive. Thus, it is apparent that in instances, such as this research, where causal links between between 'value' and 'what creates and drives value', in respect of intellectual capital, have to be established, the application of this strategy in partnership with the first one (theoretical propositions), is sound. Support of this view was provided by Pressman (1973), in which complexity of the study was described in terms of the multiplicity of decisions that had to occur in order for implementation to succeed. This descriptive data later led to its enumeration, tabulation and the eventual quantification. In this sense, the descriptive approach was used to identify a type of event that could be quantified, and an overall pattern of complexity, that was ultimately used to explain (the causal links) for the results of implementation.

The parallels between Pressman's work and this paper are clear, and in this situation, the two strategies, in tandem, have been used as part of the methodology.

3.10.3 Modes of Analysis

As stated in the foregoing sections of this Chapter, the tool that has been used to analyse the case studies is a recognised computer software with the brand name NVIVO. Yin (1994) states that one of the most desirable strategies in case study research is to use a pattern matching logic. Such a logic, (Trochim 1989), establishes patterns in the data, which, if they coincide, can help a case study strengthen its internal validity.

As these case studies contain an explanatory characteristic Trochim (1989) states that in such cases, the patterns may be related to the dependent, or independent variable of study, or both. Even if the case studies are descriptive ones, pattern matching is still relevant.

The NVIVO case analysis software uses pattern matching as one of the dominant modes of analysis. Firstly, it analyses nonequivalent dependent variables as a pattern. Where multiple variable are present, and where the initial values have been found, and at the same time alternative patterns of values (including those deriving from methodological artifacts, or threats to validity) have not been found, strong causal inferences will be made.

Secondly, the software carries out pattern matching by analysing independent variables. Where several cases are known to have a certain type of outcome, the analysis focuses on how and why this outcome occurred in each case. This means that the presence of certain independent variables in each case study, predicted by one explanation, precludes the presence of other independent variables predicted by rival explanations. The independent variables may involve several or many different types of characteristics or events, each of which require assessment with different measures and instruments. The concern of the software is, however, to analyse the case studies to establish an overall pattern of results.

This type of pattern matching has been done with the three cases in the study. This means that the problem of the threat to validity (described above) has been eliminated. Furthermore, literal replication has been accomplished, and this is seen to add robustness to the study.

The second strategy that NVIVO uses is a special type of pattern matching. It does this by building an explanation about the case, and is therefore relevant to explanatory case studies.

The manner in which the software does this is by explaining a phenomenon by stipulating a set of causal links about it, and are similar to the independent variables (described above). Even where the links may be complex and difficult to measure, the software is able to produce an effective explanation.

While the second strategy is more complex, it makes the results more credible and robust, and provides a good basis for the next stage of the research, which is to build a valuation model for nascent technologies.

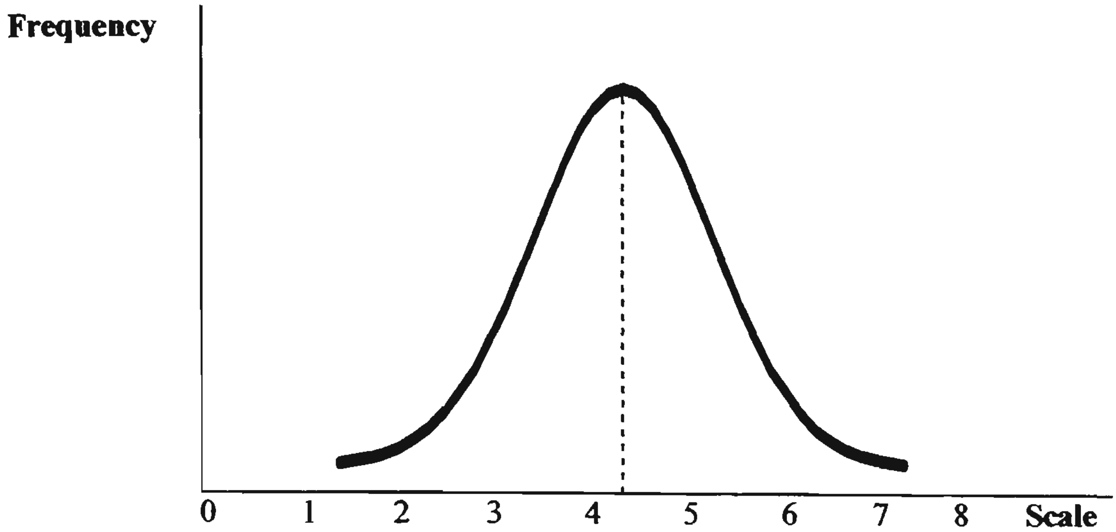
3.10.4 Use of Statistics in Data Analysis

This research will also apply descriptive statistical analysis to evaluate the frequencies and importance placed by the respondents on each pervasive variable identified. The theory of descriptive statistics to be used in the analysis is described and presented below.

Descriptive statistical methods are used to describe data that have been, or will be collected. Data collected from surveys will be of little value until they are organised, using statistical tools, into an organised form. Frequency distributions are also used to give data a meaningful form. Descriptive measures are particularly useful for comparing the response pattern for different groups or different questions.

3.10.5 Mean and Medians

The data from the survey will be organised using statistical techniques. This will allow the researcher to test the validity of the analysis arising out of the case studies on the three companies in the research park. The mean will be calculated to show the average response in the sample survey (representing the average response in terms of importance respondents place on each variable), while median values will be calculated to show the middle value after the scales have been sorted in ascending or descending order. If any extreme values are shown, a trimmed mean will be calculated by excluding the highest 5 percent and lowest 5 percent, before calculating the mean.



The median will be also be calculated, if necessary, as this is a useful measure in situations where variables are found to be skewed in distribution. A right-skew distribution has more unusual (or extreme) top values, while a left-skew distribution has more unusual (or extreme) bottom values. The mean is less reliable when the data are skewed, because its value is very sensitive to extreme values.

3.10.6 Standard deviation

The standard deviation is commonly used as a measure to compare the spread in two or more sets of observations. In other words, standard deviation is used to compare dispersions.

For the survey data, the sample standard deviation will be used as an estimator of the population standard deviation (the population standard deviation being the square root of the population variance. Likewise, the sample standard deviation will be found to be the square root of the sample variance.

For the survey data, a bell-shaped curve representing the survey data will be calculated, representing a normal distribution, where, for a (bell-shaped) frequency distribution, approximately 68% of the observations will lie within plus and minus one standard deviation of the mean; about 95% of the observations will lie within plus and minus two standard deviations of the mean; and practically all (99.7%) will lie within plus and minus three standard deviations of the mean.

The area under the curve will represent the probabilities for the occurrence of ranges of values.

Interpretation of the standard deviation will allow us to test the reliability of the variables by observing the cluster around the mean.

3.10.7 Assuring the Quality of Analysis

Consistent with the recommendations of Yin (1994), every effort will be made to ensure that the analysis in this research is of the highest quality. In this respect, four principles, named and described hereunder, will be adhered to.

Firstly, the analysis will show that it has relied on all the relevant evidence, and that the analysis, itself, is exhaustive. It will show as much evidence as is available, and the interpretation that follows will account for all the evidence, without leaving any loose ends.

Secondly, the analysis will attempt to make all major rival interpretations. If none appears in the study, it will lend weight to the major interpretation, but variables, which are of a minor nature in respect of valuation of nascent technologies, will also be considered and noted.

Thirdly, the analysis will address the most significant aspects of the case studies. It will attempt to demonstrate the best analytical skills in respect of the most important aspects of the cases in order to provide a sound foundation for building a valuation model. Since much of the analysis will be carried out using a world-recognised case analysis software, it will assure that no aspect of importance has been missed out in the analysis.

Fourthly, the investigator will bring into the case studies his prior, expert knowledge in the subject areas, resulting from analysing similar (but not the same) issues in the past, and from an awareness of current thinking and debates about the case studies topics.

The study will adopt a structured set of procedures in order to demonstrate a high degree of care for the empirical investigation. This will be reflected in the presentation of the cases themselves, and not just because of the existence of a stringent methodology section.

As stated above, the case studies data will be matched with data from the surveys to ensure that the pervasive and important factors are identified, before building a model for estimating value for new technologies. In building this model, the researcher will also use his own professional judgment, experience, and knowledge as a source of input into estimating the factors that create value for intellectual capital.

3.10.8 Developing the Econometric Model

As stated earlier in this Chapter, in Chapter 5, a logit model(s) will be developed for valuing firms in the three high technology sectors and the outcome of the analysis will highlight several pervasive value drivers for each of the three high technology sectors under investigation. Following on from this phase, Chapter 6 will continue to develop the valuation process using the results of the logit analysis to build an econometric model for the valuation of intellectual capital. The quantitative approach involves using the identified pervasive value drivers from the logit study to develop an econometric valuation model for nascent high technologies. As was noted in Chapter 1 Introduction, the use of underlying value drivers as a means for estimating the value of intellectual capital is a challenging endeavour and is also relatively a new area of research (Helfert 2000).

The use of regression analysis for the valuation of intellectual capital in high technology oriented firms is based on the principle of factor models or index models proposed by Sharp, Alexander and Bailey (1995). Factor models are 'return-generating' statistical models that assume that the market value of intellectual capital of high technology firms is sensitive to the movements of various factors or indices, and are widely used in financial markets' research. The techniques of simple or multiple regression analyses are used to define the return-generating process, depending on the number of predicted variables.

The multi-factor model is a 'return-generating process' statistical model, and is used to describe how the value of an investment or asset is produced by identifying major economic factors (variables) that systematically move the prices of 'all assets'. The multiple-factor model assumes that the value of an asset is sensitive to the movements of various market factors. The model implies that the return on two assets will be correlated through common reactions to the factors specified in the model. The factors are the characteristics being measured and could be anything that can be objectively identified and scored. In this respect Chapter 5 will show the value drivers that will be identified suing the scoring approach.

The linear multi-beta model that will be developed in Chapter 6 will use the method of ordinary least sqares (OLS) for estimating the value of intellectual capital. This is consistent with CAPM, which proves that the relationship among prices of assets in a general equilibrium, where the investors select assets to maximize the mean-variance utility, is linear. This approach is adopted in the development of the proposed model(s) titled 'Australian Multi-Factor Technology Valuation Models' for the valuation of intellectual capital of firms operating in high technology knowledge economy.

3.11 Conclusion

The qualitative and quantitative methodologies discussed in this Chapter will enable this research project to be conducted in a systematic manner and will give this research depth and robustness. The interviews and survey questionnaires will be framed accordingly. The knowledge achieved from this research will allow investors and other users to value intellectual capital of an organisation with the aim of facilitating investments to take place to secure profits and cash flows in the future.

In the following Chapter, the data from three case studies and the results of the analysis have been presented. They are based on three companies located in La Trobe University's Research Park, each operating in the three different industries stated in Chapter 1. The case studies have been written from interviews carried out with senior management personnel of these firms, in order to assure the integrity of the information.

Chapter 4. Case Studies

4.1 Introduction

It was stated in Chapter 3, Methodology, that the research approach adopted in this study is based upon the case study methodology, and a questionnaire survey covering 300 companies operating in the three different industries. The case study approach has been defined as "an empirical inquiry that investigates a contemporary phenomenon within its real life context when the boundaries between the phenomenon and its context are unclear, and where multiple sources of evidence are used" (Yin 1989).

The selection of the case study method was based on its suitability both to the purpose of the investigation and to the nature of the data to be collected and analysed. Chapter 3 stated that the three industries selected for this study are (1) Biotechnology, (2) Information Technology, and (3) Energy and Environment. Chapter 4 will discuss the general background of these technologies, and the position and role of university based research parks in fostering and commercialising nascent technologies within a national framework, before focusing specifically on each. Finally, the case studies will describe the three firms that have been selected for the interviewing process.

4.2 Background

The following sections describe links between intellectual capital and technology, and the role of research in Australia which provide an important context for the valuation of intellectual capital

4.2.1 Technology and Intellectual Capital

The world of business is now living through a pivotal period in economic history. New technologies that have evolved from innovations of the past century have now begun to bring about dramatic changes in the way goods and services are produced and in the way they are distributed to final users, be it customers or businesses. Those innovations, exemplified in recent years by the exponential growth of the internet, have resulted in a parallel growth of start-up firms, developing technologies many of which may offer the chance to revolutionise and dominate a nation's economic activity connection with the production and distribution systems.

The effects of innovations and the intention of firms to employ new technologies have returned dramatic results. For example, the 1990s turned out to be a decade of unexpected financial performance, which clearly heralded the coming of age of the knowledge economy. The numbers were impressive in every respect. In the United States, for example, firms showed a 70% increase in real profits, while maintaining inflation below 2%, and unemployment below 4.5% (Westland 2002).

Innovation and the major activity underpinning innovation – research and development - is surging throughout the world. In the US, annual R&D in 1999 was estimated to be $US 236 billion, rising by an average by 5-7% per year. This according to Razgaitis (1999), would imply that world-wide R&D spending exceeds $US 600 billion, based on the assumption that the US represents approximately 33 to 40 percent of total R&D expenditure.

According to a 1997 survey, results from 175 responding US and Canadian universities, teaching hospitals, and patent commercialisation companies, their total sponsored R&D expenditures in fiscal year 1997 was $US 22.7 billion. During FY 1997, this group totalled 11,303 invention disclosures, 4,267 new patent applications, and 2,645 new US patents.[15] Only when the economic potential of R&D can be clearly verified, will the technology be subjected to the rigours of valuation, which will lead to licensing and successful commercialisation.

[15] AUTM Licensing Survey, Published by Association of University Technology Managers (AUTM), 49 East Norwalk, CT 06851-3919.

4.2.2 Research and Development: the Australian Context

Clearly, R&D activities are the backbone of innovation. Indeed, innovation cannot exist without it. The widely held view that in a modern economy business innovation in general and R&D in particular are central to competitiveness, is as relevant Australia as it is to any developed economy. For example, the report Emerging Exporters, prepared by McKinsey and Co for the Australian Manufacturing Council, and based on a survey of Australian companies concluded that:

> High-exporting firms compete on value, particularly in quality, technology and product design. While cost competitiveness is important, it is not the key determinant of success. They have a strong customer orientation and tailor their products to meet particular customer requirements[16].

The report also found that faster growing and profitable firms are more likely to develop specific products for growth and export markets. Coming from a rather different perspective, the Industry Commission also concluded in its most recent report on R&D that:

> The opening of the Australian economy has raised technical efficiency in production and prompted a search by business for enhanced competitiveness through innovation.[17]

The report clearly states that the recent growth in R& D has contributed to improved competitiveness, profitability and growth in manufacturing businesses. Further, it has contributed to influences over price and non-price competition, productivity, and export orientation. An important aspect of the acceleration of productivity is that cost increases have been held in check. Despite the surge in demand, unit labour costs over the past few years have increased very slowly, and pricing increases have remained constrained. Clearly, firms hesitate to raise prices for fear that their competitors will be able to wrest market share from them by employing new investments to produce at a lower cost.

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[16] McKinsey and Co 1993, p.17).
[17] Industry Commission 1995, p. 8

If it can be assumed that R&D will continue to gather momentum, it will clearly indicate that the application of existing technology is still far from complete. Further, potential benefits derived from continuing synergies, support a distinct possibility that total productivity growth rates will remain high or even increase further. Despite the fact that there must exist some uncertainties about the continuing pace of productivity growth in the years ahead, knowledge is essentially irreversible. Clearly, knowledge will provide the platform for competitiveness and profitability. Thus, It is only reasonable to assume that in the next decade or so, economic growth throughout the developed world, propelled by the knowledge economy, will turn out to be only the initial stage of a much broader flowering of technological, business and financial creativity. Therefore, the importance of nascent technologies to develop to the commercialisation stage cannot be underestimated. In this respect, technologies being developed within the compounds of research parks, like those at La Trobe University play a critical role in enhancing the value and importance of knowledge within the nation's economic framework.

4.2.3 Research and Development: An Overview of the Government's Policy Framework in Australia

In examining the changes which have taken place in Australia's science and technology performance over the last fifteen years, four policy areas – tax incentives for private R&D, support for science and innovation from the Federal Budget, industry policies encouraging R&D, and commercialising university based research appear to be important. Past policies in these areas have been central to the expansion of R&D, and it is obvious that development of these policies will be vital to the nation's future in creating, generating and commercialising knowledge.

4.2.4 Research and Development: Commonwealth Government's Budget Support for Supporting the National Policy Framework

While there is sufficient data to show that business funding of R&D has grown in recent years, the Commonwealth Government still remains the dominant source of financial support for R&D in Australia. In total, its support for science and innovation (including revenue foregone through incentive schemes) still amounts to over 40% of national R&D in 1994-1995. Thus, the growth of 4.5% per annum in real terms over the decade to 1994-95 has been the major reason for the improvement in Australia's R&D performance (Sheehan et. al. 1995). This is one evidence of the government's support for nurturing nascent technologies in Australia. Further In the previous five years to 1990, total Commonwealth support had grown by only 3% per annum in real terms, with virtually all of this taking place in revenue foregone through tax concessions for private R&D. Over the next five years, to 1995, total support grew by 6.1% per annum, with the increases partly reflecting the emergence of important new programs. In recent years growth has slowed in real terms, as concern over the budget deficit has again begun to overshadow specific policy issues. This notwithstanding, the rate of growth of Commonwealth support for science and innovation will continue to be in the future an important determinant of the speed and success of the nation's intention to make the transition to a knowledge economy (Sheehan et. al. 1995).

Further, the Australian Government has, since the early 1990s, developed a plan to make Australia a true global player in e-commerce. This consistent policy means that the government takes action to provide the industry with the best possible framework to work under. The most visible result of this is the excellent network infrastructure in the country. There is also clear indications that, consistent with the other policies, the Government will support open standards and promote competition..

4.2.5 Research and Development: The Role of Educational Institutions in Making Investments in R&D within the National Framework

While private firms have access to R&D incentives through the tax system, these incentives apply only to a small number of public sector producers of goods and services. Given the importance of the quality of these activities for the welfare of the Australian economy, the government has deemed that a set of incentives for public sector agencies to undertake R&D would complement those given to the private sector. Here, public sector agencies are defined to include not only public trading enterprises, but also all agencies providing services which can be provided on a commercial basis such as universities and educational institutions.

4.2.6 Research and Development: University Based Research and Research Parks

A Melbourne Consulting Group report, commissioned by ARC in 1997, proposed an action plan, consistent with government objectives, to boost research and research commercialisation activities of universities in Australia.[18] According to the report, the traditional boundaries between education and work, research and commercialisation, basic research and applied research, and universities and industry are all blurring. It is claimed that this convergence will, in time, reduce operational impediments between universities and industry, which may be currently apparent.

In Australia there are concentrations of technology and bioscience companies around universities and research institutes. The reason for co-location is appears to be the very reason for their success: the opportunity for networking among participating firms. The rapid advances in communication and information technologies have created the possibilities for networking to expand outside the confines of research parks. Therefore, these can be thought of as virtual clusters, in the same way, albeit in a smaller framework, as the widely celebrated clusters like the Silicon Valleys in California, Boston, and Cambridge, England. In a broad sense, a cluster may be geographically concentrated or distributed through virtual networks, but in any case are smaller scale versions of a national innovation system.

Research Parks, like the one at La Trobe University represent a concentration of economic activity involving innovative universities, which act as a magnet for new technologies, skilled researchers, and investments in research. They offer firms economies of scale and scope and access to a strong science and technology base, and a culture conducive to innovation and entrepreneurship, with the objective of reducing

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[18] Australian Research Council, 1999, *Commissioned Report No 60,* **University Research: Commercialisation and Technology Transfer Practices**, Melbourne Consulting Group Pty Ltd

the cost and risks of research. In turn, this should result in successful commercialisation of new technologies.

In essence what this means for nascent technologies that they are allowed to incubate in a protective environment until they reach their verifiable potential before being valued for the purposes of commercialisation.

4.2.7 Research Park at La Trobe University: Creating, Developing and Commercialising Intellectual Capital within a Framework of the National Agenda

Commercialisation of knowledge arising out of research, is a complex and onerous concept requiring complicated interactions between research providers, the companies wishing to exploit the research, and in most cases, the investment sector. It is a key aspect of innovation. In its most obvious form, the commercialisation process involves taking laboratory research results and completing the considerable further experimental development, production and marketing that is needed to deliver the products and services to customers. Equally, it may involve the incremental changes in materials, products and processes leading to improved efficiency and competitiveness.

Commercial outcomes may result from research conducted by businesses themselves, or the licensing of intellectual property from public sector researchers such as universities or CSIRO. There are a number of commercialisation options for a researcher or research organisations, among them to sell the technology, license it to external firms, or to establish a spin-off firm to harness the commercial benefits of the new technology. One of the underlying factors that leads to the success of nascent technologies is the option the developing firms adopts to commercialise the technology. In the case of La Trobe University, the general strategy has been to licence out the technology prior to its commercialisation. And herein lies the major problem: The question of value of this new technology. Currently, the pricing strategy has been one to value it on the basis of past costs. While a plethora of criticism can be levelled against such a practice, primarily on the grounds that cost has little relationship to value, other methods have been used only half-heartedly. This is mainly because of the lack of a perceived importance of valuing their innovations, and further, the lack of knowledge, time and resources available to the researching firms.

This situation notwithstanding, research can generate substantial benefits if the commercialisation process, which is both complex and costly, can be successfully mastered. For every \$1 that leads to a promising research outcome, anything up to \$100 or more of further investment may be required for successful commercialisation. Experience in Australia and overseas indicates that only one in one hundred of prospective research outcomes investigated for investment purposes can be successfully commercialised.[19] Clearly, the risks involved in developing and commercialising knowledge are substantial. These risks stem from two sources: the first is the lack of infrastructure funds available to small companies and researchers for investments in new technologies, and second, the lack of formal and accurate means of valuing innovations in order to remove the impediments to attract risk capital for commercialisation of these technologies.

Thus, a major role of Research Parks is to minimise the risks of the first type. This is achieved by providing various infrastructural advantages to firms to develop *their technologies*. However, this does not remove or reduce the risks inherent in the second impediment, that is, providing a sound valuation model for nascent technologies. This is particularly pertinent in the case of La Trobe's Research Park. Creating a valuation model based on factors that create value in new technologies thus provides a sound basis for this research.

4.2.8 La Trobe University's Strategic Approach to Research Commercialisation

In view of the risks and difficulties involved in commercialising research, the strategic approach of the University's Research Park is constructed around six key action areas:

1. Develop effective commercialisation support structures

[19] Department of Industry, Science and Tourism, 1998, **Science & Technology Budget Statement 1998 - 1999**

2. Create the right academic environment
3. Motivate academics to research for benefits to both themselves and the University
4. Develop and expand relationships with existing companies who may benefit from commercialising the technologies
5. Strengthen the corporate base
6. Develop a framework for establishing new spin-off companies derived from the University's research activities
7. Increase the amount of finance available for the commercialisation of research and technological innovation
8. Attract the major types of profitable technological developments to the Research Park, which will make it easier to commercialise, on the basis of demand for such new technologies, locally and internationally
9. Reduce, if not eliminate, the infrastructural impediments and risks of developing new technologies
10. Provide financial services in respect of assistance to researchers to accurately value their technologies
11. Provide financial services by finding sources of investments at the commercialisation stage
12. Provide, where possible and appropriate, consultancy services sourced within the university, to add to the possibility of nascent technologies succeeding at the commercialisation stage. These include advice in relation to legal matters, patent and trademark issues, marketing (both local and international), financial valuations, competitor analysis, and specific issues of risk reduction techniques. The strategic direction of the university is to add value to the portfolio of new technologies by reducing the many identified risks and uncertainties that impede commercial success.

While all these plans indirectly are believed to add to value, this research is most concerned with the pre-penultimate point: formal valuation of nascent technologies, without which, there would be major impediments to securing investment capital.

Consistent with its action plans 6., La Trobe University has actively sought to attract three types of technologies to the Park, (1) Biotechnology (2) Information

Technology, and (3) Energy and Environment. While there are other types of technologies being developed there, these three aggregates to a substantial proportion of La Trobe's investments in its Research Park.

4.3 Case Study 1: The Walter and Eliza Hall Institute of Medical Research

This case study relates to a leading biotech company, which conducts innovative research with the objective of commercializing their successful research output.

4.3.1 Biotechnology

The following sections describe the biotech industry, and the various applications which represent important investments in intellectual capital

4.3.2 Industry Background

Biotechnology, in the modern sense, consists of new and innovative techniques to modify or to manipulate biological organisms to produce useful products. Essentially this translates into the technologies such as genetic engineering, gene splicing, recombinant DNA, and cloning.

Simply, by manipulating with cells, modern biotech has the potential to turn out safer, more potent products that can improve health, and diagnose, treat, or cure many diseases. Or it can improve and increase the food supply. Further applications of biotechnology include improving vegetation in the world, particularly where there has been massive deforestation, or where there has been a steady encroachment of the desert. Other applications of biotechnology include cleaning up dangerous chemicals and wastes.

The potential for growth in biotechnology applications is immense. Thus, it provides ample opportunities for investments to take place once the commercial viability of the technology has been proved. While there has been a high growth rate in biotechnology in the last decade it is believed that its full impact has yet to be felt. The Commerce Department in America predicted in 1995 that the sales of biotech-derived products will grow 15 – 20% world-wide for the decade beyond the end the of the century[20].

The US Commerce Department's National Critical Technologies Panel states in the same report that biotechnology demonstrates perhaps more vividly than any other discipline the synergy between scientific discovery and the commercialisation of innovative and life-enhancing products. Given this promise, US$ 1.5 billion of investment monies found its way every year into biotechnology innovations. Currently, total revenues for the biotechnology industry are estimated at between $US4 – 5 billion in America alone. Growth will see revenues world-wide rise to approximately US$ 100 billion in the decade to 2005. [21] Financially or otherwise, the ability to alter genes can have immense implications for competiveness, growth and profitability. It is apparent that if there is one emerging industry that probably most symbolises the 21st century, with all its contradictory scenarios of potential utopias and dystopias, it is biotechnology (Georgiou 1994).

4.3.3 Applications of Biotechnology

The following sections describe and evaluate the innovative directions in biotech research which provide profitable commercialisation opportunities.

4.3.4 Treatment of Diseases

In the twenty years or so that modern biotechnology has existed, biotechnology firms using gene splicing and other techniques, have manufactured commercial quantities of substances which can check and treat many diseases. These include vaccines against

[20] Commerce Department's **Report on National Critical Technologies**, 1995, p.85
[21] Office of Technology Assessment (OTA) report, **Biotechnology in a Global Economy**, 1994

the flu and hepatitis, human insulin for diabetics, human growth hormones, drugs that battle cancer, and biopharmaceuticals that break up blood clots and treat anaemia.
In addition to therapies, biotech is creating new ways, to detect or diagnose many diseases including hepatitis, cystic fibrosis and various kinds of cancer, and diseases that are sexually transmitted. All these include areas where there are huge opportunities for profitability, given that the diseases are widespread throughout the world. But the key is innovation and creativity in the product lines, not merely just adding to the list of other therapies available in the market.

Other areas of technological innovation include techniques to make monoclonal antibodies. These are essentially produced from a hybrid – part disease-fighting white-blood cells, part tumour cells, which divide to create a cell culture that turns out identical antibodies. Because the are cloned from a single cell, the term used to describe them is monoclonal. Monoclonal antibodies are designed to recognise and attack a specific disease-causing agent. Technological innovation must be supplemented by management innovation, both in terms of organising the resources of the firm, not least its human resources, and the skills and knowledge of its employees, to harvest the financial and market opportunities that are available in the competitive arena. The growth and financial potential afforded by the global market for these products must be underpinned by a drive to innovate, seize market opportunities, secure patent and legal protection, and make investments in ongoing developmental research to avoid technological obsolescence. Such a management view would produce huge financial profits for the company.

Another area of research occurs in the area called antisense technology which tries to trip-up disease causing genes with molecules that can block certain messages to them. Using these and other methods, biotech firms are developing drugs to speed-up wound healing, and are finding ways to treat or detect many diseases and disorders, including AIDS and cancer, anxiety, rheumatoid arthritis, psoriasis, and various disorders of the central nervous and cardiovascular systems. The difficulties in finding cures for stubborn diseases like AIDS and psoriasis, and more recently, SARS, provides innovative companies in biotech research with ample opportunities for profits and growth.

Using gene therapy, scientists hope to someday treat or cure the more than 3500 diseases that are inherited, such as sickle cell anaemia, or Alzheimer's, and are essentially caused by a mutant or malfunctioning gene. For pharmaceutical companies able to commercialise such therapies, and reduce costs to governments and individuals of medical treatment, the potential for profit and adding value to their stocks and shares is significant.

The market size world-wide for pharmaceutical products is approximately $US 800 billion, with growth forecast at approximately 15% per annum. (Georgiou 1994). This potential has moved firms and governments to make large scale investments in bio-technology. The governments of developed economies spend a very high percentage of their budget on public health, and this is regarded an immense burden on the public purse. Therefore research into biotechnology that reduces the costs of medical treatment is regarded as an important research activity. It is important to recognise that biotechnology is a revolution in how drugs are developed, and will eventually dominate the drugs industry. In the not too distant future, biotechnology could impact virtually every illness mankind suffers from. However, biotechnology, until now, has barely scratched the surface and therefore, its potential for commercial success is substantial. In one opinion, it has been said that biotechnology is likely to be the principal scientific driving force for the discovery of new drugs as we progress through the 21st century, and the impact of biotechnology on the discovery of new therapeutic entities is difficult to underestimate[22].

4.3.5 Agriculture and Related Industries

Less spectacular, but perhaps just as important, biotechnology has a huge potential for applications in agriculture and related industries. In fact it has the potential to reduce and alleviate hunger and malnutrition in the world. But to an even lesser degree than the health field, very few biotech products are on the market at the moment, which include a few pesticides and genetically engineered animal vaccines. But a number of new products are on the verge of cracking through, and thus, agricultural biotechnology has been called the new frontier for biotech. World-wide sales for ag-

[22] M. Montague, research operations director, Monsanto Company, quoted in the OTA Report on biotechnology in a global economy, December 1990.

bio products are expected to grow to $US 25 – 30 billion by 2005 (Georgiou 1994), which will give firms adopting new technologies the opportunity to significantly improve their financial value.

With biotech, scientists can essentially speed-up the conventional selective cross-breeding process, and quickly create new traits in plants that otherwise would have taken years. Also, gene splicing can introduce completely new traits from one plant to another. Current policy thinking about agriculture is going to be totally irrelevant in the near future. Good and proven biotechnology products will assist in reducing wastage and costs and boosting productivity substantially. Major crops such as corn and wheat could see thousand-fold increases in yield through genetic manipulation, providing huge financial rewards for firms applying such technologies[23].

Crops that are more disease, drought and insect resistant will be developed. The ultimate upshot is the application of biotech to produce higher crop yields, better quality and more nutritious crops, and importantly, a lower production base.

Research into biotechnology has been successful in creating alternatives to chemical pesticides. Biopesticides using microbes not dangerous to humans, wildlife, or crops, and are less polluting are gaining success, but have been able to take only a small share of the pesticides market. The potential is, however, enormous. In 1992 the FDA in the US made a monumental ruling for ag-bio, stating genetically modified foods present no greater safety concerns than regular foods, and consequently would be regulated the same way. That is, no special labelling would be required for genetically treated foods. This has enormous implications for the ag-bio industries and their profitability. Value of this technology will increase enormously when the fear of safety and costly legal and ethical threats has been removed. Following the ruling, there would now be no need for firms to engage in costly field and safety tests, thereby reducing the costs of development.

[23] Office of Technology Assessment (OTA) report, **Biotechnology in a Global Economy**, 1994

A further application of biotechnology lies in the development of various genetically engineered animal hormones that will lead to better chicken, pigs, lambs, deer and beef. Productivity will be increased in two ways: there will be higher milk yields from animals, and, higher meat contents. For example, the cow hormone BST can increase milk production by as much as 40%. Throughout the world, huge markets could be affected profitably, since the dairy and meat markets are each worth billions of dollars every year.

In various stages of development, there are a series of other innovative af-bio products. Among them are sweeter tasting carrots, peas, and tomatoes, pest resistant corn, herbicide-tolerant tomatoes, cotton, and soy beans, and canola plants that can produce cosmetics, detergents, food ingredients, and industrial lubricants.

4.3.6 Environment

Innovative biotechnology has begun to play a major role in helping with environmental issues. The most obvious example was in 1989, after the now infamous Exxon Valdez oil spill off the Alaskan coast. Scientists using naturally occurring, non-genetically engineered micro-organisms helped degrade the crude oil.

Biotechnology has created pioneering products that can also be used in disposing off of dangerous garbage and waste, and is called bioremediation. This technology can be used in several situations, including the cleaning up of industrial wastes and waste-water sites.

Currently, all commercial bioremediation projects use naturally occurring organism. Some genetic engineering research for bioremediation is continuing, but recently the US government concluded that commercial use of gene spliced micro-organisms for waste disposal is unlikely anytime soon because of a range of scientific, regulatory, and economic problems. Because of the risks, bioremediation products that exist now do not have a high profit margin, and consequently, investment capital is attracted in only a small way.

So far, according to the OTA report, referred to above, research and product developments in the environmental sectors are minuscule, compared to more commercially profitable sectors, influenced by biotechnology, and international activity to date is limited. This clearly indicates that it is the potential for financial profits that underpins commercial success of nascent biotechnologies. However, while investments are currently low, the report states that the estimate put on bioremediation market at $US 220 million at the beginning of the 21st century. This scenario of market growth is likely to fuel considerable investments in bioremediation technologies.

4.3.7 Chemical Industry

Biotech also has widespread possibilities in the huge chemical industry worldwide. The size and profitability of this industry has also induced many competitors to partake in its profitability. Adopting innovative technologies is perceived as a necessary strategy to maintain competitiveness, and financial profitability. Further, as established markets become crowded, nascent technologies provide the means to establish and capture new markets.

In theory, any chemical change can be brought about by a genetically engineered bacterium. But instead of using pressurised vessels and electricity, as chemical companies now use, the bacterium would do its job in a warm liquid, using sugar or sunlight for energy. For example, fuel could be produced from waste products instead of from crude oil, several plastics could be made, and alcohol could be made from wood pulp. However, for the time being, the potential of this technology is yet to be realised. Therefore, it does not make economic sense to use genetic engineering to produce bulk chemicals. The lack of prospect of commercial success that has stunted investments in this specialised segment of the chemical industry.

The future of biotechnology suggests a successful blend of innovative technologies and commercial profitability that support the development of financially successful companies, more commercially available products, and solid returns on investments. However, there are some provisos in this promising scenario. Firstly, active research has to occur to convert ideas that have been a major factor in driving the value of biotech firms, to concrete and commercial products with financial viability. Secondly, biotech firms have to acquire the ability to continue to attract large investments to produce ideas into commercially viable products. In other words, they must show the ability to convert themselves from a laboratory into a business that can fight for market share, and show profits and positive cash flows. Capital providers are often uneasy about the long time frames and capital intensity this industry characterises, but with their increasing maturity, they have learnt to be selective. Central to this problem has been the lack of knowledge about the value of nascent technologies, which prevented the inflow of investments for development. Financial returns can be very good, because there is a steady flow of new technologies, as well as diseases that can be treated by biotechnology. However, biotech firms have begun to realise that good technologies do not guarantee success. They have to grow business legs now that products are emerging from research, which are entering the market. For example, in the past few years, R&D spending as a percentage of total biotech expenditures has shrunk, primarily because of high risks involved in getting an idea from a laboratory to the marketplace. At the same time, biotech firms are spending more to build sales and marketing infrastructures to support commercialised technologies with high profit potential, and low risks. Many firms have focused goals and many firms are hiring experienced executives from other industries to ensure success (Georgiou 1994). Thirdly, because of their large cash requirements, and often their inability to focus on the marketing aspects of their businesses, it will be necessary for many firms to enter into strategic alliances within the biotech industry. That is the standard when companies face high costs and increasing competition for a market or cash. The ability to enter into joint venture agreements, mergers, licensing agreements and marketing agreements will help diffuse financial risks. The result will be a strong and growing industry, producing a positive impact on our quality of life and environment for a better future.

THE WALTER AND ELIZA HALL INSTITUTE OF MEDICAL RESEARCH, located in Parkville just north of Melbourne's CBD, is one of Australia's foremost medical research establishments. The work of the Institute is centered on cancer, the immune system, autoimmune diseases – such as diabetes, multiple sclerosis and rheumatoid arthritis – malaria, neural development, genetics and drug discovery.

Over many decades, advances and discoveries in these areas have led to significant benefits for patients throughout the world, and provided firms with avenues of growth and profitability.

Under Sir Gustav Nossal, Director 1965 – 1996, the institute grew significantly in size and research scope. Scientists at the Institute, led and inspired by Sir Gustav and Professor Jacque Miller, investigated and revealed the basic mechanisms controlling immune responses and new approaches to autoimmune diseases such as diabetes were explored. Professor Don Metcalf and his team discovered key regulators of cell production – the CSFs – which led to great benefits for cancer patients. With the introduction of molecular biology came exciting new insights about antibody production and the onset of leukemia. Molecular biology also catalysed significant progress in understanding and combating malaria, which has a huge international market potential in Africa, Asia and Latin America.

Led from 1996 by Professor Suzanne Cory, the institute – or WEHI, as it is sometimes called – remains committed to biomedical research and the pursuit of new therapies which has the potential for commercial success. Today's scientists are applying the groundbreaking discoveries of the human genome project, collaborating in many projects worldwide, reducing the cost and risks associated with innovative research. The Institute is in the front line of the biotechnology revolution, which will bring great financial rewards and benefits to the pharmaceutical industry.

With its distinguished international reputation, the Institute attracts the best and brightest of Australian and Overseas scientists, who thrive in what Sir Gustav Nossal memorably described as "a bubbling cauldron of ideas". Developing pioneering technologies is one of the objectives of the Institute, because it adds value to it, and delivers competitive advantage to the adopters of these technologies. This also has the effect of reducing the risks associated with innovative research, reducing costs, and increasing the possibilities of securing venture capital. Further, the reputation of the technology developers and scientists is important from a marketing perspective. The better the reputation, the more credible the technology is. This leads to market success. Today, the Institute hosts over five hundred scientists, post-doctoral fellows, technologists, post-graduate and support staff working towards the mission of mastery of disease through discovery.

The Institute has gained worldwide recognition as a leading research centre. Its many innovative research projects have resulted in financially viable products which have been profitably commercialised within the organisation, or through spin-off companies, or by selling the technologies, or by entering into joint ventures as a marketing strategy. For many nascent technologies, joint venture agreements combine the benefits of partnership: the Institute develops the technology, while the joint venture partner provides the marketing expertise, both local and international. For this reason, the Institute is increasingly favouring joint venture agreements as a strategic means of commercialising nascent technologies.

4.3.8 Establishment of a Biotechnology Centre

After many months of building and planning, a small group of some of the Institute's most experienced staff spear-headed the establishment of Stage one of the Biotechnology Centre in La Trobe's R&D Park in Bundoora in September 2001.

The objectives of the centre were unambiguous: While the institute recognised its social responsibilities, and were eager to contribute to society at large, their major goal was to initiate research which would deliver commercially viable products and processes. Projects which failed to deliver financial value would be eliminated, and precious resources would be diverted to nascent technologies that showed promise of commercial success. The major areas of research at the centre would be required to fit within the framework of its objectives.

4.3.9 Major Areas of Research

The following sections describe the major areas of research in biotechnology which represent substantial investments in intellectual capital.

4.3.10 Cancer and Haematology

The work of the cancer and Haematology Division is directed at understanding what controls the production and biological activities of blood cells and what molecular changes might cause diseases of blood cells, including their development into cancers such as the leukaemias.

Worldwide research into cancer and haematology is of huge proportions, but the risks are high because it is cost intensive, with no guarantee of returns. Yet major progress into the treatment of these diseases has been made, and for those technologies that have gained commercial success, the financial rewards have been very high. In many ways, research in this area has been driven by market needs. Cancer rates are very high in developed countries, and while the percentage of the population suffering from this disease is relatively lower in developing economies, that is expected to climb in the coming decades. This provides high market opportunities to pharmaceutical firms to increase their profits. However, products are required to go through extensive testing before they are introduced into the marketplace. Therefore the technology must not only be quickly developed, but must be safe and free from side effects. For this reason, the reputation and skills of the research teams is necessary to bring value to the technology. But competition is high among firms to bring innovative and pioneering remedies to the market. But innovative and pioneering products can give a firm a high competitive advantage, and allow it to attain large market share. Further, for products that are safe and don't incorporate product liability risks, there is a low rate of technological obsolescence. This means that firms can harvest the financial benefits of established and good products for long periods of time.

4.3.11 Molecular Genetics of Cancer

This Division is exploring how cancers arise from accidental damage to genes that control cell accumulation. A cancer develops when one cell in any tissue becomes a rogue and its progeny accumulate inexorably. For instance, certain genes normally limit the cell numbers in our tissues by ordering any damaged or superfluous cell to die by a process termed "apoptosis". A cell in which programmed cell death is faulty may initiate a tumour. They have identified several of the genes that control apoptosis and determined how their alteration lead to tumours. Eventually, understanding of apoptosis regulation will lead to new forms of cancer therapy.

The Institute looks upon this branch of activity as another one of its pioneering research. Its immediate financial benefits are uncertain, but it will lead to new products for cancer treatment. Understanding of apoptosis regulations will cut the cost of developing new technology, make it more financially viable, and deliver safe and effective remedies to the marketplace. In turn, it will yield substantial financial profits to the company. But in order to achieve this potential, development time and costs will have to be minimised by ulilising the knowledge and skills of the research scientists. The quality of management will play a key role in this process: from organising the research team with the skills, dedication and reputation, to finding the financial resources to fund the research, to organising the marketing of the products, or the technology, to securing the legal protection and patents in respect of the technology.

4.3.12 Immunology

The Division aims to understand the basic functions of the immune system and the way it develops from stem cells in bone marrow. In collaboration with other laboratories, this basic information will be applied to improving vaccines and avoiding autoimmune disease.

The goal of the Division is to improve methods for preventing and treating two important parasitic diseases – malaria and leishmaniasis. They believe that the development of vaccines and novel chemotherapeutic treatments for malaria and leishmaniasis depend upon understanding the basic mechanisms of immunology, cell biology and genetics, since these determine the outcome of the relationship between the host and the invasive organism.

Malaria infects from 5 to 10% of humanity and kills two million people annually. The cost to societies in which malaria is endemic is horrendous, both in terms of the economy and human lives. Governments in affected countries, as well as those in Australia, the U.S, Europe, and Canada are keenly interested in proving a solution to this disease. Just as is the case with cancer research, products and processes, which are used to treat such diseases receive government support, and appear not to be susceptible to economic cycles or downturns. This creates value for the technology, because even when there is recession in an economy, it is not likely to result in falling sales and profits for these products. Further, the markets are so large that risks in any one market will not affect the overall sales and profitability of the products. There is yet another economic and financial benefit associated with the development of this type of therapy. The disease is widespread in South America, Africa, and Asia. Because of its huge impact on human lives and the economy of those countries, the market size for antimalarial drugs is enormous, primarily driven by governments in those continents, and the aid program of developed countries in Europe, and America, and Australia. Nevertheless, firms with safe and low-risk products will have to engage in aggressive marketing techniques to maintain a good share of these potential markets.

4.3.13 Autoimmunity and Transplantation

The immune system is essential to survival. It evolved to ward of external attack by infectious agents such as bacteria, viruses and parasites, and guards internally against the growth of foreign tumour tissue. Included in this branch of research is insulin dependent (type 1) diabetes, rheumatoid arthritis, in which the synovial tissues lining the joints are the targets of immune attack, DNA-based vaccines to regulate immunity, and the generation of insulin-producing cells that may be genetically engineered to withstand immune rejection after transplantation.

These three technologies stand at a higher level of development, and many of the drugs resulting from the research should eventuate in commercialisation. Most of the expensive research which impedes development of ideas into realisable commercial products has already been undertaken. What remains now is for the clinical and other tests of many promising drugs to be completed. Since the Institute and its research teams have a very good reputation, finding a market for the products should be relatively easy through one of their strategic marketing methods. Thus marketing management will play an important role in ensuring the success of these drugs in a very competitive market place. But in view of the fact that diabetes, and transplantation surgery is widespread, the commercial viability of drugs to treat them is very high. The potential for growth of sales and profits, with very little risk, based on these drugs, is undoubted for firms commercialising these products. As with other commercially viable, value added research the Institute undertakes, these technologies are not affected by economic cycles, or by short product life cycles. However, high commercial profit and growth potential does bring competition to the arena, but prohibitive R&D costs keeps the range of products available in the market at low levels. The marketing ability of firms to expand their market size becomes very important in this scenario.

4.3.14 Structural Biology and Mouse Genome Manipulation Services

The Division's goal is to contribute to the discovery of new medicines through studies of the three-dimensional structures of biological macromolecules that are likely to be targets for drugs. They expect this facility to generate many new drug leads in the future.

The Mouse Genome Manipulation Services incorporate a transgenic mouse production service provided by the Institute's Animal Services staff to both internal and external scientists and the mouse embryonic stem (ES) cell laboratory. The last 12 months have seen the relocation of the ES cell laboratory to new facilities within the Institute's Biotechnology Centre at La Trobe University's R&D Park in Bundoora. From is new location the ES cell laboratory continues to provide a gene targeting service allowing Institute scientists to delete or specifically alter genes in ES cells.

The commercial viability of these technologies is some distance away, but the potential for commercialisation and profitability is very high. In order to protect their investments in nascent technologies, WEHI would have to patent their inventions in order to give value to the technology at its commercialisation stage. Genetic engineering, which has been used to modify agricultural products and animals, remain shrouded by doubts, risks, safety issues and ethical considerations. While many of the products have been used to alter crops, vegetation, and yields from animals, controversy continues to follow these technologies, impeding their commercial application. Consequently, the risks of financial losses arising from government policies and legislation, and product liability suits remain high until the technologies are refined to eliminate their current problems.

4.3.15 Management of Intellectual Property

The granting of patents is a key form of international recognition of the innovative work being conducted at the Institute. Such patents also acknowledge, add, and protect the potential commercial value of the intellectual property of the Institute, while guaranteeing that the technology is original and pioneering. The Institute therefore moves to secure patents on all technologies it develops as soon as they reach the stage where their commercial value becomes evident.

The practise of the Institute is to transfer the technology for commercialisation, along with its patents. Without patents, there is very little protection for investors of this technology, which would, consequently, adversely affect the value of it.

WEHI's policy on patenting also helps its strategic marketing efforts. It is committed to forming relationships with commercial partners to licence the Institute's Intellectual Property and advance their medical discoveries to their clinical application. This model of partnership based upon the research skills and reputation of the institute, and the financial strength, marketing skills and management expertise of the partners has brought financial value and commercial profitability to all parties in the alliance.

4.3.16 Finance

The change in the structure of finding from the Commonwealth Government via the NHMRC, from Block funding to a Fellows and Program/Project structure, began to phase in from this year. Overall the Institute's growth that has been driven by a very significant increase in peer-reviewed, competitive new grants, which is a measure of the excellence of both the scientists and research programs.

The quality of research and the reputation of the Institute are critical in determining the level of income from government grants. Without such grants, much of the innovative and pioneering research would not take place.

Secondly, the quality of research and the reputation of the Institute also give value to the technologies being developed. This helps the strategic marketing effort at the commercialisation stage. Whatever channel is chosen for commercialisation, value is determined upon the financial benefits that technology will bring, at the lowest possible risk.

4.4 Case Study 2: Websyte Corporation

The Websyte Corporation is an innovative information technology firm which focuses efforts in areas which offer substantial opportunities for commercialisation.

4.4.1 Information Technology

The following sections describe the industry background and areas of research which represent important investments in intellectual capital.

4.4.2 Industry Background

Since the advent of computers and information technology, the nature of the enterprise has chanted. Business relies on different methods and skills than those of our predecessors in order to access our customers and provide them with goods and services. These new skills have been developed as a result of information technology, telecommunications technology and the requirement for a more sophisticated work force which relies on expertise and technology, more than manual labour.

Information technology has not just replaced manual methods of working, but has enabled the creation of new services which were not previously possible. Examples include international banking services, supported by modern telecommunications, credit card transactions of all types, booking of airline travel, and making hotel reservations in distant places. Information technology has changed the way people work. Many workers now do not have a fixed place of work anymore, but instead work form their homes using the information highway. Information technology has allowed 'teleworking' to greatly reduce the cost of operations of many firms with fewer offices, fewer meeting rooms, reduced travel and savings in time and money (Brooking 1997).

Such a scenario requires employees with new skills and knowledge. Organisations depend on people who use computers as part of their day-to-day job. Their know-how often takes a long time to develop. Technology is used to communicate with customers and deliver products and services. Databases tell us what products and services to sell to a particular customer and record his buying history, product preferences and preferred paying method. Computers are used to monitor customers' credit card spending patterns, and recognise changes in our buying habits.

Continuing developments and innovation in information technology is necessary, which act to provide a dynamic platform for new technologies to operate in a competitive environment. In fact, the role of technology in maintaining the competitive standing and profitability of firms is undoubted. Thus, business investments in information technology cannot be seen to be discretionary expenditures any more, but rather, as vitally necessary outlays in order to remain profitability and growth. In such a situation, the chances of nascent technologies succeeding at the commercialisation stage are very good, because they bring with them the benefits of lowering operating can manufacturing costs, increasing productivity, and the ability to turn out goods and services quickly into the marketplace.

New technologies that have evolved from the cumulative innovations of the past two decades have now begun to bring about dramatic changes in the way goods and services are produced, and in the way they are distributed to final users. Those innovations exemplified by the increasing use of the internet, have caused the a myriad of start-up information technology firms, all developing promising technology which have the potential to revolutionise and dominate a nation's production and distribution systems, making them more efficient, lowering costs, reducing risks, and increasing profits.

The promise of success for nascent technologies is evident in the progress of history primarily because the process of innovation is never ending. The advent of the age of information technology appears to have commenced after the Second World War with the development of the transistor. This defining innovation released a burst of synergistic developmental research that produced the microprocessor, the computer, satellites, and the joining of laser and fibre-optic technologies. By the 1990s, these and some other critical innovations had in turn, fostered an enormous new capacity to capture, analyse, and disseminate information. In essence, it is the growing market for information technology throughout all economies that makes the current period unique, and indeed, provides the most profitable financial opportunities for nascent technologies.

However, until the middle of the last decade, the billions of dollars that businesses had invested in information technology seemed to have only a limited impact on a nation's economy. The recession and trade cycles, combined with hostile trade union attitudes of the early 1990s raised serious doubts about the earlier promise of information technology to deliver verifiable and substantial financial benefits to firms. It was quite clear that adoption of new technologies suffered from economic cycles, recessions and adverse trade union attitudes. Optimists argued that investments in new technologies had not yet cumulated to produce the financial benefits. One problem, they pointed out, was that businesses were still using computers on a stand-alone basis. The full value of information technology and computing power could be realised only after ways had been devised to link computers into large-scale networks. This claim provided the opportunity for many technology developers to develop new network based goods and services for an ever increasing market.

The end of the recession in Australia in the middle of the last decade coincided with the increasing positive momentum of the US economy. In its wake the investment boom also occurred, suggesting that earlier expectations of elevated profitability had not been disappointed. Firms' operating profits started to rise, and there were strong indications that unit costs were slowing. These developments signaled that productivity growth was probably beginning to increase. At the end of the millennium there was no doubt that in Australia, as well as in the US, productivity growth had increased, delivering sustainable profit increases. This was clearly evident in the performance of good shares in the stock exchanges. Significantly, the ability of information technology to deliver continuing productivity increases shows no signs of slowing, and this, probably more than any other factor, promises a very robust future for nascent information technologies.

At a rudimentary level, the essential contribution of information technology to this process is the expansion of knowledge. But its role in reducing business risks cannot be overlooked. Prior to the phase when information became easily available, business decisions suffered from a whole host of uncertainties arising from the unavailability of information. Productivity suffered in this environment from firms being obliged to maintain expensive back-up systems in manpower and materials. The availability of up-to-the-minute information derived from sophisticated information technology systems, have reduced uncertainty, made the process of decision making more efficient, and most importantly, increased productivity and profits.

Undoubtedly, the current phase cannot be seen to be the end of the cycle. As long as business needs information to operate more effectively, there will be a need for new innovations. Large voids of information still exist, and forecasts of future events on which all business decisions ultimately depend will always be prone to uncertainties, risks and errors. But information has become more easily available resulting, for example, in highly efficient inventory management, allowing firms to increase productivity, reduce waste and pilferage, and increase profit margins. The surge in the availability of more timely information has enabled business management to remove large holdings of inventory, safety stock and worker redundancies.

The benefits of information technology have extended far beyond the factory and distribution channels. Increasingly, information technology has been applied to computer modelling, reducing the time and costs required to design items ranging from motor vehicles to aeroplanes and buildings to oil wells. As described in the preceding case study on biotechnology, medical diagnoses have become more thorough, more accurate, and far faster, thereby reducing costs and adding to the value of the technology.

The increasing influence of information technology has also been felt in the financial sector of the economy. Perhaps the most significant innovation has been the development of financial instruments that enable risk to be managed. Many new financial products have been created, financial derivatives being the most notable, that have contributed to economic value and financial gain. Since the capital market is truly global in nature, technologies that manage risk and increase profits for users attracts a huge market worldwide.

Most believe that the pace of innovation will continue to progress in the next few years, as firms exploit the still largely untapped potential for e-commerce, especially in the business-to-business segment, where there is a potential for rapid financial growth. An electronic market that would automatically solicit bids from suppliers has the potential for substantially reducing operating costs and increasing productivity for individual firms, and for the economy as a whole. This reduction would mean less unproductive search and fewer working hours more generally embodied in each unit of output, enhancing productivity.

In sum, indications that the extent of the application of existing technology is still far from complete, plus potential benefits derived from continuing synergistic gains, add to the possibility that total productivity growth will remain high or even increase further. Despite the fact that there may exist some uncertainty about the pace of productivity growth in the years to come, knowledge is essentially irreversible. This means that the recent gains in productivity, value, and productivity, arising out of the utilisation of new technologies and innovations, are permanent.

4.4.3 Applications of Information Technology

The following sections describe the important applications of information technology, and identify the areas of research in which there are substantial investments in intellectual capital.

4.4.4 Internet Technologies

While the framework for the internet had been developed as a military application during the cold war, it had little or no applicability in business until the advent of the World Wide Web. The software and networking protocols which define the web and facilitate browsing was developed between 1989 and 1991. However, it was the release by Netscape of its Mosaic software in 1995 that allowed the internet to acquire its full functionality, and make it readily available and accessible to business and to the international community generally. Since the mid 1990s there has been intense activity in the development of software systems for the internet (Weintraut 1997; Coppel 2000).

The Internet is, however only one element of the overall picture: The potential national and international market size, and the ability to profit from it has fuelled the substantial development of internet technologies by innovative firms. In October 1989, there were a mere 159,000 IP hosts. This grew to almost 30 million by the beginning of 1998, suggesting a total world-wide user base of more than 60 million.[24]. A large proportion of Internet usage is still, at present, located in the English speaking countries, but this will change as countries like China and India increasingly embrace the technology. By 2000 it was estimated that 600 million people world-wide was

[24] Network Wizards (http://www.nw.com)

using the technology, which represented a mere 10% of the population (Sheehan 1998).

This suggests that there is enormous scope for Internet to expand in the coming years, generating a huge level of demand for internet related software and tools. The implication for this is that for firms willing to make the necessary investments in value added internet and related technologies, the opportunity for growth and profitability by providing innovative Internet oriented technologies is immense.

4.4.5 Software Technologies

The increasing capabilities of computing and communications technologies in respect of hardware are vital enabling technologies, but without effective software development they remain useless. Thus, the past decade has seen major efforts being exercised in the area of software developments to meet market demand by competitors wishing to increase their profitability and market share. This has included pioneering research and innovations to create sophisticated software tools for the development of software. Firms using skilled software engineers have been able to produce commercially successful products that have produced high financial benefits for both the firms commercialising these products as well as for the actual users of such software. While it is certain that the capabilities of hardware will increase many folds over the next few years, the role of software development to power sophisticated hardware will also be commensurately enhanced, providing yet another avenue of opportunity to develop value added products and technologies which will add to their growth and profitability.

4.4.6 Supporting Technologies

Central to the actual application of these new computing and communications systems have been parallel advances in technologies related to the capture, storage and use of information in digital form. These include scanning and imaging technologies, memory and storage technologies, display systems and copying technologies. High definition monitors and other display systems are, for example, critical to the information industries. This has created substantial market opportunities for nascent technologies to produce light weight, energy efficient systems for a future mass market, with the active thin film transistor driven LCD display system apparently being the most well developed (Chaudhuri 1995). Market opportunities provide both the firm marketing value added technology, and their customers with avenues of increased productivity, profitability and growth.

4.4.7 Photonic Communications Technologies

There have been massive advances made in communications technologies, focusing largely, but not only on optical fibre and photonic technologies. The potential of the opportunity provided nascent technologies in this area to help realise this capacity is undoubted, providing long-term growth and profit potential. However, this must be underpinned by massive investments in optical fibre networks and innovations in transmission and switching technologies. These investments are risky and require adequacy of capital, skilled researchers, and good financial and marketing management. Products that are genuine improvements, and those that are truly innovative will find financial profitability after commercialisation. Thus, nascent technologies have the potential to substantially fill the needs of photonic communications systems, increase productivity, and reduce the costs of communications, which characterise value in new P.C technologies, and are critical to a firm for maintaining competitiveness, and increasing profitability.

4.4.8 Digitisation, and Open Systems

Developments in the capabilities of integrated circuits have led to the digitisation of products, processes and services, not only in the communications industry but also, many other industries. According to Mayo (1995), in this branch of technology development, the increasing movements towards international standards will permit the upgrading of existing systems and the construction of new products and services on an integrated world-wide basis, with low financial risks arising from problems arising out of compatibility. This will help firms to increase their markets and profitability.

4.4.9 Chip Technology

The development of miniaturisation technologies has now progressed to a stage where engineers can design and produce integrated circuits of extremely small sizes. In concert with the development of parallel technologies, advances in chip technologies has enabled massive changes to take place in the performance of computing devices, and equally, enormous reduction in the price of such equipment and related software. Innovations have not stopped there. The race has commenced to produce commercially affordable chips at their physical limits, which are transistors only 300-400 atoms wide (Mayo 1995; Chaudhuri 1995). This is likely to be achieved within a few years, releasing, in their turn, the development of related software. Nevertheless the challenges to developmental research are immense. Firstly, the research is very costly, and secondly, there are high risks to expected financial returns. Thirdly, sales are susceptible to economic cycles, and other problems like overcapacity in the industry. Thus, no company presently tenanting the Research Park or in Australia currently undertakes significant R&D in chip technology.

WEBSYTE CORPORATION, founded in Australia in 1999, has as their goal, to develop tools and software for use with the Opera Browser, being developed by the parent company in Norway, The firm's vision is to deliver the best Internet experience on any device on all major platforms. This vision is defined as the leveraging of a firm's internal resources, capabilities, and core competencies to accomplish the firm's goals in the competitive environment.

The gives rise to its mission, which is the firm's unique purpose and the scope of its operations in product and market terms. The parent company Opera's mission is to strive to develop a superior Internet browser and related internet tools and software for their users through state-of-the-art technology, innovation, leadership and partnership.

4.4.10 Resources

Opera's profitability has previous been based on maixmising revenues from development fees or prepaid license income from strategic marketing agreements in the embedded market, and from license sales and advertising banners in the desktop market. But realizing that this is not enough in order to be able to continue the development, effort Websyte's finance director admits that they need to increase their revenues in advance. In doing so the firm has entered into several long term marketing contracts to develop web tools which can be controlled by human voice, independent of projects related to the development of its parent's browser, and related products.

The company's organizational resources are regarded as a key to commercial success based on a flat structure. The organic model is flat, uses cross-hierarchical and cross-functional teams, has low formalisation, possesses a comprehensive information network, and relies on participative decision-making to underpin the value of research work developed by the organisation. It regards the quality of management as a critical factor in ensuring the success of its major financial and marketing objectives. Developing value added technologies that will bring profitability and economic rewards to it customers. Websyte's flat structure, closely resembling its parent's is speeding up the decision making process, since it enables and encourages employees to make their own decisions.

The human resources, especially the knowledge and skills of their employees is considered by the firm to be their most valuable resource. The firm expects their employees to produce the most innovative technology that meets the needs of the market, at the lowest possible costs. Cost minimisation and increased productivity are important because they ensure commercial success in an industry where competition is intense.

The innovation resources of Websyte are based on its employee's knowledge, and the employees' capacity to innovate and to pioneer ideas which can be used to develop or improve new products. It is the firm's view that there is very little commercial value in technologies that do not provide the opportunity to customers to increase productivity, reduce costs and risks, and increase profits.

The firm's parent has, since its founding in 1995 managed to build up a reputation with customers as IBM, Ericsson, and Sony etc. By virtue of quality and reliability the company has developed a brand name within the software and hardware industry. The firm hopes that with time and expansion, its reputation and reach will make it a truly profitable and prosperous company. Indeed, its international marketing achievements have been largely due to its reputation as a firm able to deliver reliable, safe, and stable technologies to its markets, which is very price sensitive, intensely competed, and susceptible to economic conditions. Proof can be found in the value of exports shrinking in recent months as a result of the strong Australian dollar.

Capabilities

The firm believes that a firm's capabilities emerge over time through complex interactions among tangible and intangible resources. The efficiency of their software in the desktop and the related market has emerged through interaction between human resources and financial resources. The firm's financial structure is conservatively managed and is in a sound condition. The high quality of their products ensures a robust profit base, strong cash flows, and a stable balance sheet.

Core Competencies

Not all resources and capabilities are core competencies. In order to be a core competency a capability has to be either; valuable, rare, costly-to-imitate or non-substitutable. The firm's core competencies which add value to the company and its shareholders are:

- Its ability to develop technologies which are innovative and which have a high level of commercial applicability.
- Its ability to create differentiated products which creates value and goes a long way in ensuring commercial success.
- Its ability to be cost effective, allowing its products to compete with those of other firms.
- Its ability to design and engineer nascent technologies which bring perceptible benefits of increased productivity and profitability to customers.

- Its ability to create innovative products that are easy to use, are reliable, stable, and effective.
- Its ability to create market-oriented products to ensure commercial success.
- Its ability to secure worldwide patents on its products and technologies, and its ability and determination to aggressively defend patent violations.
- Its ability to adequately fund research projects for software developments in an industry in which, driven by intense competition, the life cycle of technologies is very short. This means that the ability of firms to develop products quickly and roll them out in the market is important to ensure commercial success.
- Its strength in its marketing and general management, which has built a wide and cost effective distribution systems, human resources (knowledge) base, strong innovation resources (research and development), and brand name.
- Its financial management strength which has made it a risk- taking enterprise to profit from innovative research., which stems from the firm's belief that financial success comes from innovation and originality in research.
- Its basic management philosophy which chooses to have a global focus when developing a customer base. This is based on the assumption that the PC is moving to the center of an ever-expanding network of smart, connected devices – from mobile phones to televisions and handheld devices, even household appliances, and that the coming digital decade will be a time of huge financial opportunity: for consumers, for the technology industry, and for the firm.

4.5 Case Study 3: Environment Protection Authority

The Authority is a quasi government organization which conducts research in environmental protection, and has a successful record of commercialising its innovative research.

4.5.1 Energy and Environment

Energy and the environment are innovative research areas which are critical to Australia's economic well-being, and thus, represents one of the industries for this investigation.

4.5.2 Industry Background

There is a growing realisation that human activities increasingly are threatening the health of the natural systems that make life possible on this planet. Human beings have the power to alter nature fundamentally and perhaps irreversibly.
Increasing awareness of the dangers of unsustainable economic growth and profitability at the expense of the environment has made the subject of environment management and conservation key social and political issues. The environment and energy industries are therefore sensitive to government legislation and political intervention. Increasingly, there is an understanding that in this planet 'everything is connected to everything else' in the natural and man-made systems that sustain our lives. For example, burning trees in Indonesia adversely affects the global atmosphere, just as much as the exhaust from the cars that fill our streets and freeways.

Central to the understanding of environmental issues is the need to recognise the complexity of the problems we face and the relationship between environmental and other needs in our society. Global warming provides a good example. Controlling emissions of carbon dioxide, the principal greenhouse gas, will involve efforts to reduce the use of fossil fuels to generate electricity. Such a reduction will include energy conservation and the promotion of alternative energy sources such as nuclear and solar power. But clearly, there is a need to conserve and protect. The massive problems of global warming, green house gas emissions, and degradation of land and water resources have spawned the growth of technologies, many f them with active government support, that have wide applications throughout the world, which provide the opportunities for growth and profitability for firms able to develop innovative solutions.

There are several environmental challenges the world faces: petroleum fuel emissions from car exhaust systems, the widespread use of liquid nitrogen based agricultural fertilisers, cattle and sheep farming, deforestation and land degradation, and the threat to water supplies, among others. The inability to control environmental degradation has resulted in such problems as acid rain, ground-level ozone and smog and airborne toxins, groundwater pollution, and decimation of wetlands. Governments throughout the world have shown considerable concern at these seemingly intractable problems, and many have legislated with the view that urgent steps are needed to control the damage. Technology has played a major role in helping to solve environmental problems. Many firms with the resources and the will to find solutions have engaged in developing nascent technologies, which have wide applications. There has been a clear realisation that the market for these products is widespread, both with companies and governments. Intrinsic to the success of these technologies is the quality of research, and the reputation of the research teams. Further, the ability of the firm to finance the research and development of such technologies without any guarantee of commercial success has been an important factor driving technology development.

While there appears to be a general recognition that it is important to protect the environment, all too often, this objective has been seen to be at cross-purposes with other considerations vital to society. Thus, environmental protection is often viewed as being in conflict with economic growth, with energy needs, agricultural productions, tourism industry etc. For most firms, the economic and financial implications are clear: Profit goals must take consideration of environmental matters in which society and governments have shown increasing concern.

Of course, the study of environmental conflicts with economic and financial objectives is nothing new. Classical economists such as Smith (1723-1790), Malthus (1766-1834), Ricardo (1772-1823) and Mill (1806-1873) all expressed concerns about environmental questions. Most expressed a gloomy prognosis, based on the *law* of diminishing returns in agricultural production. However, Malthus and Ricardo assumed an unchanging technology of production, whereas, the industrial revolution set in train a progressive process of technological change, which until today, has not only maintained, but dramatically quickened its momentum. In its wake, innovative value-added technologies have been developed by firms to provide avenues of growth and profitability. Increasing concern for environment and conservation matters shown by society and government has created a market for technologies to address the perceived problems. Since the problems are pervasive throughout the world, the market for new technologies enjoys worldwide coverage. For firms willing to make the investments in new technologies, the potential for growth and profitability is substantial.

Environmental and energy problems cross international borders, and this is the reason why it must be managed by governments within a partnership framework. The most critical global conservation problems are the destruction of tropical rain forests. Goldberg (1993) states that the loss of biological capital resulting from the massive destruction of the rain forests have been calculated by scientists to be an extinction rate of 11 species per hour. There is general agreement that the loss of species has never been greater that which is occurring now. This, according to scientists, does not compare even with the disappearance of the dinosaurs some 30 million years ago.

Thus the nations of the world and their governments face a massive problem in balancing economic growth and financial goals with the protection and conservation of energy resources and the environment. Most responsible governments have legislation in place, and some have gone even further by managing the problems in partnership with business entities. Responsible managers know that the firms' social responsibilities must take into account environment, energy and conservation issues. Rather than viewing this as a threat, they have embarked on using technology to help manage these problems. This has provided a huge impetus to market-oriented firms to develop the needed technologies. From environment monitoring to the development of fuel substitutes, firms with good management abilities have found opportunities to develop much needed technologies.

In addition to species extinction, the loss of tropical forests may represent as much as 20% of the total carbon dioxide emissions to the atmosphere. Clearly, any international approach to the problem of global warming must include major efforts to stop the destruction of forests and to manage those that remain on a renewable basis. But innovative technologies is required for this, and given widespread concern and interest, the opportunities exist for many risk-taking firms to profit from it.

Global environmental issues inevitably will become the principal focus in international relations. But the single overriding issue facing the world community today is how to achieve a sustainable balance between growing human populations and the earth's natural systems (Train 1993). Expanding populations in developing countries are seriously weakening the earth's resource base. Rampant deforestation, eroding soils, spreading deserts, loss of biological diversity, the destruction of fisheries, and polluted and degraded urban environments threaten to spread environmental impoverishment, particularly in the tropics, where human population growth is the highest in the world (Common 1988). In such situations, given the magnitude of the problems, and the potential of new technologies to help manage them, there is a much scope for news technologies to manage the earth's resources and eliminate wastage. This potential will yield huge financial success for firms providing the best reliable solutions.

It was stated earlier in this Chapter that in the environment 'everything is connected to everything'. Governments' efforts to manage populations will assist with land degradation and deforestation controls. Atmospheric pollution, acid rain, salinity in rivers, and all other major environmental problems can be managed hand-in-hand with a framework for sustainable economic development. The problems are immense, but human resolve and technology can combine to conquer some of the greatest environmental challenges facing mankind. And herein lies unending opportunities for nascent technologies to meet the growing consciousness of peoples and governments, both nationally and internationally, to provide solutions enabling the management of our fragile environment.

Of course, a major question of controversy is the question affecting all nations, which is how long cheap energy will be available. Proven oil reserves should last another 30 to 40 years at the mid- 1980s rates of consumption, while reserves of natural gas, at least another 60 years. The rate of consumption, however, increases every year as populations grow and newly industrialised countries claim a greater share of energy resources. Coal reserves could last for more than another 200 years, (Polesetsky 1991) but the burning of coal may create another problem: unacceptable levels of air pollution, acid rain, and gases that promote global warming.

However, almost every previous prediction of energy catastrophe has proven wrong. Innovative technologies have clearly managed to conquer these threatened economic catastrophes. The history of energy is the history of the discovery of new reserves, the discovery of economical substitutes for existing energy sources, and the discovery of new and more potent energy technologies. This according to Goldberg (1993) has traversed from wood to coal to oil to plutonium. Some analysts even deny that there is a energy crisis now, or in the making (Simon 1984). They assert that there are no practical limits to supplying all the energy the world needs and, therefore, no need to worry about economic growth in this regard.

Simon (1984), who studied the history of energy prices, believes that technological innovation will continue to make sufficient energy available at a reasonable cost in future.

Clearly, there are two opposing points of view. Those who agree with Simon place great faith in technology and innovation to provide continuous solutions to the energy problem, and generally look with favour upon nuclear power, solar power, wind power, and marine-based power all of which will need new and innovative technologies to manage and bring to financial viability.

Whatever the belief, the need for management of energy resources is paramount, whether it is for conservation, or for delaying the inevitable exhaustion of resources. Here again, the need for innovation and new technologies is undoubted, and nascent technologies being developed in such R&D centres such as La Trobe's Research Park have enormous chances of commercial profitability.

What is clear about this industry is this: there is considerable interest in environmental and energy problems throughout the world. Governments are keen to be seen at the forefront of protecting the environment and solving energy problems. Given the enormity of the problems, there are considerable opportunities for technology developers to provide solutions in a wide variety of applications, and enjoy high financial rewards from market size and growth, and profitability.

4.5.3 Environment Protection Authority

EPA Victoria was established under the *Environment Protection Act* 1970 with a charter to protect the Victorian environment. EPA reports to Parliament through the Minister for Environment and Conservation.

EPA's Corporate Plan is updated each year through a structured process built around two major strategic planning meetings (program evaluation meetings) of executives and management representatives. The process involves identifying opportunities and threats at the business unit level and filtering these for presentation at the program evaluation meetings held in November and June each year. About every five years or so, an all staff conference is held to revisit organizational fundamentals. This is vital elements for the planning process, to ensure that the strategic direction reflects the views of the organisation and stakeholders. Further, it ensures that developing technologies are value added, by meeting the objectives of providing the organisation with profit and growth opportunities.

4.5.4 Quality

Quality involves delivering innovative products and services that meet the requirements of the particular situation and client needs of increasing their returns on financial investments.

4.5.5 Role and Function

EPA's most fundamental responsibility is to be the Victorian community's environmental watchdog – vigilant in ensuring the protection of beneficial uses of the air, water and land from the adverse impacts of wastes and unwanted noise. EPA's approach to meeting this responsibility has evolved during the past 30 years from an almost exclusive reliance on traditional 'command and control' methods to place greater emphasis on prevention rather than cure through developing a wide range value added and innovative technologies. Environmental protection has become a mainstream activity for most western countries, with the emphasis strongly on achieving sustainability through the integration of social, environmental and economic goals. This has generated the need for new and innovative technologies. Indeed, so high is this need that it provides an unending avenue of financial opportunity to technology developers.

4.5.6 Operating Environment

The globalisation of the economy has been accompanied by the globalisation of environment protection. Trade liberalization regimes, global and regional environmental impacts and inter-country pollution problems (including the trade in hazardous waste) have resulted in international treaties and conventions that impact directly on State and local environmental policy. The need for monitoring, controlling and reporting environment problems has never been greater. This has also created the need for the developing of unique and innovative technologies which provide a low risk means to growth and profitability, and meet social and environmental goals.

EPA Victoria uses many sources of intelligence at home and abroad to assist in identifying emerging environmental trends and issues and in developing effective strategies to address these. As a result they have a record of success in taking prompt and effective action to deal with major environmental issues and with the changing impacts of international and national policies. This ability to develop preventative strategies had provided greater certainty and better environmental outcomes at lower cost to the community, and to governments.

4.5.7 Four Pillars

Over the past several years, the corporate planning process has highlighted the central importance of what they have come to describe as Four Pillars which underpin all of the work of the organisation. These Pillars are increasingly important to their activities of developing innovative, value added technologies which have the characteristics of stability, reliability and effectiveness, whether it be in seeking to improve the quality of air, water and land, or in working to reduce waste and its impacts on the environment.

The Four Pillars are as follows:

Knowledge

EPA is a knowledge-based organisation. They seek to ensure their technologies are founded on sound knowledge of the environment and of the community's social and environmental needs and priorities. At the same time, they aim to be a prime source of knowledge about the environment upon which the community can draw and rely. This adds value to their technologies because they are designed to meet client needs and are cost effective.

Environmental Audit

Environmental audit is a powerful tool for comprehensively assessing the status of and threats to any segment of the environment. Through means of audits, EPA can provide the community with authoritative assessments of the condition of various segments of the environment and of the success of our efforts to protect and improve environmental quality. To enable the organisation to do this, innovative technologies have been developed by reputable teams of researchers. These are very specialised and have a small but captive market. With the organisation looking to expand its market reach internationally, the prospect for profitability appear to be certain.

Neighbourhood Environment Improvement Plans (NEIPs)

The NEIP mechanism was established via amendments to the *Environment Protection Act* in 2001. NEIPs are an innovative approach to tackling complex local environmental problems, which have in the past wound up in the 'too hard' basket. New and innovative technologies have been developed to solve these problems. Investments in nascent technologies are nearly risk free since there is an assured, albeit, small market for it. Considerable profits have come from it, and the organisation believes that in the future, it will explore the international market for its technologies through licensing agreements.

Ecological Footprint

The goods and services upon which our modern society has increasingly come to depend impact on our environment in a great many ways. Too often we notice and attempt to ameliorate only the most obvious of these, overlooking the much broader range of impacts associated with the full 'life cycle' of such goods and services. The Ecological Footprint is a concept that has been developed in an attempt to encapsulate in a highly simplified measure the totality of our ecological impact. The concept is flexible – it can be applied at a variety of scales – from the footprint of an individual to that of a national, or of mankind or as a whole. The financial potential for technologies in this area are immense. EPA is therefore developing innovative technologies to provide solutions to this problem. These technologies are highly profitable because the market and its potential for growth is assured, protected from competition from high barriers to entry, and high development costs.

4.5.8 Looking to the Future

The current Premier's recent elaboration of the Government's vision for the State (Growing Victoria Together) sets out a number of issues that the Government and community together must address if we are to achieve our shared vision of long-term sustainability for the State. Prominent amongst these are the sustainable use of energy and other resources and the protection of the environment. The proactive government views on these issues provide the organisation with the opportunity to develop new and innovative technologies. Here again, the development of nascent technologies suffers from little or no risk of commercial failure. Further, value is added from the fact that government assistance with funding is assured for the developmental research, while at the same time, the risks from product liability suits are not present.

4.5.9 Resources

The demands on EPA Victoria are ever changing and there is a need to continue to be a flexible organisation that is able to alter direction at any time. Their resources underpin the technological developments that they have so successfully achieved. These are highly skilled researchers, the good name and reputation of the organisation, excellent marketing and management skills, and the ability to be

financially viable. Government support for research funding is another certainty that adds value to their nascent technologies.

4.5.10 Government Financial Support

Since 1999-2000 the government has provided EPA with an additional $1 million per year to enable the development of technologies to improving, monitoring, and controlling environmental problems. Much of this funding has been devoted to the establishment of a highly skilled research team to focus on developing technologies for solving environment control.

Commencing in 2000-2001 ($5m), some $7.5m was made available in 2001-02 for environment control programs. This very successful EPA managed program will be in its third year of operation in 2002-2003 with $10m. Key to their success is their ability to develop technologies that meets client objectives specifically and effectively. The clear implication of financial support for environment protection is that the government is proactive in terms of community concerns which have deep economic connotations, and are willing to back its views with legislation and financial means. This means that the organisation is able to develop and market critical environmental and energy conservation technologies without any fear from competition. Further operating in a very specialised field give it enormous marketing advantages to commercialise their value-added technologies with potential for huge profits worldwide. .For the organisation their ability to satisfy client needs assures them of continual financing of nascent and innovative technologies for future needs.

4.5.11 Nascent Technologies

1. Enhanced Air Quality

Strategic Context

With the release of the SEPP (Air Quality Management) in 2001 Victoria now has in place a contemporary, comprehensive and scientifically up to date policy framework. A major challenge of this year will be to develop technologies and processes to meet the objectives of SEPP, and therefore the national ambient air quality standards.

Strategic Goal

To improve the health and well-being of the community by ensuring the goals of the SEPP are met, and promoting continuous environment improvement across all activities of our society.

2. Enhanced Water Quality

Strategic Context

Victorians from all walks of life are heeding the wake up calls resonation from scientific appraisals of the damage being done to our waterways, our land and our marine environments. The iconic Murray and Snowy rivers and many other river systems are showing the stresses of unsustainable extractions and pollutant loads associated with urban growth and agriculture. Significant areas of productive land, the source of so much of Victoria's wealth and culture are threatened by salinity, declining soil health and erosion, with consequent impacts on catchment health and community well-being. Beaches and bays, which Victorians so enjoy, are also showing signs of strain, with catchment based pollutants and exotic marine pests threatening so many of the uses we have taken for granted. The Yarra in the heart of Melbourne is both visibly and bacteriological sill below the standard Melbournians want.

Strategic Goal

To protect and sustain our water environments and the uses they support by ensuring the goals set out in SEPP (WoV) legislation and its schedules are met.

3. Protecting Groundwater and the Land Environment

Strategic Context

Past industrial, commercial, mining and agricultural land use practices have in some cases resulted in contamination of land and groundwater. Current activities, which can contaminate groundwater or the land environment, include poor waste disposal practices, spillages and other emergencies, unsewered urban development, and the use of underground tanks and pipelines to store or convey petroleum products that in many situations have severely degraded groundwater quality through leakage. Experience has shown that this contamination can severely significantly limit the use of land and groundwater and pose a threat to public health or the environment.

Strategic Goal

Measures established to ensure current contamination of land and groundwater is managed to maximise usefulness of the resource and land and groundwater resources are protected from pollution in the future.

4.Noise

Strategic context

The impacts of noise on the community are many and varied and difficult to manage given that individual reactions are often very subjective. In addition, humans do adapt to noise levels to some extent in different circumstances for example a noise level that does not cause annoyance in an urban area may well cause annoyance in a rural area with a generally quieter noise environment. This is particularly the case where a development in a rural area cause a change in the noise environment even with the adoption of best practice noise minimization measures have been adopted. Community involvement through planning and other government approval processes is therefore important in dealing with such situations.

Strategic Goal

Compliance with SEPP and general community acceptance of noise limits.

5. Reducion and Management of Waste

Strategic Context

As corporations and communities move towards sustainability, avoidable use of natural resources and production of wastes, particularly hazardous wastes, will need to be reduced. The benefits of this approach include conservation of non-renewable natural resources, reduced business overheads as waste handling and disposal costs are reduced, more efficient use of raw materials, water and energy, reduced environmental and health and safety risks, and enhanced local amenity.

Strategic Goal

To support sustainable development by industry and the community by assisting them reduce waste production, particularly hazardous wastes, and litter and improving sound management of residual wastes, in line with measures and targets established in SEPPs and IWMPs.

6. Building Community Capacity

This will be achieved through effectiveness of organizational and business practice and knowledge and communications systems excellence. We must engage those who manage and impact on the environment and we must work with and for the community to achieve an environment that meets shared expectations.

Strategic context

EPA Victoria seeks to build community capacity in environmental management and decision making through improved organizational systems and processes that focus on the provision of consistent, trusted and timely knowledge services to both staff and Victorians. The EPA approach is one of constant review and renewal of systems, procedures and employment practices to achieve a stimulating learning environment for staff that fosters scientific and environmental expertise to meet community needs and to provide system efficiencies for industry to meet requirements.

To achieve closer alignment with all Victorian communities and stakeholders a new program of skills development will focus on further improving expertise of all staff, including scientific and technical staff, in communications including facilitation, listening and building relationships and strategic alliances.

Strategic Goal:

To be the environmental knowledge provider of choice for all Victorians.

7. Neighbourhood Environment Improvement Plan

Strategic Context

They have made real progress in cleaning up and protecting Victoria's environment, however, many challenges remain. Today's environmental problems require new ways of thinking, new studies, new partnerships and new tools. For example, much of the remaining pollution of air and water comes from many diffuse sources, including households, small businesses, roads and vehicles. Sustainable consumption – what and how each of use buys, consumes and even how we invest our money – increasingly dictates environmental quality. The way we plan for development and redevelopment of our urban and regional centers is critical to our environmental impact.

Strategic Goal

To develop and implement a neighbourhood environment improvement planning model which bring communities together to investigate and address environmental issues at a local level.

The decisions about which type of technology to develop are based on the following criteria:

- The technologies must be true innovations, which are able to solve specific environmental problems.
- The technologies must be capable of commercialisation, whether in respect of firms or of governments.
- The technologies must deliver effective solutions, and increase productivity.
- The technologies must yield verifiable financial or other benefits.
- The technologies must meet social and environmental objectives.
- The developmental costs must be minimised by tight budgetary control, and by the employment of reputable research teams who are able to achieve results quickly.

- The technologies must be protected by patents, notwithstanding the fact that it is difficult for competitors to duplicate such technologies, and the limited size of the potential market.

4.6 Summary of Case Studies

The case studies, written from interviews and additional materials supplied, have demonstrated the importance of financial aspects of nascent technologies, that are related and connected to their inherent valuations. While there are common underlying drivers of value present in nascent technologies in all three industries, certain idiosyncratic characteristics differences are also evident as the analysis shows. This aspect was discussed in research methodology (Chapter 3), which is the exploratory research facet of this thesis. In summary, this means that the valuation of nascent technologies in each industry would depend on the pervasiveness of relevant value drivers. Consequently, the valuation models hypothesised would vary for each industry, which will be formulated and in Chapters 5 and 6.

4.6.1 Results of Case Studies Analysis and Interpretation of the Value-Drivers

The results from the case study analysis have been tabulated in Table 1 and Table 2 below. In Table 1, the key value-drivers are ranked in order of frequency of observations.

Value-Driver	**Biotech**	**Infotech**	**En & Env**	**Total**	**Ranking**
Profitability	16	7	12	35	1
Uniqueness of innovation	11	9	14	34	2
Reputation of research team & firm	6	11	8	25	3
Growth prospects	16	4	4	24	4
Quality of management	11	8	4	23	5
Economic factors	6	7	2	15	6

Risks	6	6	2	14	7
Patent protection	7	3	1	11	8
Productivity	6	4	1	11	8
Governmental support	0	0	10	10	9
Cost effectiveness	0	1	3	4	10

Table 1 Comparison of Value-Drivers in Different Sectors

4.6.2 Profitability

There is an intuitive notion that most individual stocks move with the aggregate market (Reilly 1989) and the aggregate market returns over a specified time period has traditionally been used as a benchmark to measure the performance of individual portfolios. The perceived value-driver with the highest observations (i.e. a total of 35 observations across all sectors) is "profitability", indicating the underlying importance of commercial viability of a venture for wealth creation. However, profitability among the three sectors is features less prominently in the infotech sector compared to the other two.

This perception of profitability as a key value-driver is consistent with the belief that investments in knowledge assets are no different to tangible assets in their role as a vehicle of wealth creation. The objective of achieving profitability is a reflection of the awareness of managers to make commercially viable investments. Day (1999) states that profitability, a major objective of any business, is the reward for making investments in the past, which is also a strategic step in establishing a firm's competitive position, and intended market share. Reflecting this view, Anthony (1995) states that the dominant purpose of firms is to earn profits, and therefore, resources are invested in assets with the objective of deriving profits from their employment. Assets sourced from a firm's innovation extend its technological capabilities, and contribute to the wealth of the firm and society Narayanan (2001).

4.6.3 Uniqueness of Innovation

The "uniqueness of an innovation" has the next highest number of observations with 34 and again infotech has far less observations to the other two sectors. Nevertheless, there is a strong indication that firms view uniqueness of products as a major determinant of value.

Uniqueness of innovation arises out of creativity, and this has a major role to play in the creation of products that are genuinely unique as distinct from those that are merely extensions or improvements Kuratko (1998). Most innovations result from a conscious, purposeful search for new opportunities (Josty 1990). Intellectual (or knowledge based) assets are products of innovative thinking, new methods or new knowledge (Drucker 1985). Further, there is a strong perception that firms in the knowledge economy succeed because they are able to develop range of unique products and services (Karakaya 1994).

4.6.4 Reputation of Research Team and Firm

This perceived value-driver by management in the case studies has the third highest observations with the infotech sector considering it as being relatively more critical than the others. This ranking is consistent with the findings of Darby et al. (1999) who hypothesised that high-tech ventures with strong link to "star scientists" should be more highly valued by investors and examined the effects of ties to star scientists on the market value for new biotechnology firms. They concluded that an increase in a firm's intellectual human capital would lead to higher market valuation.

4.6.5 Growth Prospects

This is the fourth most important value-driver and Lee (1992), Fama (1990) and Schwert (1990) found that aggregate annual stock return variations could be explained by future values of measures of aggregate real activity, such as GNP, in the United States.

Growth is derived from a firm's market share, competitive positioning and profitability. Thus business managers are keenly aware of the need to make the necessary investments to maintain and increase their market share (Kotler 2001). Competition is played out over many time periods, while the rules of the game keep changing. Thus business managers may consider it dangerous to extend the interpretation of market share from an indication of past performance to a predictor of future advantages (Day 1999). Thus firms invest in assets that yield long term value creation by giving them a strong market position based on superior customer value, or the lowest delivered cost (Narayanan 2000; Westland 2002), which in turn, give them the competitive advantages of growth in market share and profitability, both of which are strongly related (Day 1999).

4.6.6 Quality of Management

This value factor has 23 observations across the three sectors with the highest in the biotechnology sector. These firms appear to be well aware of the need to understand and manage all aspects of a firm's operations in order to profit in the knowledge economy. Successful management involves not merely discovering new solutions or adopting seemingly effective innovations, but also finding a home for the discovered products and services in the marketplace (Day 1999) The key to effective management in knowledge based companies lies in linking products and services to market realities Narayanan 2001). Further, the costs and risks inherent in developing intellectual assets must be issues of careful management consideration (Weil 1983; Contractor 1988).

4.6.7 Economic Factors

The fundamental value of a firm is the expected present value of the firm's future payouts if these expectations take all currently available information into account, consistent with the efficient market hypothesis. Thus future payout must ultimately reflect real economic activity as measured by, for instance, gross domestic product - GDP (Shapiro 1988). Consequently, stock prices should react to these measures of real activity as stock prices are built on expectations of these activities. Barro (1990) and Fama (1990) support the argument that stock price should lead real activity.

This value factor would be a proxy for market conditions. From Table 1, all the sectors have a relatively low number of observations for this value-driver. The interpretation of the low ranking could be that most nascent knowledge based firms may be unable to fully evaluate or significantly appreciate the impact of market conditions on their business performance. This is understandable as most of theses intellectual firms are in the process of developing their innovation and would not yet have a fully developed product or process to market. It is therefore difficult for the management of this type of firms to relate their firms' business performance to market conditions. The marketability of and the scope of application that the technology under development may be capable of could still be relatively unclear at this stage. The focus at this stage of business development would be on ensuring the success of the R&D activity.

4.6.8 Risks

The view of risk derived from the extensive work in portfolio theory and capital market theory by Markowitz (1952) and Sharpe (1964) is that investors incorporate risk considerations in making financial decisions. Judging from the low observations, it appears that the risk factors inherent in the intellectual ventures are either not a major concern or still not fully understood or acknowledged by the management of the firms. This situation could possibly be due to the lack of appreciation about the full implications of both financial and operational risks that exists in the knowledge-based industries. There is a systematic risk component associated with the cash flows of technology-intensive ventures while the technical risks are idiosyncratic (Berk, Green and Naik 1998; Oh 2001). The relevant risks affecting the valuation of technology ventures need to be determined and measured in the evaluation process for high-tech firms be they in the form of risk premia earned for firm external factors such as *NAS*, *CC* and *FE* (Oh 2001), during development (Berk et al. 1998) or human capital Darby et al. (1999).

4.6.9 Patent Protection

This value factor reflects the legal environment in regard to the protection of intellectual assets. The highest number of observations is in the biotechnology industry followed by infotech and this implies a major concern about this aspect of the legal environment pertaining to proprietary rights to innovations developed in these industries.

The value implication of patent protection is in the challenges posed by the knowledge economy in calculating the value of intellectual assets, primarily because of their intangibility. Nevertheless managers are well aware that that these assets need to be protected as vehicles of wealth creation, just as much as any tangible assets (Cheeseman 2002). And the very reason why firms invest in intellectual assets is to gain rewards from their use in the knowledge economy (Hovey 2002). Patents not only protect a firm's investments in intellectual assets, but also provide a basis of valuation (Leuhrmann 1997).

4.6.10 Productivity

This factor defines the productivity benefits that the end-user would derive from using the technology developed by the knowledge firm. The level of productivity in an economy can be measured using the industrial production index, which measures the change in output in manufacturing, mining, and electric and gas utilities, in conjunction with labour expenditure. Chen, Roll and Ross (1986) suggest that industrial production is one of the economic variables that have a high correlation with the value factors derived from their factor analysis. Therefore, the low ranking of this factor is unusual as it is closely related to performance, growth and profitability.

4.6.11 Governmental Support

This aspect of the value chain scores very low overall, with the biotechnology and infotech sectors regarding it as of zero importance. A plausible explanation for this could be that the firms are already experiencing R&D and infrastructure support through operating in an established technology park and thus consider this type of support less critical for success. Some would argue that the knowledge economy is a new market impetus, in a relatively nascent stage of development, and with its potential to pervade all facets of the economy, is probably too important to be left entirely to market forces (Oh 2001).

4.6.12 Cost Effectiveness

This factor refers to the cost effectiveness of the R&D activity conducted in the venture firm. It has the lowest ranking in the evaluation. A plausible explanation for the low ranking could be, despite the fact that cost control is an important management function that the potential of the technology in terms of future economic benefits is still highly nebulous for the firms interviewed in this research. This would render a cost to benefit analysis challenging due to the lack of information about outcomes. Therefore the emphasis of the firm would be on achieving a successful outcome, contingent on the continuation of funding, as opposed to a preoccupation with cost-control and risk losing focus on the technical aspects. This is realistic as the majority of entrepreneurs are from a scientific background and therefore their major emphasis is on technical rather financial matters.

However, it is an established fact that investments in R&D are risk intensive because of a low probability that such expenditures will result in any tangible commercial success. In the knowledge economy, there is ongoing pressure to make those investments in developing intellectual capital assets, in order to maintain a firm's market and competitive standing (Weinstein 2001)[25]. But expenditures on R&D are business costs, and like any other costs and expenses, they have to be effective, that is, they must yield profitable results (Narayanan 2001). Thus business managers must establish budgetary controls over R&D expenditures, and subject them to the same budgetary rigours similar to other classes of expenditures (Kuratko 1998). Thus

[25] Weinstein MM., Curbing the High Cost of Health. *New York Times*, July 29, 2001

business managers try and ensure that R&D costs are minimised, while the probabilities of commercial success are maximised.

4.6.13 Correlation of Value-Drivers Between Industries

From Table 2 below, the level of correlation of value-drivers between industries seems to be higher for biotechnology and infotech than for biotechnology and energy & environment and infotech and energy & environment.

	Biotech	Infotech	En & Env
Biotech	1		
Infotech	0.4843	1	
En & Env	0.2697	0.3125	1

Table 2 Correlation of Value-Drivers Between Sectors

Arising from the identification of pervasive value drivers from the case studies analysis, the following questions have been developed for the general questionnaire. Each of the questions is tabulated and discussed in the table below

Questionnaire	Value-Driver	Literature
The possibility of profiting from the good reputation of the user firm of the technology.	Reputation of technology recipient.	Firms developing new technologies often refer to well known companies who have either purchased their technologies in the past, or have licensed their development (Hovey 2002).
Reputation of the technology developer for defending its invention and for technology protection.	Patent Protection.	This is an important value driver because managers and markets are well aware that that these assets need to be protected as

		vehicles of wealth creation, just as much as any tangible assets (Cheeseman 2002). And the very reason why firms invest in intellectual assets is to gain rewards from their use in the knowledge economy (Hovey 2002). Patents not only protect a firm's investments in intellectual assets, but also provide a basis of valuation (Leuhrmann 1997).
Manufacturing, management and marketing capability of the technology recipient.	Quality of Management.	Firms appear to be well aware of the need to understand and manage all aspects of a firm's operations in order to profit in the knowledge economy. Successful management involves not merely discovering new solutions or adopting seemingly effective innovations, but also finding a home for the discovered products and services in the marketplace (Day 1999). The key to effective management in knowledge based companies lies in linking products and services to market realities Narayanan 2001). Further, the costs and risks inherent in developing intellectual assets must be issues of careful management consideration (Weil 1983; Contractor 1988).
Capital, marketing talent and other values invested	Investment in Capital and Marketing Values and	In order to succeed, innovate firms must

by the technology recipient/licensor.	Talent.	develop the skills and talents in managing the financial and marketing resources of the firm (Razgaitis 1999), Day (1999).
The ability of the technology recipient/licensee to significantly increase their profit margin by using this technology.	Profitability.	This perceived value-driver is reasoned to be important because technologists and scientists with a tract record of success in developing intellectual assets add weight to the chances of commercial success, and is consistent with the findings of Darby et al. (1999) who hypothesised that high-tech ventures with strong link to "star scientists" should be more highly valued by investors and examined the effects. They concluded that an increase in a firm's intellectual capital would lead to higher market valuation.
Ability of the technology recipient/licensee to roll out the products quickly.	Expediency of Roll-Out.	One of the results of globalisation is that of 'time compression', that is, firms must roll-out products and services quickly into the market place, to ensure profitability at the 'innovative pricing' phase of the life cycle (Georgiou 1994).
The amount of the technology recipient/licensee's expected cost savings, risk savings, and other burden	Quantifiable Benefits.	Cost savings in operations, and the reductions of specific, identifiable risks will enhance the chances of commercialisation

saving which follow using this technology.		(Helfert 2000). Thus, these factors are regarded as value drivers.
The reputation of the firm developing the technology.	Reputation of research team and firm.	This perceived value-driver is consistent with the findings of Darby et al. (1999) who hypothesised that high-tech ventures with strong link to "star scientists" should be more highly valued by investors and examined the effects of ties to star scientists on the market value for new biotechnology firms. They concluded that an increase in a firm's intellectual human capital would lead to higher market valuation.
A lower risk of technological obsolescence.	Technological Obsolescence.	Firms are reluctant to invest in technologies which evaporate into obsolescence quickly because this introduces an additional risk, in that, investments will not be recovered during its commercial life (Levy 1998).
Strategic alliances entered into with other firms to ensure the profitability of the technology.	Extending the Market Reach through Strategic Alliances.	Often value is added when small firms who have an advantage in developing technologies, but are at a disadvantage in marketing them, enter into strategic alliances with firms who have national or global marketing networks, which can be employed in successfully commercialising innovative products (Sullivan 2000).

The technology is a pioneering technology, not just a mere improvement.	Uniqueness of Innovation.	The uniqueness of an innovation is a major determinant of value, because it would have intrinsic market appeal (Levy 1998). Uniqueness of innovation arises out of creativity, and this has a major role to play in the creation of products that are genuinely unique as distinct from those that are merely extensions or improvements (Kuratko 1998). Most innovations result from a conscious, purposeful search for new opportunities (Josty 1990). Intellectual (or knowledge based) assets are products of innovative thinking, new methods or new knowledge (Drucker 1985). Further, there is a strong perception that firms in the knowledge economy succeed because they are able to develop range of unique products and services (Karakaya 1994).
With reference to question 3 in section A, this area of innovation would produce a higher differentiated value.	Whether the technology is highly specialised or may be applied to a wider user base.	Razgaitis (1999) states that certain technologies will not attract competitor reaction, not because of highly complex technological barriers, but because the target market may be too small to afford sustained profits.
Non- reliance on the state of the economy and the effect of trade cycles.	Economic Factors.	The fundamental value of a firm is the expected present value of the firm's future payouts if these expectations take all

		currently available information into account, consistent with the efficient market hypothesis. Thus future payout must ultimately reflect real economic activity as measured by, for instance, gross domestic product - GDP (Shapiro 1988). Consequently, stock prices should react to these measures of real activity as stock prices are built on expectations of these activities. Barro (1990) and Fama (1990) support the argument that stock price should lead real activity.
A low possibility of the demand for the technology being depressed by unemployment, union attitudes etc. in the main markets for the technology.	Union Attitudes to Possibility of Job Losses Arising out of the Adoption of the New Technolgogy.	Delays in respect of the adoption of new technologies may result from union perceptions of job losses. Labour laws should, therefore, be flexible to accomodate changes without disruptions to business activities (Cheeseman 2002).
The degree of economic and industrial development, the labour and capital availability and cost, etc. in the technology recipient's country.	Degree of Sophistication of Labour and Capital Market.	Nascent technologies are more likely to survive the rigours of commercialisation if educated and trained staff, and capital is available to realise their potential for revenue growth (Sullivan 2000).
Availability and cost of capital and labour.	Availability and Cost of Capital and Skilled Workforce.	Availability is insufficient to guarantee success. Costs of a skilled workforce and capital, if excessive, will

		have the effect of driving up the costs of operations (Sullivan 2000).
With reference to question 4 in Section A, the costs associated with this option.	Options for commercialization.	The decision to sell, patent, transfer or commercialise within own organisation has different costs and benefits attached to them. In order to maximise the financial benefits, managers must weigh each option carefully (Razgaitis 1999).
A low possibility of product liability suits.	Costs of Product Liability.	Where it can be perceived that nascent technology will not, in reasonable circumstances, result in high legal costs arising out of product liability litigation, the commercialiser will pay a premium for this lower risk (Cheeseman 2002).
The ability of the technology recipient/licensee to use clauses protective against product liability suits, particularly in connection with trademark licenses.	Defences Against Legal Actions.	In situations where the commercialiser is able use protective clauses to block costly legal action in respect of alleged breaches of patents, product liability suits and trademark, the value of nascent technologies will increase (Cheeseman 2002).
Low risks and costs of litigation in product liability suits.	Risks and Costs associated with Product Liability Litigation.	As in Question 18 above (Cheeseman 2002).
Low financial and other risks arising from a failure to police patent infringements.	Policing Policy of Patent Holders.	If firms holding legal ownership of intellectual capital assets like patents and trademarks acquire a reputation for aggressively defending their positions,

		it will discourage infringements which will add value to the owners (Cheeseman 2002).
Proactive Government policies in respect of the technology being developed.	Government Attitude to Specific Branches of Technology Development.	In many countries, firms often lobby their governments for legal and financial support, and to adopt policies which support the development of technologies which will foster economic progress. If such support is given, it will impute value to innovative technologies (Dabek 1999).
Lack of legal restrictions on the technology being developed.	Legal Impediments to New Technologies Development.	In situations where proactive government support is not available, value can still arise if there is an absence of legal restrictions on particular types of technologies being developed (Dabek 1999).
Lack of ethical and environmental issues connected with the technology.	Ethical and Environmental Issues.	Innovative firms now must not only have to contend with business risks, but with increasing concern of ethical and environmental issues (Common 1998).
The stage of the technology's technical and market development (commercially proven).	Envisaged Commercial Promise.	From a glint in the eye to commercial success is a long and tortuous road, but the closer that idea gets to commercial production, the better the basis for valuing it (Levy 1998).
The intrinsic quality of the technology as a cost effective, marketable quality, safe, stable technology.	Cost Effectiveness.	This factor refers to the cost effectiveness of the R&D activity which is aimed at creating marketable, safe and stable

		technologies. It is an established fact that investments in R&D are risk intensive because of a low probability that such expenditures will result in any tangible commercial success. In the knowledge economy, there is ongoing pressure to make those investments in developing intellectual capital assets, in order to maintain a firm's market and competitive standing (Weinstein 2001)[26]. But expenditures on R&D are business costs, and like any other costs and expenses, they have to be effective, that is, they must yield profitable results (Narayanan 2001). Thus business managers must establish budgetary controls over R&D expenditures, and subject them to the same budgetary rigours similar to other classes of expenditures (Kuratko 1998). Thus business managers try and ensure that R&D costs are minimised, while the probabilities of commercial success are maximised.
The perceived utility by the buyer or user of the technology or its product, in terms of increased productivity.	Productivity.	This factor defines the productivity benefits that the end-user would derive from using the technology developed by the knowledge firm. Chen, Roll and Ross (1986)

[26] Weinstein MM., Curbing the High Cost of Health. *New York Times*, July 29, 2001

		suggest that industrial productivity is one of the economic variables that have a high correlation with value and is related to performance, growth and profitability.
The lack of ability of competitors to develop around the technology, or patent, or independently duplicate the secrets, in terms of the burdens of cost, time, quality, and risks of a legal, technological, environmental ethical nature.	Risks.	Major risks for nascent technologies arise from competitors (Levy 1998), breaches of patent laws (Hovey 2002), and safety fears (Razgaitis 1999). There is a systematic risk component associated with the cash flows of technology-intensive ventures while the technical risks are idiosyncratic (Berk, Green and Naik 1998; Oh 2001). The relevant risks affecting the valuation of technology ventures need to be determined and measured in the evaluation process for high-tech firms be they in the form of risk premia earned for firm external factors such as *NAS*, *CC* and *FE* (Oh 2001), during development (Berk et al. 1998) or human capital Darby et al. (1999).
Size of the total relevant market (local, national and international), and the licensee's likely share.	Market Size Potential.	In order to achieve satisfactory profits, a firm has to establish a critical mass in its target market segment, and much will depend upon its ability to tap the potential of the local and international market place (Barwise 1997)

Low price sensitivity of the potential market for the technology.	Price Sensitivity.	If a new technology is sensitive to price, it may signal the presence of competitors, each with their own offering in the market, thus reducing the ability of the firm to profit from innovations (Day 1999).
Lack of intense competitive activity in the target market(s).	Competition and Rivalry.	Competition has the effect of margin reduction. The higher the competition the lower the margins. Innovative products allow a breathing space for firms to increase their profits, even it is for a short time (Levy 1998).
The potential of the technology to deliver differentiated products to the target segments, or deliver price and non-price competitive edge to the user of this technology.	Differentiated Products and Non-Price Competition.	Differentiated products and factors that allow firms to compete strongly create the basis for additional value. Innovations are one way to achieve differentiated products (Lehman 1996.)
The potential of the technology to allow technology recipient to achieve increased market reach.	Market Reach.	In order to achieve satisfactory profits, a firm has to establish a critical mass in its target market segment, and much will depend upon its ability to tap the potential of the local and international market place (Barwise 1997)
High barriers to competitors developing the same or competitive technology by their own effort.	Technological Barriers.	Major risks for nascent technologies arise from competitors (Levy 1998). Highly innovative firms impede the entry of possible competitors, both by their speed of roll-outs, and by the quality of

		innovations (Levy 1998).
The scope and reliability of the protections of the technology, be it patent, trade secret, trademark, or copyright.		If firms holding legal ownership of intellectual capital assets like patents and trademarks can effectively defend their inventions, it will add to the price that a purchaser is willing to pay (Hovey 2002)
Low risk arising from non-protection of the technology.	Risk form non-protection.	There are a few examples where the risk from not patenting innovations is relatively low Hovey 2002). Certainly this would reduce the costs of commercialisation, but management must be careful that it does not underestimate the risks arising from failing to make investments in legally protecting its innovations (Razgaitis 1999).
The potential for achieving financial growth by the user adopting this technology.	Growth prospects.	Growth is derived from a firm's market share, competitive positioning and profitability. Thus business managers are keenly aware of the need to make the necessary investments to maintain and increase their market share (Kotler 2001).
The potential for export and/or export growth for adopters of this technology.	.Export Potential.	The ability to find external markets would certainly add to commercial appeal as this would extend the market size and reach, which will increase the revenue potential (Day 1999).

The availability of government or other grants for the adopters of this technology.	Government Support.	The government's legal, R&D and infrastructure support is regarded as an important value driver, primarily because it reduces the costs and risks of developing intellectual assets Westland 2002). In many countries such as the U. S, there are active lobbies that seek to maximise the availability of governnment support for the development of intellectual capital (Razgaitis 1999).

The responses will be analysed statistically in accordance with the procedures detailed in Chapter 3 Methodology, and the results reported in Chapter 5.

4.6.14 Conclusions and Implications for Biotechnology, Infotech and Energy & Environment Technology Valuation

The implications from the research findings on these sectors, from both a corporate equity fund-raising and portfolio investment perspectives, would be prudence on the part of all parties by monitoring and evaluating the trend of the identified pervasive value-drivers to obtain an intimation of values in these sectors for formulating investment strategy. There appears to be a distinct agreement among the three sectors on the pervasiveness of the top five value-drivers, being profitability, uniqueness of innovation, reputation of research team & firm, growth prospects and quality of management.

4.6.15 Conclusion and implications for designing the questions in the postal survey

Section B contains 40 questions, of which 39 questions seek to determine the underlying value drivers in the three chosen industries. Question 40 is a general question, which seeks information about anything that may have been missed in the previous 39 questions.

As stated in Chapter 3 Methodology, the questions contained in the postal survey have been framed in relation to the findings from the case study analysis, with the objective of determining:

- Whether the pervasive value-drivers are the same, or similar, as for the three companies in the Research Park.
- The factors that create value in nascent technologies.
- Whether the pervasive factors are the same, or similar, within the three chosen industries.
- Whether the established methods of valuation were appropriate to the valuation of nascent technologies.

Chapter 5. Results of Analysis of Questionnaire and Valuation Models for the Intellectual-Capital Sectors

5.1 Introduction

As described in the previous Chapters on literature review and methodology, this Chapter presents the various models developed from the case study analysis and survey questionnaire conducted.

The use of logistic models (logit) to evaluate the results of the primary questionnaire survey is to cater for the Likert scale response in the case studies. In the survey the dependent variables, i.e. value drivers, have taken on values between 0 and 7 and by adopting the logit approach, it is assured that the situation has been properly addressed and the value drivers are satisfactorily specified using statistically appropriate functional form.

5.2 Logit Models

The matrix notation of the standard regression may be written as:

$$y = X\beta + \varepsilon \qquad (5.1)$$

where:
y = a vector containing observations on the dependent variable;
X = is a matrix of independent variables;
β = a k-vector of coefficients; and
ε = is the disturbances.

Assume T is the number of observations and k is the number of right-hand side regressors.

From the literature on the logit model in Chapter 2, the operations of the model are applied in this section on the data collected from the questionnaire survey to be analysed for the pervasiveness of the specified set of value-drivers. By doing so, the specified logit equations will help in explaining whether the set of independent variables (i.e. value-drivers) are statistically significance in collectively determining the value of firms in each sector.

The statistical tests conducted are to determine the pervasiveness of the value-drivers on the individual sectors. The statistical manipulation starts with the assumption that there are *m* companies, and *n* questions, and I give every response a score as below:

Scale	Score
Strongly disagree	=0
Disagree	=1
Neither agree nor disagree	=2
Agree	=3
Strongly agree	=4

Then the matrix $C_{i,j}, i = 1,2,\Lambda\ m, j = 1,2\Lambda\ n$ is specified and the above can then be denoted as follows:

$$\pi_j = \sum_{i=1}^{m} (C_{i,j} / 4m), j = 1,2\Lambda\ n \qquad (5.2)$$

where:
π_j = the degree of agreement;
C_{ij} = the matrix $C_{i,j}, i = 1,2,\Lambda\ m, j = 1,2\Lambda\ n$
m = m companies; and
n = n questions.

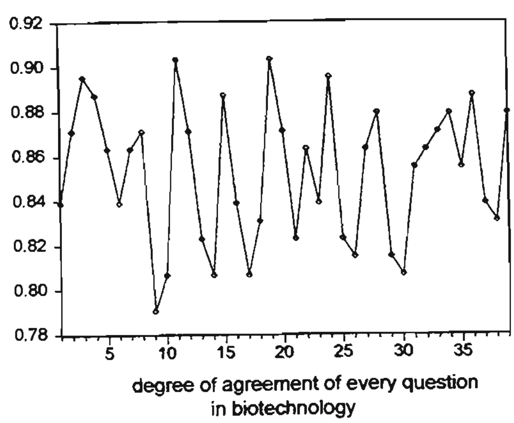
The parameter $0 < \pi_j < 1$ is specified, and π_j represents the degree of agreement to a question of j and the degree of agreement can be seen as a proportion which is a Bernoulli variable. Its distribution is specified by probabilities $P = (Y = 1) = \pi$ for success and $P\ (Y = 0) = (1 - \pi)$ for failure. Therefore I can now use logit model and by denoting $\log(\frac{\pi}{1-\pi})$ as the dependent variable.

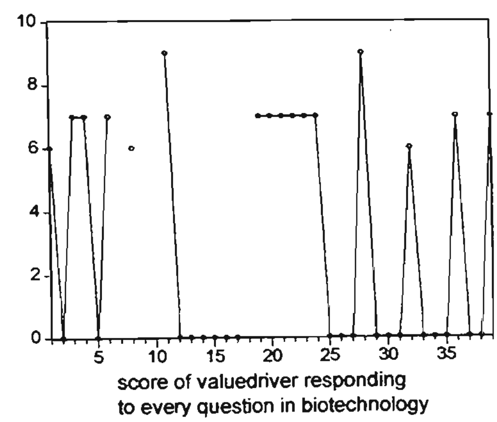
The objective of this regression manipulation is to statistically specify the value-drivers and determine the pervasiveness of these variables on the dependent variable according to the scores given by the respondents to the questionnaire. By giving each value driver a score between 0 to10, the scores of the value-drivers are treated as the independent variable. The first step of the process is to observe from the graphs for each sector for the degree of agreement accorded by the respondents to the value-drivers, the higher the degree of agreement to a question, the higher the score will be for the corresponding value-driver as can be seen for Diagram 5.1 below. In the second step, the scores are statistically adjusted to find the best-fit model. In other words, between 3 to 5 of the most pervasive value driver are scored from a scale of 1-10, and the remaining value driver are given a score of zero and excluded.

The relationships between the identified independent variables *(x)* and dependent variable *(y)* in each sector have been plotted and the graphs are presents below:

Diagram 5.1 Degree of Agreement and Scores for the Value-Drivers

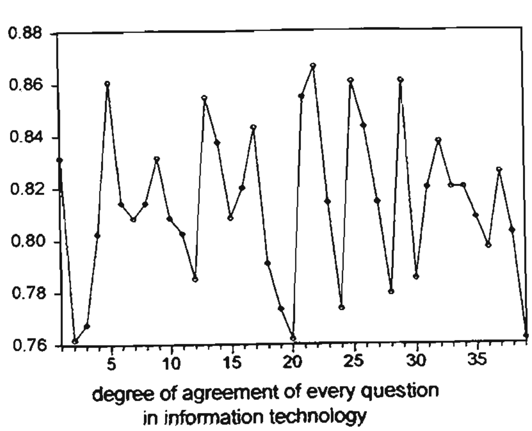
Biotechnology

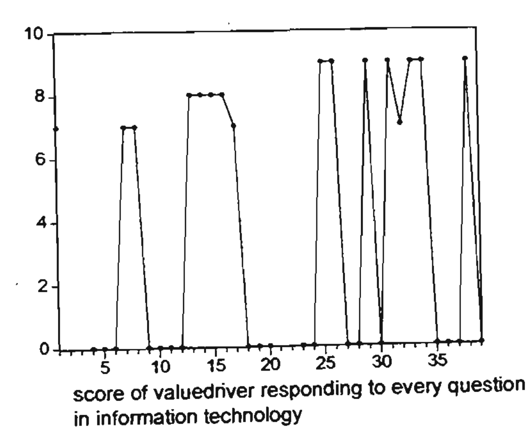




Correlation :0.5173
The average score for the questions (value-drivers) in the biotech sector is 3.23

Information:

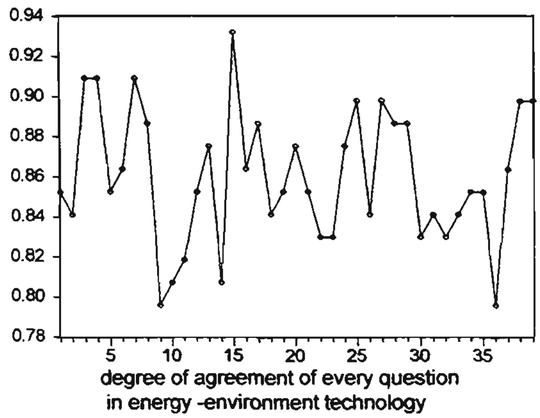


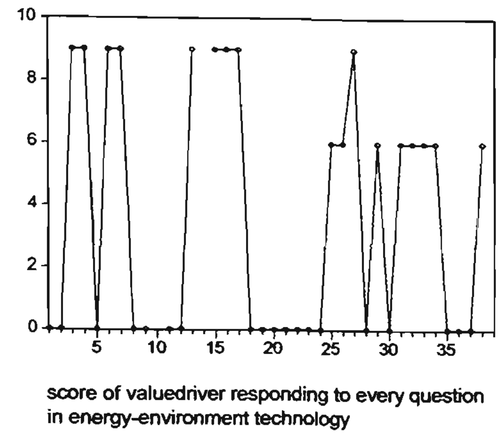


Correlation: 0.5692

The average score for the questions (value-drivers) in the infotech sector is 3.62

Energy:





Correlation: 0.5948

The average score for the questions (value-drivers) in the energy and environment sector is 3.58

From the graphs above, it can be seen that the correlation between the dependent and independent variables is highest in the E&E (0.5948) sector followed by infotech (0.5692) and biotech (0.5173). This confirms the earlier analysis of correlation between the industries as tabulated in 4.5.27 in Chapter 4.

Generally, the correlation between the value of the firm and the value-drivers for all sector are between 0.52 and 0.59 and suggest a moderate correlation.

In developing the sectorial Logit models, transformation by way of statistical manipulations between correlation and the assigned scores (see above) are conducted on the independent variables. This process identifies the 3-5 most pervasive independent variables (value-drivers) according to their distinctive scores and selects the four most pervasive value-drivers. Lehmann and Modest (1988), and Connor and Korajczyk (1988) find little sensitivity to increasing the number of factors beyond five and Fama and French (1995) find that stocks require only three factors and that five factors are necessary when bond portfolios are included (Campbell et al. 1997, p. 240).

The statistical rationale in the selection process for exclusion of the less pervasive independent variables is that, from the response of a value-driver within the group of questions in the survey, the degree of agreement defined by 5.2 in the group of questions varies, if the degree of agreement for a value driver is highly different from the others, it is considered non-pervasive and excluded from the selection process. The use of the highest correlations as the basis for identifying the top 3-5 value-drivers, which are incorporated on a collective basis for their value-generating power as a group of pervasive value-drivers in each sector. This approach is considered appropriate as strong corporate performance is dependent on the right combination and effectiveness of various corporate and market factors as generally practised in equity value market analysis. Roll and Ross (1980) using factor analysis found that only three and possibly four factors explained the return generating process of US equities. Factor modelling potentially provides the benefit of reducing the variance of the abnormal return by explaining more of the variation in the normal return. This variance reduction is typically the greatest in cases where the sample firms have a common characteristic, in this case the three sectors, where they are all members of one industry sector (Campbell et al. 1997, pp. 155-156).

The limitation[27] of such an approach for selecting the value-pervasive variables is that it may reflect a management bias in the data collected from the survey as they consistently express the management's inherent perceptions. The test for multicollinearity in the logit models are not necessary as there is only one non-constant independent (explanatory) variable, so the issue does not arise and there is no need to check for multicollinearity among the variables.

5.2.1 Interpretation of the Models

The selection of the independent variables was done on a cumulative basis according to the principle of logit modelling. By observing the degree of agreement (from the plotting, i.e. visually, separation of the points is conducted in 3 levels, being high,

[27] Another limitation is the lack of market perception of value. The multi-factor regression analysis using market data will help to minimise this bias as done in Chapter 6 and elaborated in Chapter 7.

middle and low and then each level is allocated a score, for example 10, 8 and 6. A value-driver may score several points, and I calculate an average score of the points, the score is that for the independent variables or value-drivers. For instance, the lowest scores of zero are first selected and are then combined with the other scores in the set to produce the R^2 and the set of value-drivers which produces the highest R^2 constitutes the final set of independent variables, which have been identified in the table in section 5.3 of this Chapter.

The output from the selection process above is used to construct a logit model for each of the industrial sectors. The specified logit models are presented with the comments on each equation form.

5.2.1.1 Biotechnology

The specified equation for the biotech valuation model is as follows (the summary output is shown in Table 5.1:

$$Log(Y/(1\text{-}Y)_{biotech} = \underset{(35.32)}{1.689} + \underset{(3.47)}{0.0345}(VALUE\text{-}DRIVERS)_{biotech} \qquad (5.3)$$

$R\text{-}SQUARE = 0.268 \quad DW = 1.86$

where:

$Log(Y/(1\text{-}Y)_{biotech}$ = the value of a firm in the biotech sector;

$(VALUE\text{-}DRIVERS)_{biotech}$ = the set of specified value-drivers for biotech.

The above results suggest that the specified set of value drivers for the biotech sector has a positive relationship with the value of a firm in the sector as represented by the positive coefficient (+0.0345) in Equation 5.3 above. The R^2 of 26.8% signifies a reasonably high degree of correlation between the specified variables in the equation and implies that approximately 26.8% of the value of the biotech firm is explained by the specified set of independent variables. The Durbin-Watson (*DW*) statistic for autocorrelation, which measures the extent to which the errors are probabilistically independent, is 1.86. The *DW* statistic of 1.86 for biotech indicates there is very little *lag 1* autocorrelation. The residual of this model (see page 10) suggests that there is no heteroskedasticity in its residual, and the residual follows a normal distribution.

The financial implications of the results of the Logit model (Equation 5.3) suggest that the specified value-drivers are pervasive in determining the value of a firm in the biotech sector.

5.2.1.2 Information Technology

The specified equation for the infotech valuation model is as follows (the summary output is shown in Table 5.2:

$$Log(Y/(1-Y))_{infotech} = \underset{(40.39)}{1.3894} + \underset{(3.98)}{0.02476}(VALUE\text{-}DRIVERS)_{infotech} \qquad (5.4)$$

$R\text{-}SQUARE = 0.324 \quad DW = 2.01$

where:
$Log(Y/(1-Y))_{infotech}$ = the value of a firm in the infotech sector;
$(VALUE\text{-}DRIVERS)_{infotech}$ = the set of specified value-drivers for infotech.

The above results suggest that the specified set of value drivers for the biotech sector has a positive relationship with the value of a firm in the sector as represented by the positive coefficient (+0.02476) in Equation 5.4 above. The R^2 of 32.4% signifies a relatively high degree of correlation between the specified variables in the equation and implies that approximately 32.4% of the value of the biotech firm is explained by the specified set of independent variables. The Durbin-Watson (*DW*) statistic for autocorrelation, which measures the extent to which the errors are probabilistically independent, is 2.01. The *DW* statistic of 2.01 for biotech indicates there may be a small degree of *lag 1* negative autocorrelation in the error terms. The residual of this model (see page 10) suggests that there is no heteroskedasticity in its residual, and the residual follows a normal distribution.

The financial implications of the results of the Logit model (Equation 5.4) suggest that the specified value-drivers are pervasive in determining the value of a firm in the infotech sector.

5.2.1.3 Energy and Environment

The specified equation for the E&E valuation model is as follows (the summary output is inTable 5.3:

$$Log(Y/(1\text{-}Y)_{E\&E} = \underset{(32.51)}{1.7025} + \underset{(4.31)}{0.0425}(VALUE\text{-}DRIVERS)_{E\&E} \qquad (5.5)$$

$R\text{-}SQUARE = 0.354 \quad DW = 1.71$

where:

$Log(Y/(1\text{-}Y)_{E\&E}$ = the value of a firm in the infotech sector;

$(VALUE\text{-}DRIVERS)_{E\&E}$ = the set of specified value-drivers for E&E.

The above results suggest that the specified set of value drivers for the biotech sector has a positive relationship with the value of a firm in the sector as represented by the positive coefficient (+0.0425) in Equation 5.5 above. In other words, a one unit change in the collective value-drivers would cause value to change by 4.25%. The R^2 of 35.4% signifies a relatively high degree of correlation between the specified variables in the equation and implies that approximately 35.4% of the value of the biotech firm is explained by the specified set of independent variables. The Durbin-Watson (*DW*) statistic for autocorrelation, which measures the extent to which the errors are probabilistically independent, is 1.71, hence below the *DW* benchmark of 2. The *DW* statistic of 1.71 for the *E&E* sector indicates there may be a degree of *lag 1* positive autocorrelation in the error terms. The residual of this model (see page 10) suggests that there is no heteroskedasticity in its residual, and the residual follows a normal distribution.

The financial implications of the results of the Logit model (Equation 5.5) suggest that the specified value-drivers are pervasive in determining the value of a firm in the *E&E* sector.

5.2.1.4 Summary Output and Coefficient Results

The summary output for the developed models are presented in Table 5.1, Table 5.2 and Table 5.3 below. The interpretations of the summary results are also done in this section for all the three intellectual-capital intensive sectors.

Table 5.1 Biotechnology Sector Summary Output

Dependent Variable: LOGBIONEW
Method: Least Squares
Date: 07/29/03 Time: 19:46
Sample: 1 39
Included observations: 35
Excluded observations: 4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
VALUEDRIVERBIO	0.034544	0.009947	3.472813	0.0015
C	1.689006	0.047823	35.31790	0.0000

R-squared	0.267650	Mean dependent var	1.800535
Adjusted R-squared	0.245458	S.D. dependent var	0.241340
S.E. of regression	0.209639	Akaike info criterion	-0.231418
Sum squared resid	1.450295	Schwarz criterion	-0.142541
Log likelihood	6.049816	F-statistic	12.06043
Durbin-Watson stat	1.863019	Prob(F-statistic)	0.001460

Table 5.2 Information Technology Sector Summary Output

Dependent Variable: LOGINFORNEW
Method: Least Squares
Date: 07/29/03 Time: 19:47
Sample: 1 39
Included observations: 35
Excluded observations: 4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
VALUEDRIVERINFO	0.024763	0.006227	3.976448	0.0004
C	1.389410	0.034400	40.38927	0.0000

R-squared	0.323939	Mean dependent var	1.481388
Adjusted R-squared	0.303452	S.D. dependent var	0.180496
S.E. of regression	0.150641	Akaike info criterion	-0.892386
Sum squared resid	0.748862	Schwarz criterion	-0.803509
Log likelihood	17.61675	F-statistic	15.81214
Durbin-Watson stat	2.010822	Prob(F-statistic)	0.000360

Table 5.3 Energy and Environment Sector Summary Output

Energy

Dependent Variable: LOGENERGYNEW
Method: Least Squares
Date: 07/29/03 Time: 19:44
Sample(adjusted): 1 38
Included observations: 36
Excluded observations: 2 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
VALUEDRIVEREN	0.042502	0.009850	4.314789	0.0001
C	1.702531	0.052355	32.51907	0.0000

R-squared	0.353826	Mean dependent var	1.854829
Adjusted R-squared	0.334821	S.D. dependent var	0.284464
S.E. of regression	0.232005	Akaike info criterion	-0.030167
Sum squared resid	1.830088	Schwarz criterion	0.057806
Log likelihood	2.543004	F-statistic	18.61740
Durbin-Watson stat	1.718473	Prob(F-statistic)	0.000130

Regression Coefficients

The column labelled "coefficient" depicts the estimated coefficients. The least squares regression coefficients b are computed by the standard OLS formula:

$$b = (X'X)^{-1}X'y \qquad (5.6)$$

For the simple linear models considered here, the coefficient measures the marginal contribution of the independent variable to the dependent variable, holding all other variables fixed. The statistical significance of the coefficient for each sector is discussed in Section 5.2.1.1 (biotechnology), Section 5.2.1.2 (information technology) and Section 5.2.1.3 (energy and environment) above.

Standard Errors

The "standard error" column reports the estimated standard errors of the coefficient estimates. The standard errors measure the statistical reliability of the coefficient estimate-the larger the standard errors, the more statistical noise in the estimates.

The covariance matrix of the estimated coefficients is computed as:

$$s^2(X'X)^{-1},\ s^2 = \tilde{\varepsilon}'\tilde{\varepsilon}/(T-k),\ \tilde{\varepsilon} = y - Xb \qquad (5.7)$$

and the standard errors of the estimated coefficients are the square roots of the diagonal elements of this matrix. The confidence interval of the coefficients is obtained from the standard errors. The confidence interval is $[b - t_{\alpha/2}(n-2) * Std.Error, b + t_{\alpha/2}(n-2) * Std.Error]$.

In *biotechnology model* the variable C's (C is the constant independent variable) at the 95% confidence interval is:

$$[1.689 - t_{0.025}(33) * 0.047823, 1.689 + t_{0.025}(33) * 0.047823] = [1.5913,\ 1.7867]$$

The variable *VALUE-DRIVER* for the biotechnology sector at 95% confidence interval is:

$$[0.034544 - t_{0.025}(33) * 0.009947, 0.034544 + t_{0.025}(33) * 0.009947] = [0.01424,\ 0.05486].$$

In *information technology model* the variable C's at the 95% confidence interval is:

$$[1.389 - t_{0.025}(33) * 0.0344, 1.389 + t_{0.025}(33) * 0.0344] = [1.5913,\ 1.4592]$$

The variable VALUE-DRIVER at the 95% confidence interval is:

$$[0.024763 - t_{0.025}(33) * 0.006227, 0.024763 + t_{0.025}(33) * 0.006227] = [0.01195,\ 0.03758].$$

In *energy and environment model* the variable C's 95% confidence interval is:

$$[1.7025 - t_{0.025}(35) * 0.052355, 1.7025 + t_{0.025}(35) * 0.052355] = [1.5956,\ 1.8094]$$

The variable VALUE-DRIVER at the 95% confidence interval is:

$$[0.042502 - t_{0.025}(33) * 0.00985, 0.042502 + t_{0.025}(33) * 0.00985] = [0.02239,\ 0.06262].$$

t-Statistics Tests

The t-statistic, which is computed as the ratio of an estimated coefficient to its standard error, is used to test the hypothesis that a coefficient is equal to zero. To interpret the t-statistic, one should examine the probability of observing the t-statistic given that the coefficient is equal to zero. This probability computation is described below.

Biotechnology

In the case of the biotechnology sector, the *t*-statistic of C is:

$$T - statistic = 35.31 > T_{0.025}(33) = 2.042$$

So I reject the null hypothesis that the coefficient is zero, the t-statistic of VALUE-DRIVER for the biotechnology equation is:

$$T - statistic = 3.47 > T_{0.025}(33) = 2.042$$

and I *reject the null hypothesis* that the coefficient is zero.

Information Technology

In the case of information technology, the T-statistic of C is:

$$T - statistic = 40.39 > T_{0.025}(33) = 2.042$$

so I reject the null hypothesis that all of the regression coefficients are zero, the T-statistic of *VALUE-DRIVER* for information technology equation is:

$$T - statistic = 3.98 > T_{0.025}(33) = 2.042$$

and so I reject the null hypothesis that the coefficient is zero.

Energy and Environment

In the case of energy and environment technology sector, the T-statistic of C is:

$$T - statistic = 32.52 > T_{0.025}(34) = 2.042$$

and so I reject the null hypothesis that all of the regression coefficients are zero, the T-statistic of *VALUE-DRIVER* for the energy and environment equation is:

$$T - statistic = 4.31 > T_{0.025}(34) = 2.042$$

and so I reject the null hypothesis that the coefficient is zero.

Probability

The last column of the output shows the probability of drawing a t-statistic as extreme as the one actually observed, under the assumption that the errors are normally distributed, or that the estimated coefficients are asymptotically normally distributed.

This probability is also known as the *p*-value or the marginal significance level. Given a *p*-value, you can tell at a glance if you reject or accept the hypothesis that the true coefficient is zero against a two-sided alternative that it differs from zero. For example, if you are performing the test at the 5% significance level, a p-value smaller than .05 is taken as evidence to reject the null hypothesis of a zero coefficient.

The *p*-values are computed from a t-distribution with T - k degrees of freedom.

In the case of biotechnology, information technology and energy technology, the *p*-value of the variable C are 0.00, 0.00 and 0.00 respectively, all of them are less than 0.05, so I can reject the null hypothesis that the coefficient is equal to zero.

In the case of biotechnology, information technology and energy technology, the *p*-value of the variable $VALUE\text{-}DRIVER_{biotech}$, $VALUE\text{-}DRIVER_{infotech}$ and $VALUE\text{-}DRIVER_{E\&E}$ are 0.0015, 0.0004 and 0.0001 respectively, all of them are less than 0.05, so I can reject the null hypothesis that the coefficient is equal to zero.

Summary Statistics

R-squared

The R-squared (R^2) statistic measures the success of the regression in predicting the values of the dependent variable within the sample. R^2 is the fraction of the variance of the dependent variable explained by the independent variables. The statistic will equal one if the regression fits perfectly, and zero if it fits no better than the simple mean of the dependent variable. It can be negative if the regression does not have an intercept or constant, or if the estimation method is two-stage least squares.

R^2 is computed as

$$R^2 = 1 - \frac{\tilde{\varepsilon}'\tilde{\varepsilon}}{(y-\bar{y})'(y-\bar{y})}, \ \tilde{\varepsilon} = y - Xb, \ \bar{y} = \sum_{i=1}^{T} y_i / T \tag{5.8}$$

where:
$\tilde{\varepsilon}$ = the residual; and
$\bar{y}$ = the mean of the dependent (left-hand) variable.

Adjusted R-squared

One problem with using R^2 as a measure of goodness of fit is that the R^2 will never decrease as you add more regressors. In the extreme case, you can always obtain an R^2 of one if you include as many independent regressors as there are sample observations.

The adjusted R^2, commonly denoted as $\bar{R}^2$, penalizes the R^2 for the addition of regressors which do not contribute to the explanatory power of the model. The adjusted R^2 is computed as:

$$\bar{R}^2 = 1 - (1 - R^2)\frac{T-1}{T-k} \tag{5.9}$$

Where T is the number of observations, and
K is the number of regressors

The $\bar{R}^2$ is never larger than the R^2, can decrease as you add regressors, and for poorly fitting models, may be negative.

In the case of biotechnology, information technology and energy technology, R^2 is 0.2676, 0.3239 and 0.3538 respectively, and the $\bar{R}^2$ is 0.2455, 0.3035 and 0.3348. They are not too small. By observing R^2 or $\bar{R}^2$ alone I cannot say the fit is good or not, I need to conduct further investigate of the F-statistic.

Standard Error of the Regression (S.E. of regression)

The standard error of the regression is a summary measure based on the estimated variance of the residuals. The standard error of the regression is computed as:

$$S = \sqrt{\tilde{\varepsilon}'\tilde{\varepsilon} / (T-k)}, \quad \tilde{\varepsilon} = y - Xb \tag{5.10}$$

Sum of Squared Residuals

The sum of squared residuals can be used in a variety of statistical calculations:

$$\tilde{\varepsilon}'\tilde{\varepsilon} = \sum_{i=1}^{T} (y_i - X_i b)^2 \tag{5.11}$$

Log Likelihood

The log likelihood function (assuming normally distributed errors) is evaluated at the estimated values of the coefficients. Likelihood ratio tests may be conducted by looking at the difference between the log likelihood values of the restricted and unrestricted versions of an equation. The log likelihood is computed as:

$$l = -\frac{T}{2}(1 + \log(2\pi) + \log(\tilde{\varepsilon}'\tilde{\varepsilon} / T)) \tag{5.12}$$

Durbin-Watson Statistic

The Durbin-Watson statistic measures the serial correlation in the residuals. The statistic is computed as:

$$DW = \sum_{i=2}^{T} (\tilde{\varepsilon}_i - \varepsilon'_{i-1})^2 / \sum_{i=1}^{T} \tilde{\varepsilon}_i^2 \tag{5.13}$$

As a rule of thumb, if the DW is less than 2, there is evidence of positive serial correlation.

In the case of biotechnology, information technology and energy technology, the D-W statistic is 1.86, 2.01 and 1.72 respectively, all of them are nearly 2, so I can say there is not significant serial correlation in the models and is discussed in Section 5.2.11, Section 5.2.1.2 and Section 5.2.1.3 for biotech, infotech and E&E sectors respectively.

Mean and Standard Deviation (S.D.) of the Dependent Variable

The mean and standard deviation of y are computed using the standard formulas:

$$\text{Mean} = \frac{1}{T}\sum_{i=1}^{T} y_i$$

$$S.D = \sqrt{\frac{1}{T-1}\sum_{i=1}^{T}(y_i - \bar{y})^2}$$

Akaike Information Criterion

The Akaike Information Criterion (AIC) is computed as:

$$AIC = -2l/T + 2k/T \qquad (5.14)$$

where:
l = the log likelihood.

The AIC is often used in model selection for non-nested alternatives smaller values of the AIC are preferred. For example, you can choose the length of a lag distribution by choosing the specification with the lowest value of the AIC.

Schwarz Criterion

The Schwarz Criterion (SC) is an alternative to the AIC that imposes a larger penalty for additional coefficients:

$$SC = -2l/T + (k \log T)T \qquad (5.15)$$

F-Statistic and Probability

The F-statistic tests the hypothesis that all of the slope coefficients (excluding the constant, or intercept) in a regression are zero. For ordinary least squares models, the F-statistic is computed as:

$$F = \frac{R^2(k-1)}{(1-R^2)(T-k)} \qquad (5.16)$$

Where R^2 is R-squared statistic, T is the number of observations, and

K is the number of regressors

Under the null hypothesis with normally distributed errors, this statistic has an F-distribution with k-1 numerator degrees of freedom and T-k denominator degrees of freedom.

In the case of biotechnology;

$F - statistic = 12.06 > F_{0.05}(1,33) = 4.08$

so I reject the null hypothesis that all of the regression coefficients are zero.

In the case of information technology;

$F - statistic = 15.81 > F_{0.05}(1,33) = 4.08$

so I reject the null hypothesis that all of the regression coefficients are zero.

In the case of energy technology;

$F - statistic = 18.61 > F_{0.05}(1,34) = 4.08$

so I reject the null hypothesis that all of the regression coefficients are zero.

The p-value given just below the F-statistic, denoted Prob(*F*-statistic), is the marginal significance level of the F-test. If the p-value is less than the significance level you are testing, say0.05, I reject the null hypothesis that all slope coefficients are equal to zero.

In the case of biotechnology, information technology and energy technology, the *p*-value is 0.00146, 0.00036 and 0.00013, respectively, and all of them are less than 0.05, so I can reject the null hypothesis that all slope coefficients are equal to zero.

Test of normality of residual

To test the normality of residual I form a Jarque-Bera statistic. The Jarque-Bera statistic has a distribution with two degrees of freedom under the null hypothesis of normally distributed errors.

In the case of biotechnology;

$$Jarque-Bera-statistic = 1.9358 < X^2{}_{0.05}(2) = 5.99$$

so I accept the null hypothesis of normally distributed errors.

In the case of information technology;

$$Jarque-Bera-statistic = 2.2425 < X^2{}_{0.05}(2) = 5.99$$

so I accept the null hypothesis of normally distributed errors.

In the case of energy and environment technology;

$$Jarque-Bera-statistic = 0.9797 < X^2{}_{0.05}(2) = 5.99$$

so I accept the null hypothesis of normally distributed errors.

Test of Heteroskedasticity

To test the Heteroskedasticity I conduct a White statistic test, which is a test of the null hypothesis of no heteroskedasticity against heteroskedasticity of some unknown general form. The test statistic is computed by an auxiliary regression, where I regress the squared residuals on all possible (nonredundant) cross products of the regressors. White test statistic is asymptotically distributed as a X^2 distribution with degrees of freedom equal to the number of slope coefficients (excluding the constant) in the test regression.

In the case of biotechnology;

$$White-statistic = 0.023 < X^2{}_{0.05}(1) = 3.84146$$

so I accept the null hypothesis of no heteroskedasticity.

In the case of information technology;

$$White - statistic = 1.165 < X^2{}_{0.05}(1) = 3.84146$$

so I accept the null hypothesis of no heteroskedasticity.

In the case of energy and environment technology;

$$White - statistic = 2.059 < X^2{}_{0.05}(1) = 3.84146$$

so I accept the null hypothesis of no heteroskedasticity.

5.2.1.5 The Properties of Estimated Coefficients

For the Logit models developed in the preceding sections, they have been tested to be satisfactory under the criteria of best linear unbiased estimator (BLUE) of good-fit in Ramanathan (1999) as follows:

1. Errors average to zero;
2. independent variables are given and non-random;
3. there is no heteroskedasticity; and
4. serial independent, ordinary least square estimators are unbiased, most efficient and consistent.

The tests for condition 3 and condition 4 have been done. Condition 2 is also satisfied because the independent variables in our models are given. About condition 1, I did the T-test which's null hypothesis is the mean of residual is zero in the three models, I can accept the null hypothesis, that means condition 1 is satisfied in the three models. So I can conclude that the estimated coefficients are unbiased, efficient and consistent.

5.3 Australian Multi-Factor Technology Valuation Models (AMTVM)

Value of every value-driver: (see above about how independent value are derived)

Value-Driver	Biotech	Infotech	E & E
1. Profitability	0	0	0
2. Uniqueness of innovation	9	0	0
3. Reputation of research team & firm	0	7	0
4. Growth prospects	0	9	6
5. Quality of management	8	0	9
6. Economic factors	0	8	9
7. Risks	7	0	0
8. Patent protection	0	0	0
9. Productivity	0	0	9
10. Government support	7	0	0
11.Cost effectiveness	0	7	9

Table 5.4 Value of Every Value-Driver

5.3.1 Biotechnology AMTVM

The biotechnology MICVM model is specified as follows:

$FirmValue_{Biotech} = \alpha + \beta_1(P) + \beta_2(MQ) + \beta_3(MRP) + \beta_4(R\&D) + \varepsilon$
$FirmValue_{Biotech}$ = the biotech firm's market value;
P = Patents issued in biotechnology sector;
MQ = Quality of management;
MRP = Market risk premium;
$R\&D$ = Research and development intensity;
(β_1), (β_2), (β_3) & (β_4) = sensitivities of biotech firm to the factors, and
ε_{it} = random error term.

5.3.2 Information Technology AMTVM

The information technology MICVM model is specified as follows:

$FirmValue_{Infotech} = \alpha + \beta_1(Q) + \beta_2(GDP) + \beta_3(EXP) + \beta_4(R\&D) + \varepsilon$

$FirmValue_{Infotech}$ = the infotech sector firm's market value;
Q = Qaulifications in the infotech sector;
GDP = Gross domestic production;
EXP = Infotech expenditure in the market;
$R\&D$ = Research and development intensity;
(β_1), (β_2), (β_3) & (β_4) = sensitivities of biotech firm to the factors, and
ε_{it} = random error term.

5.3.3 Energy & Environment AMTVM

The E & E MICVM model is specified as follows:

$FirmValue_{E\&E} = \alpha + \beta_1(EXP_{E\&E}) + \beta_2(Q) + \beta_3(P) + \beta_4(R\&D) + \varepsilon$

$FirmValue_{E\&E}$ = the E&E firm's market value;
$EXP_{E\&E}$ = E&E expenditures;
Q = Qualifications in the E&E sector;
P = Productivity level in the market;
$R\&D_{E\&E}$ = Research and development intensity in the sector;
(β_1), (β_2), (β_3) & (β_4) = sensitivities of biotech firm to the factors, and

ε_{it} = random error term.

5.3.4 Conclusion

This Chapter presented the various models developed from the case study analysis and survey questionnaire conducted.

The use of logistic models (logit) to evaluate the results of the primary questionnaire survey assured that the situation had been properly addressed and the value drivers were satisfactorily specified using statistically appropriate functional form.

As described in the previous Chapters on literature review and methodology, this Chapter presented the various models developed from the case study analysis and survey questionnaire conducted.

In terms of testing the models, the results suggested that the specified set of value drivers for the biotech sector had a positive relationship with the value of a firm in the sector as represented by the positive coefficient (+0.0345) in Equation 5.3 above. The R^2 of 26.8% signified a reasonably high degree of correlation between the specified variables in the equation and implied that approximately 26.8% of the value of the biotech firm can be explained by the specified set of independent variables. The Durbin-Watson (*DW*) statistic for autocorrelation, which measures the extent to which the errors are probabilistically independent, was shown to be 1.86. The *DW* statistic of 1.86 for biotech indicated that there is very little *lag 1* autocorrelation. The residual of this model suggests that there is no heteroskedasticity in its residual, and that the residual followed a normal distribution.

Chapter 6. Econometric Model Development

6.1 Introduction

In Chapter 5, a logit model was developed for valuing firms in the three high technology sectors and the outcome of the analysis highlights several pervasive value drivers for each of the three high technology sectors studied (see Table 6.1). This Chapter continues developing the valuation process using the results of the logit analysis in Chapter 5 to build an econometric model for the valuing high technology firms. The quantitative approach involves using the identified pervasive value drivers from the logit study to develop an econometric valuation model for the high technology firm. It is noted that the use of underlying value drivers as a means for estimating the value of intellectual capital is a challenging endeavour and is also a relatively new area of research (Helfert 2000).

The use of regression analysis for the valuation of the high technology firm is based on the principle of factor models or index models presented by Sharpe, Alexander and Bailey (1995). Factor models are "return-generating" statistical models that assume that the market value of a stock, in our case the market value of a high technology firm, is sensitive to the movements of various factors or indices. These factors and their sensitivities to stock value need to be determined. The two factor models that are widely used in the financial markets are the one-factor market model and the multiple-factor models. The techniques of simple or multiple regression analyses are used to define the return-generating process, depending on the number of predicted variables.

6.2 Multifactor Regression Models

The multiple-factor model is a "return-generating process" statistical model is used to describe how the value of an investment or asset is produced by identifying major economic factors (variables) that systematically move the prices of "all assets". The multiple-factor model assumes that the value of an asset is sensitive to the movements of various market factors. The model implies that the returns on two assets will be correlated through common reactions to the factors specified in the model. Any unexplained return by the model is assumed to be unique to the stock and uncorrelated with the unique elements of returns on other assets. The factors are the characteristics being measured and could be anything that can be objectively identified and scored (see Chapter 5 for the value drivers identified using the scoring approach).

Factor models potentially provide the benefit of reducing the variance of the abnormal return by explaining more of the variation in the normal return. This variance reduction is typically the greatest in cases where the sample sectors have a common characteristic or when they are all members of one market sector or industry (Campbell et al. 1997, pp. 155-156).

As a rule of thumb, there should be a minimum of five (5) observations for every factor considered in a multivariate analysis (Page and Meyer 2000). The empirical relationships among the set of e-commerce economic factors identified will be established and evaluated using the data available from Chapter 5. The dependent factor in this case is the value of the firm and the independent factors are those variables that have been found to have a pervasive influence on the value of the high technology firm. By summarising the interrelationships among the factors in a concise but accurate manner, the influence of these factors on the value of high technology firm can be conceptualised.

The specification of factors for the analysis of financial securities is done through two basic approaches, statistical and theoretical. The statistical approach is based on portfolios constructed from sample data (Lehmann and Modest 1988; Connor and Korajczyk 1988) and involves building factors from a comprehensive set of asset returns that is usually larger than the set of returns used to estimate and test the model. The theoretical approach for factor specification is based on arguments that the factors capture economy-wide systematic risks (Chen, Roll and Ross 1986; Fama and French 1993). Chen, Roll and Ross (1986) use macroeconomic variables as factors and Fama and French specify firm characteristics to generate factor portfolios. This research adopts the principles of both approaches for estimating the value of a firm. This is evident from the list of value drivers identified from the case study interviews and the subsequent logit analysis in Chapter 5, where the pervasive factors consist of those that are essentially derived from both statistical and theoretical specifications.

In using the statistical approach, Lehmann and Modest (1988), and Connor and Korajczyk (1988) find little sensitivity to increasing the number of factors beyond five and Fama and French (1995) find that stocks require only three factors and that five factors are necessary when bond portfolios are included (Campbell et al. 1997, p. 240). Roll and Ross (1980) using factor analysis found that only three and possibly four factors explained the return generating process of US equities. Whilst Dhrymes, Friend and Gultekin (1984) suggested that the number of factors may depend on the number of securities in each portfolio. The theoretical approaches for selecting factors generally fall into two categories of macroeconomic and financial market variables that are considered to capture the systematic risks of the economy (Oh 2001, Islam and Oh 2003, Chen, Roll and Ross 1986) and firm specific variables with explanatory power of differential sensitivity to the systemic risks.

In this Chapter, the linear multi-beta model is developed, using the method of ordinary least squares (OLS) for estimating the value of technology companies. This is consistent with the CAPM, which proves that the relationship among prices of assets in a general equilibrium, where the investors select assets to maximise the mean-variance utility, is linear. Traditional asset pricing methodologies, such as those of Breeden (1979), Ross (1976), Black (1972), Lintner (1965b) and Sharpe (1964) show that the expected return on a financial asset is a linear function of its covariances with some systemic risk factors (as in the CAPM). This approach is adopted in the development of the proposed Australian Multi-Factor Technology Valuation Models (AMTVM) for firms in the high-technology sectors in the following sections, subject to statistical testing, using Microsoft Excel software. The AMTVM models are developed incorporating significant pervasive variables. The AMTVM models are estimated for their ability to capture the essence of the fundamental economic and financial forces that affect the firm's value, in a concise and readily testable form. If there are k factors, a general representation of the typical AMTVM model can be written as:

$$FirmsValue_{it} = \alpha_i + (\beta_1)_i(F_1)_t + (\beta_2)_i(F_2)_t + \ldots + (\beta_k)_i(F_k)_t + \varepsilon_{it}$$

where:

$FirmsValue_{it}$	= the value of firm in i sector in period t;
α_i	= the expected value if each factor has a value of zero;
$(F_1)_t, (F_2)_t \ldots (F_k)_t$	= the values of pervasive factors 1, 2 … k in period t;
$(\beta_1)_i$ & $(\beta_2)_i$	= sensitivities of firm i to the factors;
$(\beta_k)_i$	= the change in the value of firm i per change in factor k;
…	= terms of the form $(\beta_k)_i(F_k)_t$ with k going from 3 to $k-1$ in period t; and
ε_{it}	= random error term.

The sector specific models are presented in Section 6.3 below and these models are statistically tested and estimated in Section 6.4.

The Arbitrage Pricing Theory - APT (Ross 1976) is a classic application of factor analysis and it assumes that in markets where there are arbitrage activities, all assets with similar characteristics trade at similar prices because the arbitrage activities will remove any mispricing. The APT is a multiple-factor model that is an alternative to the CAPM and measures the sensitivity of a company's stock return to a separate underlying factor in the economy. The valuation model that is develop here has similarity to the APT in that it the high technology firms within a specific sector are subject to the same market conditions and any "mispricing" or valuation would be removed by market arbitrage.

APT does not specify which portfolios are efficient, rather it assumes that each share portfolio depends partly on pervasive macroeconomic influences or factors (systematic risk) and partly on noise – events that are unique to that company (unsystematic risk) (Brealey et al. 2000). Thus only systematic risk is priced in the market and the factors are not identified in the model and must be ascertained through empirical research, as has been performed in this research.

6.2.1 Data Collection

The data used for developing the multi-variate valuation models for the three sectors studied in this research come from several sources, predominantly from the Australian Bureau of Statistics, Australian Stock Exchange and Reserve Bank of Australia. The study period is from 1992 to 2002, which constitutes 11 years of time series data.

On the aggregate level, to capture the relationships between the high-technology firm's value and the pervasive explanatory variables, the time series of sectorial returns data for each sector is used as proxy for the firm's value. This data is regressed on a cross-sectional pooling basis with the identified explanatory variables to capture individual differences in behaviour for estimation and inference purposes. This ensures the simulated parameters exhibit reasonable stability in different cross-sectional samples (Keenan 1970). The proxy for sector return in the study period is calculated from the closing SP/ASX 200 index on the last trading day of the year in the period 1992 to 2002.

6.3 Australian Multi-Factor Technology Valuation Models

The preceding Chapters have shown that alternative models of expected returns give rise to different expressions for the determination of fundamental values for a firm. Rational valuation models based on the widely accepted DCF methodology require earnings and discount rates as variables and they assume that only the arrival of new information or news about fundamentals affecting these variables will influence stock prices – as representative of the high technology firm's value (Cuthbertson 1997). The focus of this research is hence to identify these pervasive factors that consistently influence high technology corporate value and to investigate whether the returns of e-commerce stocks can be attributed to their factor loadings.

The approach and the data manipulations to derive the sector models and their statistical significance are discussed in this section. Table 6.1 presents the pervasive economic variables identified from the logit statistical analysis conducted in Chapter 5. The observed values from the logit evaluations are used to build the multifactor models for each of sectors used in this research. The absence of positive cash-flows and a generally accepted determinant of discount rates for the high-technology sectors necessitate proxies to act for these key variables, such as market interest rates acting as proxy for discount rates.

The process for factor selection is initially based on computing the average correlation of the individual firm's value in each sector from the Logit analysis and those variables with consistent high correlation and pervasiveness are selected for inclusion in the AMTVM regression model (see Chapter 5 and Table 6.1 below). The degree of freedom (*df*) for the general ordinary least square (OLS) problem with n observations and k independent variables is:

$$df = n - k - 1$$

$$\text{or} = n - (k + 1)$$

$$= \text{(number of observations)} - \text{(number of estimated parameters)}$$

and in this research df is equal to (11) – (5) = 6 for the estimated AMTVM models for the *Biotech* and *E&E* sectors and (11) – (3) = 8 for the *Infotech* sector (see Sections 6.4.1, 6.4.2 and 6.4.3 below). The OLS produces unbiased estimators of the coefficient, β_F, for each factor in the AMTVM model, and statistical inference on values of the population will be conducted using hypothesis testing. The null hypothesis (H_0) will be tested against a two-sided alternative (H_1), i.e.:

$$H_0: \quad \beta_F = 0 \qquad (5.1)$$

$$H_1: \quad \beta_F \neq 0 \qquad (5.2)$$

at the 20% significance level for this parameter in the research, where β_F is the factor coefficient. The rationale for using this alternative is to assume that each factor, F (the independent variable x), has a ceteris paribus effect on high-technology firm's value ($FirmsValue_{it}$ or the dependent variable y). This is considered the prudent and relevant alternative in the context of the firm's value, as the sign of β_F for this type of firm is not well determined by theory or common sense (Wooldridge 2000). As the alternative is two-sided, the interest is in the absolute value of the t-statistic. The rejection rule for the null hypothesis (equation (5.1)), H_0: $\beta_F = 0$ against equation (5.2) (i.e. H_1) is:

$$|t_{\beta F}| > c$$

where, $|\bullet|$ is the absolute value and c is the chosen critical value.

Using the Logit generated pervasive variables, the sector-specific valuation models are specified in sections 6.3.1, 6.3.2 and 6.3.3 below.

Value-Driver	**Biotech**	**Infotech**	**E & E**
1. Quality of management	7	0	9
2. Reputation of research team & firm	0	7	0
3. Uniqueness of innovation (Patents issued)	9	0	0
4. Gross Domestic Production (R&D effectiveness)	0	8	9
5. Cost effectiveness	0	7	9
6. Productivity	0	0	9
7. Risks (Market Risk Premium)	7	0	0
8. Growth prospects	0	9	0
9. Government support	7	0	0

Table 6.1 Pervasive value drivers identified from Logit Analysis

6.3.1 Biotechnology AMTVM

The hypothesized MICVM model for the biotechnology sector is specified as follows:

$$FirmsValue_{Biotech} = \alpha + \beta_1(P) + \beta_2(MQ) + \beta_3(MRP) + \beta_4(R\&D) + \varepsilon \quad (5.3)$$

$FirmsValue_{Biotech}$	= the biotech firm's market value;
P	= Patents issued in biotechnology sector;
MQ	= Quality of management;
MRP	= Market risk premium;
$R\&D$	= Research and development intensity;
(β_1), (β_2), (β_3) & (β_4)	= sensitivities of biotech firm to the factors, and
ε_{it}	= random error term.

6.3.2 Information Technology AMTVM

The hypothesized AMTVM model for the infotech sector is specified as follows:

$$FirmsValue_{IT} = \alpha + \beta_1(Q) + \beta_2(GDP) + \beta_3(EXP_{IT}) + \beta_4(R\&D) + \varepsilon \quad (5.4)$$

$FirmsValue_{IT}$	= the infotech sector firm's market value;
Q	= Qualifications in the infotech sector;
GDP	= Gross domestic production;
EXP_{IT}	= Infotech expenditure in the market;
$R\&D$	= Research and development intensity;
(β_1), (β_2), (β_3) & (β_4)	= sensitivities of biotech firm to the factors, and
ε_{it}	= random error term.

6.3.3 Energy & Environment AMTVM

The hypothesized MICVM model for the E&E sector is specified as follows:

$$FirmsValue_{E\&E} = \alpha + \beta_1(EXP_{E\&E}) + \beta_2(MQ) + \beta_3(P) + \beta_4(R\&D) + \varepsilon \qquad (3)$$

(5.5)

$FirmsValue_{E\&E}$	= the E&E firm's market value;
$EXP_{E\&E}$	= *E&E* expenditures;
MQ	= Management qualifications in the *E&E* sector;
P	= Productivity level in the market;
$R\&D_{E\&E}$	= Research and development intensity in the sector;
(β_1), (β_2), (β_3) & (β_4)	= sensitivities of biotech firm to the factors, and
ε_{it}	= random error term.

6.4 The Estimated Valuation Models: Results and Factor Analyses

The model building process involves the selection of significant explanatory factors for high technology firms' value. The objective is to construct a valuation model, using regression analysis, with 3 to 5 factors that could parsimoniously estimate the value of high-technology firms in the three sectors. The process includes statistical tests, regression estimation and hypothesis testing, to confirm that the selected factors are significantly correlated to the value of the firm. If there are no significant relations between the factors and the value of the high-technology firm, we can conclude that these statistically identified factors do not reflect the real activities in the sectors that are pervasive to value.

The more liberal 20% significance level for testing the coefficient is used due to the small sample size (n = 11 yearly observations) and the fact that the valuation of firms involved in high-technology and innovative industries are a rather new market phenomenon with the effects of the variables still relatively undiscovered and the hypothesis tests against a two-sided alternative at 20% significance level is appropriate for a research of an exploratory nature, as that conducted in this study, to tease out any pervasive characteristics in the explanatory variables.

According to Wooldridge (2000), "different researchers prefer different significant levels depending on the particular application and underlying agenda and there is no 'correct' significance level". The *p*-values for the *t*-statistics will also be computed for those factors that are considered pervasive to e-commerce returns to ascertain their degree of influence even if their β_F coefficients are statistically insignificant. By including those factors judged pervasive from their *p*-values, we attempt to tease out the characteristics of these explanatory variables for an area that is very much at a pioneering stage with very little information to rely on.

The estimated AMTVM from the regression runs (summary outputs are in Appendixes xx, xx and xx) are presented as follows:

6.4.1 Estimated Biotechnology AMTVM

From the regression summary output (Appendix 6.xx) for the biotech sector, the following estimated equation is derived from the regression analysis.

$$FirmsValue_{Biotech} = \underset{(1.4082)}{144.80} - \underset{(-1.5150)}{0.0055(\mathbf{P})} + \underset{(1.4510)}{0.7465(\mathbf{MQ})} - \underset{(-1.6196)}{15.0301(\mathbf{MRP})} - \underset{(-1.1874)}{0.3607(\mathbf{R\&D})} \quad (5.6)$$

$R^2 = 0.86$

$FirmsValue_{Biotech}$	= the biotech firm's market value;
P	= Patents issued in biotechnology sector;
MQ	= Quality of management;
MRP	= Market risk premium;
$R\&D$	= Research and development intensity;

6.4.1.1 Hypothesis tests

Equation (4) above summarises the important statistics of the estimated regression AMTVM equation for the *Biotech* sector with the coefficient of determination or R^2. The statistical significance of the coefficient of each value-driver for statistical inference at the 20% level of significance is shown in Table 6.2 below.

Value-Driver	*t-statistics*	*Critical Value (at 20% significance level & df = 6)*	*Accept/Reject the Null Hypothesis*
Patents Issued (**P**)	*1.5150*	*1.440*	*Reject*
*Quality of Management (**MQ**)*	*1.4510*	*1.440*	*Reject*
*Market Risk Premium (**MRP**)*	*1.6196*	*1.440*	*Reject*
*R&D Intensity (**R&D**)*	*1.1874*	*1.440*	*Accept*

Table 6.2 t-Statistics Tests of the 4 Pervasive Value-Drivers Model – Biotech Sector

Though the R&D value driver is statistically insignificant at the 20% level in terms of t-statistic, its p-value is 0.2799 (Appendix 6.1), hence we would observe only 29.97% of the t-statistics in all random samples for these factors when the null hypothesis is true. This is relatively strong evidence against H_0 and signifies that this factor does have a certain degree of pervasive influence on the biotech firms' returns despite its insignificant t-statistics.

Table 6.3 shows the explanatory factors *P*, *MQ* and *MRP* are accepted in the hypothesis testing of the estimated value-drivers. This indicates that the accepted value-drivers are statistically significant and have inferential implications about the population values. The revised AMTVM for the *Biotech* sector incorporating the three value-drivers is present as follows:

$$FirmsValue_{Biotech} = 254.81 - 0.0018(\mathbf{P}) + 0.1531\ (\mathbf{MQ}) - 24.3700(\mathbf{MRP})$$
(5.7)

$$(5.5535)\quad(0.9353)\qquad(1.2161)\qquad(4.8097)$$

$R^2 = 0.82$

Value-Driver	***t-statistics***	***Critical Value*** *(at 20% significance level & df = 7)*	***Accept/Reject the Null Hypothesis***
Patents Issued (**P**)	*0.9353*	*1.415*	*Accept*
*Quality of Management (***MQ***)*	*1.2161*	*1.415*	*Accept*
*Market Risk Premium (***MRP***)*	*4.8097*	*1.415*	*Reject*

Table 6.3 t-Statistics Tests of the 3 Pervasive Value-Drivers Model – Biotech Sector

Table 6.3 shows the explanatory factors *MRP* is the only value-driver accepted in the hypothesis test for statistical specification of pervasive value-drivers. This indicates that *MRP* is the only value-driver that is statistically significant and have inferential implications about the population values. The revised AMTVM for the *Biotech* sector incorporating only *MRP* is present as follows:

$$FirmsValue_{Biotech} = 219.23 - 19.7331(\mathbf{MRP})$$
(5.7)

$$(6.1038)\qquad(-5.5875)$$

$R^2 = 0.78$

The critical value for a two-sided hypothesis test at 9 degrees of freedom is 1.383. The t-statistics of the revised AMTVM as represented by Equation 5.x) is -5.5875, which therefore rejects the null hypothesis. Equation (5.x) represents the final valuation model for firms in the biotech sector.

6.4.1.2 Empirical Results of the Biotech AMTVM

The problem of deciding which value-drivers or independent variables to include in the multiple regression equation is closely linked the decision of how to define the best model that explains the dependent variable, which is the value of the high-technology firm, using the smallest possible set of independent variables. The estimated AMTVM Equation (5.7) for the *Biotech* sector, best represents the long-term relationship between the high-technology firm's value and the value-drivers or economic variables. The inferred economic rationale of each value-driver in the *Biotech* AMTVM is discussed below.

Patents Issued *(P)*

The proxy for measuring the "uniqueness of innovation" in this research is the number of patents issued. According to Levy (1998), the uniqueness of an innovation is a major determinant of value, because it would have intrinsic market appeal and are genuinely unique as distinct from those that are merely extensions or improvements (Kuratko 1998). In the *Biotech* sector, the ability of pharmaceutical companies to develop new drugs to cure chronic diseases conjures greater value than mere improvements to existing medications, whose benefits may be marginal or incremental. A case in point is Viagra, the miracle impotent drug, which has helped Pfizer (Viagra's manufacturer) in increasing the firm's market value substantially.

Quality of Management *(MQ)*

Other than be able to discover new pharmaceutical solutions or adopt effective innovations, the successful biotechnology firm needs to understand and manage all aspects of a firm's operations and be able to find a home for the newly discovered products and services in the marketplace (Day 1999). The key to effective management in the biotechnology sector also lies in the effective control or management of costs and risks (Weil 1983; Contractor 1988) inherent in developing new drugs.

Market Risk Premium (*MRP*)

Like firms in other industries, major risks for nascent biotechnology firms can arise from funding strategies (Narayanan 2001), competitors (Levy 1998), breaches of patent laws (Hovey 2002), and safety fears (Razgaitis 1999). There is a systematic risk component associated with the cash flows of technology-intensive ventures while the technical risks are idiosyncratic (Berk, Green and Naik 1998; Oh 2001). In this research, the market risk premium (being the difference between the risk free rate and the return of a risky investment) is used as proxy for the *Biotech* sector risk factor. The *MRP* is assumed to be representative of the various types of risk (both systematic and unsystematic – see Oh (2001) inherent in the value of a Biotech firm, be it funding, competition or other classes of risk. The relevant and definitive risks affecting the valuation of individual biotechnology ventures need to be determined and measured in the evaluation process for firms in the sector, be they in the form of risk premia earned for firm external factors such as *NAS*, *CC* and *FE* (Oh 2001), during development (Berk et al. 1998) or human capital Darby et al. (1999).

6.4.2 Estimated Infotech AMTVM

From Appendix 6.2, it can be seen that both the logit specified value drivers of infotech spending and GDP have a coefficient value of zero. This means that the regression analysis fails to ascertain any relationship between these hypothesized value drivers and the infotech firm's value. In other words, coefficients of these value drivers are zero for these independent variables. From the regression summary output (Appendix 6.2) for the infotech sector, the following estimated equation is derived from the regression analysis.

$$FirmsValue_{Infotech} = 0.2554 + 0.0031(\mathbf{Q}) - 0.0001(\mathbf{GDP}) - 0.0000(\mathbf{EXP_{IT}}) - 0.0000(\mathbf{R\&D}) \quad (5.8)$$

$$(4.5588) \quad (0.7731) \quad (-2.2483) \quad (-0.2038) \quad (-0.0108)$$

$R^2 = 0.73$

$FirmsValue_{Infotech}$	= the *Infotech* sector firm's market value;
Q	= Qualifications in the *Infotech* sector;
GDP	= Gross domestic production;

6.4.2.1 Hypothesis Tests

Equation (5.8) above summarises the important statistics of the estimated regression AMTVM equation for the *Infotech* sector with the coefficient of determination or R^2. The statistical significance of the coefficient at the 20% level of significance is shown below each factor for statistical inference.

Value-Driver	***t-statistics***	***Critical Value*** *(at 20% significance level & df = 8)*	***Accept/Reject the Null Hypothesis***
IT Qualifications (**Q**)	*0.7731*	*1.397*	*Accept*
*Gross Domestic Production (***GDP***)*	*2.2483*	*1.397*	*Reject*
Infotech Sector Expenditure ($\mathbf{EXP_{IT}}$*)*	*0.2038*	*1.397*	*Accept*
*Research and Development (***R&D***)*	*0.0108*	*1.397*	*Accept*

Table 6.4 t-Statistics Tests of the Pervasive Value-Drivers – Infotech Sector

Table 6.4 shows that there is only one *Infotech* value-driver, being gross domestic production (*GDP*), which is defined as statistically significant from the hypothesis tests conducted at 20% significance level. This implies that only one explanatory value-driver for the value of firms operating in the *Infotech* sector is statistically significant. This indicates that this accepted value-driver is statistically significant and has inferential implications about the population parameters. The revised AMTVM for the *Infotech* sector is presented in Equation (5.9) as follows:

$$FirmsValue_{Infotech} = 0.29801483 - 0.0003827(\mathbf{GDP}) \qquad (5.9)$$

$$(7.1855) \qquad (-3.9307)$$

$R^2 = 0.73$

Though the factor IT qualifications (Q) is tested to be statistically insignificant at the 20% level in terms of t-statistic, its p-value for Q is 0.4688 (Appendix 6.2), hence we would observe only 46.88% of the t-statistics in all random samples for these factors when the null hypothesis is true. This is relatively strong evidence against H_0 and signifies that this factor does have a rather strong influence on the biotech firm's value despite its insignificant t-statistics. Likewise, the same can be said about the value drivers IT spending ($EXP_{infotech}$) – p-value of 84.52% and research and development expenditure ($R\&D$) – p-value of 99.17% for the sector.

6.4.2.2 Empirical Results of the *Infotech* AMTVM

The inferred economic rationale of the GDP as the value-driver in the *Infotech* AMTVM is discussed below.

Gross Domestic Production (GDP)

The cash flows of a firm reflect real economic activity as measured by, for instance, gross domestic product - GDP (Shapiro 1988). The diffusion of information technology in the economy is pervasive and entrenched with firms only willing to commit to capital expenditure in information technology if they see a strong return from their investment. As the fundamental value of a firm is the expected present value of the firm's future payouts and if these expectations take all currently available information into account, consistent with the efficient market hypothesis, then the state of the GDP and the level of potential GDP growth by extension, would be very strong indicators of current and future value of the firm. Consequently, the firm's value should react sensitively to this measure of real activity as the price of an asset is built on expectations of these activities. Barro (1990) and Fama (1990) support the argument that stock price should lead real activity.

6.4.3 Estimated Energy & Environment AMTVM

$$FirmsValue_{E\&E} = 0.1247 - 0.0002(\mathbf{R\&D_{E\&E}}) - 0.0007(\mathbf{MQ}) - 0.6736(\mathbf{P}) + 0.1629(\mathbf{R\&D})$$

$$(1.2532) \quad (-0.1644) \quad (-1.5493) \quad (-0.6896) \quad (1.1692)$$

$$R^2 = 0.38 \qquad (5.10)$$

$FirmsValue_{E\&E}$	= the E&E firm's market value;
$R\&D_{E\&E}$	= *E&E* expenditures;
MQ	= Management qualifications in the *E&E* sector;
P	= Productivity level in the market;
$R\&D_{E\&E}$	= Research and development intensity in the sector;

6.4.3.1 Hypothesis tests

Equation (6) above summarises the important statistics of the estimated regression AMTVM equation for the *E&E* sector with the coefficient of determination or R^2. The statistical significance of the coefficient at the 20% level of significance is shown below each factor for statistical inference.

Value-Driver	***t-statistics***	***Critical Value*** *(at 20% significance level & df = 6)*	***Accept/Reject the Null Hypothesis***
E&E expenditures (**EXP**)	*0.1644*	*1.440*	*Accept*
Management Qualifications (**MQ**)	*1.5493*	*1.440*	*Reject*
Productivity level (**P**)	*0.6896*	*1.440*	*Accept*
R&D intensity (**R&D**)	*1.1692*	*1.440*	*Accept*

Table 6.5 t-Statistics Tests of the Pervasive Value-Drivers – E&E Sector

Table 6.5 shows that there is also only one value-driver for the *E&E* Sector, being gross management quality (*MQ*), which is defined as statistically significant from the hypothesis tests conducted at 20% significance level. This implies that only one explanatory value-driver for the value of firms operating in the *E&E* sector is statistically significant. This indicates that this accepted value-driver is statistically significant and has inferential implications about the population parameters. The revised AMTVM for the *E&E* sector is presented in Equation (5.9) as follows:

$$FirmsValue_{E\&E} = \underset{(6.5936)}{0.1010} - \underset{(-0.9150)}{0.0002}(\boldsymbol{MQ}) \qquad (5.11)$$

Though the value drivers E&E expenditures ***(EXP)***, Productivity level (***P***), and R&D intensity (***R&D***) are all tested to be statistically insignificant at the 20% level in terms of t-statistic, their *p*-values are 87.48%, 51.62% and 28.67% (Table 6.6) respectively. Which signifies that for these value-drivers we would observe the respective *p*-values of the *t*-statistics in all random samples for these factors when the null hypothesis is true? The p-values for these statistically "rejected" value drivers are relatively strong evidence against H_0 and signifies that this factor do have a rather pervasive strong influence on the *E&E* firm's value despite its insignificant *t*-statistics.

Value-Driver	**p-*values***
E&E expenditures (**EXP**)	*87.48%*
*Productivity level (***P***)*	*51.62%*
*R&D intensity (***R&D***)*	*28.67%*

Table 6.6 p-values for Value Drivers in the E&E Sector

6.4.3.2 Empirical Results of the *E&E* AMTVM

Like the *Infotech* sector, Table 6.6 shows that there is only one *E&E* value-driver, being the level of qualifications in the *E&E* sector, as pervasive or statistically significant to the value of firms in the *E&E* sector.

Management Qualifications in the E&E Sector (*MQ*)

E&E firms are in the forefront of innovative endeavours in countering the numerous energy and environment challenges that the world faces today. This situation has raised the awareness of these firms to understand the needs of the markets and manage their operations in such a manner in order to offer effective solutions to address these challenges and in the process generate profits to perpetuate the business. In this context, successful management according to Day (1999) involves not merely discovering new solutions or adopting seemingly effective innovations, but also finding a home for the discovered products and services in the marketplace, which means understanding and responding to market needs and realities (Narayanan 2001). The higher the quality of management (*MQ*) in firms operating in the *E&E* sector is therefore a pervasive value-driver that ensures management supremacy and performance.

6.4.4 Limitations

- The time series data available in for conducting this study have been limited in that the data was for 11 years only, not all data used were from the same source and some had to be estimated using proxy data.
- The evaluations carried out in this study had not taken into consideration the lead, coincidental or lag effects of the variables. The exploratory nature of this research means that this aspect of economic analysis has been overlooked and should be addressed for a more definitive research outcome.
- This study addresses biotech value from the perspective of the organisation rather than the shareholders. The purpose of this study is to tease out the organisational value drivers and shareholders' interests are presumed to be represented by maximising value and maximising return. The situation of information asymmetry and vagueness of early-stage innovation in new biotech firms gives the approach adopted in this research a degree of relevance in that it would be relatively more difficult for outside investors to fully appreciate the value aspects of the venture.

- The interactive influence of explanatory variables on biotech return may not have been fully understood and appreciated in this research such as the influence of each explanatory variable *A* on biotech return/explanatory variable *B* correlation. A more advanced study using "*partial correlation*" would provide a better insight into this aspect of the interactive relationships of the explanatory variables.

These limitations provide the opportunities for future research and improvement of the BVM.

6.5 Findings

The following sections present a summary of the key findings of the research done in this Chapter.

6.5.1 Biotech Valuation

The final biotech BVM model (Equation 7) suggests that the fundamental and crucial value driver for the biotech sector firm is the level of risk premium in the market. In our study this is represented by MRP and is the difference between the market return and the risk-free rate. A firm's ability to manage risk affects its corporate value or share price. When evaluating investment in new biotech firms, the price is normally justified from a fundamental perspective but the significant challenge to the investor is be able to estimate risk from further development, which may lead to success or failure. So risk management can create, sustain or destroy shareholder value and how a well company manages its risks eventually decides its worth. This requires a good risk management process to allow the firm to exploit opportunities for future growth while protecting the value already created. Through strategic risk management the value drivers that are considered vital to the success of the venture are protected and the firm's value is enhanced.

In terms of risk and return relationship, the biotech sector differs in performance to the general market as shown in Table 1. The average return of the sector was relatively higher than the market return but subject to lower risk that that exhibited by the market in the study period. This is an abnormally that could be attributed to the high unsystematic characteristics on many high technology ventures (see Islam and Oh 2004 on systematic and unsystematic risk characteristics).

6.5.2 Infotech Valuation

The infotech BVM specifies only one pervasive value-driver, being gross domestic production (*GDP*). This implies that only one explanatory value-driver for the value of firms operating in the *Infotech* sector is crucial for value creation in the infotech sector.

6.5.3 E&E Valuation

There is also only one value-driver specified in the *E&E* BVM, which is management quality (*MQ*). This value driver is defined as statistically significant from the hypothesis tests conducted at 20% significance level and implies that it is pervasive in value creation for the E&E firms operating in the sector. This also indicates that this accepted value-driver is statistically significant and has inferential implications about the population parameters.

6.6 Conclusion

The work done in this Chapter attempts to identify and measure the pervasive factors that contribute to driving the value of new biotech firms. Statistical manipulations such as logit and multivariate analyses are conducted to develop the respective BVM for the sectors by identifying and estimating the pervasive factors with the use of regression analysis modeling. The pervasive factors are then statistically tested for significance and the economic rationale and implications of their value characteristics vis-à-vis the broader biotech sector are explained.

Chapter 7. Implications and Conclusions

7.1 Introduction

Given the critical importance of knowledge as a key organizational asset, this research has sought to investigate one of the most important aspects of strategic financial management: the valuation of intellectual capital in its nascent stages. From the viewpoint that firms in the knowledge economy need to invest in intellectual capital to remain profitable and competitive, this study has contributed to knowledge in the vexatious and complex area of valuations of intellectual capital, in a contemporary stage of development, where the models used for such valuations are either inappropriate or inadequate. The objective of this research has been to formulate models to remove, or at least, minimize impediments to investments that naturally occur from an insufficient or unclear understanding of underlying value of investments. It has been established from the findings that idiosyncratic differences in the three industries, selected for this study, required the formulation of three different valuation models, presenting management with different strategic implications for the maximization of shareholder wealth, through the management and investment processes of the intellectual capital of the firm.

The direction of the research and its methodology was founded on the extensive literature review contained in Chapter 2. Clearly, there was a major gap in knowledge in the area of valuation of nascent intellectual assets and intellectual capital, given that techniques and methodologies, chief amongst them being discounted cash flow models, and accounting models, developed for a different class of assets, and for a different economic paradigm, were being used. The need for new valuation methodologies, discussed in Chapter 2, section 2.11, was clearly evident, which provided the foundation for the methodology of this research, that is, the developing branch of research termed value-driver research proposed, amongst others, by Helfert (2000).

One of the major objectives of this research has been to develop a different dimension to the valuation of intellectual assets and intellectual capital. Literature had clearly pointed to the need to develop new valuation methodologies for valuing nascent technologies (Chapter 2, section 2.11). The methodology selected for this study, intended to uncover the underlying pervasive value-drivers in each of the industries (in the study), has been able to propose model(s) that are robust, flexible, and easy to use. This has been achieved by both qualitative and quantitative means, and included case studies, a general survey, (Chapter 4) and statistical analysis and manipulation of data using logit modeling (Chapter 5). Following this phase, the valuation models were proposed (Chapter 5) which accounted for the idiosyncratic differences between the three different industries in the research. Finally empirical data was analysed to test the models, (Chapter 6) and the results (Chapter 6 section 6.5) proved, yet again, that there were discernable differences in the three industries, and that using a standard model to value each type of industry was erroneous.

The results from the anlaysis of case studies clearly lent weight to critics' observations that standard DCF models or accounting models should not be used to value nascent technologies, primarily because they fail to capture the value of underlying qualities or value drivers which are idiosyncratic to individual industries (Chapter 2, section 2.11). The results of case study analysis (Chapter 4 section 4.5.16, table 1) also showed that there is the presence of pervasive value drivers in each industry. Thus, criticisms of current valuation techniques stemming from using standard models, both financial and accounting models (e.g. DCF and ROA or DIC models), appear to be well justified. Therefore, by implication, the valuation models which has been formulated on pervasive underlying value drivers (Chapter 6) has to be recognized as being a more accurate means of determining the value of nascent intellectual capital assets.

The analysis of the case studies identified the underlying value drivers in each of the three industries in the study (Chapter 4 section 4.5.16, table 1). The exploratory nature of this research meant that a wide variety of value drivers had to be included in the survey, based on the findings of the case studies, in order to test the findings against empirical data. Respondents did not express the opinion that there could exist value drivers beyond the ones present in the survey. In other words, the questionnaire was exhaustive in its content, which has given the model building process for each industry, a high degree of robustness.

The validity and rigour of the analysis have been assured using logit modeling techniques. By doing so, the specified logit equations helped in explaining whether the set of independent variables (i.e. value-drivers) were statistically significant in collectively determining the value of firms in each sector. The objective of this regression manipulation was to statistically specify the value-drivers and determine the pervasiveness of these variables on the dependent variable according to the scores given by the respondents to the questionnaire.

The significant and pervasive value drivers, specific to each industry, had been determined, and the ones that are relatively less important have been eliminated from the model building process (Chapter 5 sections 5.2.1.1 – 5.2.1.3). Clearly the implication for management is that in order to reduce risks in investments in intellectual capital, it must focus on creating value through managing those factors that infuse value in their respective industries.

Consistent with the proposal in Chapter 1 and Chapter 3, this research had been successful in formulating valuation models for the three industries in the study, based on pervasive underlying value drivers. Empirical data seems to be at odds with the findings from the survey in the number of value drivers that aggregate to total value for each industry, but given some of the limitations of the research (section 7.3.2) this is quite a plausible outcome. As proposed in Chapter 1, robust, flexible models of a linear multi-beta type were developed, using the method of ordinary least squares (OLS) for estimating the value of intellectual capital, and was given the title 'Australian Multi-Factor Technology Valuation Model'. This meets a major objective of the research, that is, to provide a new and appropriate means of measuring the value of intellectual capital of the firm.

7.2 Implications and Extrapolations

The following sections discusses the implications and extrapolations of the research, and tabulates the triangulation of results.

7.2.1 Literature Review

The literature review in Chapter 2 had centred upon the following key topics:

- The importance of intellectual capital in its role as the major organisational asset in the knowledge era (Chapter 2, section 2.3)
- The importance of valuation issues connected with intellectual capital (Chapter 2, sections 2.2 – 2.3)
- An analysis and evaluation of current valuation methods being employed to value intellectual capital in their nascent stages of development, which included accounting methods, discounted cash flow methods and their variants, options pricing models, and the CAPM (Chapter 2, sections 2.4.1 – 2.9)
- Risks issues in valuation of nascent technologies, which are products of intellectual capital investments, and the manner in which current valuation techniques and methodologies address them (Chapter 2, section 2.10).

What clearly emerged was that the application of currently available economic and accounting models to the valuation of intellectual capital contained fundamental inadequacies, leading to uncertainties and risk for investors and managers. Since the bulk of the traditional source of venture capital arises from private sources, uncertainties would naturally impede the investments processes in respect of nascent technologies. This has serious strategic management implications, primarily because a failure to invest in intellectual capital projects would lead to a future decline in competitiveness, profitability and shareholder wealth formation.

The research has been successful in meeting the major motivation for this research: to provide a valuation model which would be specific to valuing the intellectual capital of the firm, and possess the flexibility to be applied to different industries to account for their idiosyncratic characteristics.

The Australian Multi-Factor Technology Valuation Model proposed in Chapter 6 clearly addresses the issues raised in the Literature Review, and meets the primary objectives of the research. Of utmost importance, the findings from the case study analysis, which identified the value drivers in the three different industries (Chapter 4, section 4.5.16, Table 1), and which were validated by empirical data, statistically analysed from the survey (Chapter 5, sections 5.3.1 – 5.3.3), clearly corroborated critics' claims that factors which give an indication of value but which are never accounted for (Chapter 2, section 2.11), lie at the root of calculating the value of intellectual capital and intellectual assets. Significantly, the findings also established that factors that drive value are idiosyncratic in each of the three industries. Thus, the models, developed to account for characteristics peculiar to each industry in the study, allow venture capitalists and strategic managers to value nascent intellectual capital, reducing risks of investments, and facilitating the flow of funds to developmental projects, to ensure future profitability and competitiveness. Secondly, the models, based on identifying and incorporating underlying value drivers, successfully, avoided the pitfalls and shortcomings of current valuation models in the following ways:

- The models do not require a history of General Purpose Financial Statements, nor the identification of complex inputs in order to calculate the value of intellectual capital, as is the case with accounting based models (Chapter 2, sections 2.4.2)
- The models do not rely on historical or forecast cash flows, nor the use of subjective Weighted Average Cost of Capital (WACC) to value nascent intellectual capital projects, as is the case with Discounted Cash Flow Models and their variants (Chapter 2, sections 2.4.3 – 2.4.6)
- While recognizing that Options Pricing Models are better suited to valuing nascent technologies and intellectual capital projects, literature also identifies some of the reasons why they are still unsuitable (Chapter 2, section 2.8). The Australian Multi-Factor Technology Valuation Models (AMFTVM) avoid the issues that have raised concerns with Options Pricing Models among venture capitalists, practitioners, and academics.

- The AMFTVM addresses the fundamental financial issue of risk in investment decisions, in that risk is evaluated as an underlying value driver by each industry in the study (Chapter 2, section 2.10). In this respect, it addresses a major shortcoming of accounting methods of valuations which ignore risk altogether, and of DCF methods which address risk through an often subjective premium-loading of the WACC. Thus, the AMFTVM has clear implications for risk management: identifying and evaluating the various risks inherent in each industry leads to value being created, or otherwise. Further, by inducing financial managers to identify all the risks involved, it would lead to better risk management techniques.

Finally, the AMFTVM is able to provide a much more robust and accurate means of valuation by incorporating the sources of underlying value drivers, as researched by many academics, practitioners and venture capitalists (Chapter 2, section 2.11).

7.2.2 Case Studies and Survey

Having identified the need to develop a fresh approach to valuing nascent technologies (Chapter 2, Literature Review), the selection of the case study method, followed by a general survey, was chosen as the best means to uncover pervasive value drivers in the three industries in the study. Being exploratory research in nature, this means was judged to be suitable, both to the purpose of the investigation, and to the nature of the data that had to be collected and analysed (Yin 1989, Sekaran 1992).

The wealth of information derived from the findings of the case studies analysis (Chapter 2, section 2.11) clearly justified the means of investigation. Underlying value drivers present in the three industries were found to be close in similarity to those listed by critics (Chapter 2, section 2.11) lending a weight of credibility to value driver research proposed by Helfert (2000).

The follow-up survey, designed to test the validity of the findings of the case studies analysis, statistically analysed by logit modeling, proved beyond doubt the existence of pervasive value drivers in each industry (Chapter 5, sections 5.2.1.1– 5.2. 1.3). Logit equations clearly established the correlation of identified variables to the value of the firm. This underpins the validity of the final AMFTVM as a suitable means of valuing intellectual capital, and one that is clearly better than the traditional means that Literature analysed and evaluated in Chapter 2.

The implications from the research findings on all three sectors, from both a corporate equity fund-raising and a portfolio investment perspective, must be the recognition of the obligation placed upon senior managers to monitor and evaluate identified pervasive value-drivers to ensure that value is yielded by their choices of investment in intellectual capital. In this objective, management will find the AMFTVM a useful tool to attract venture capital, particularly if the providers of capital use the same model to arrive at a similar valuation of nascent technologies.

7.2.3 Statistical Analysis

The statistical analysis conducted in Chapter 5 and 6 attempts to identify and estimate factors that are most likely to pervade the value of the firm in the three sectors studied in this research. The purpose has been to develop a multifactor valuation model for new technology firms in the biotech, infotech and E&E sectors incorporating the combined explanatory power of the factors vis-à-vis the value of the firm (the results and findings are presented in Chapter 5 for the logit analysis and Chapter 6 for the multivariate regression analysis).

The estimated AMTVM model developed for each sector shows that different pervasive value drivers are relevant to each sector (see Sections 6.4.1, 6.4.2 and 6.4.3 for the respective AMTVM models) and this indicates the idiosyncrasies and the level of unsystematic risk (Oh 2001) in each industry.

In earlier research of a parallel nature, Bennett (1991), BCG (1993) and McTaggart (1994), attempted to derive generic models of valuations for firms possessing high levels of knowledge assets, by employing substantially similar research methodologies. Statistical analysis of data derived from surveys carried out on firms operating across a wide spectrum of industries had formed the basis of their model-building. Each of their reports drew conclusions which closely match the findings of this research, that is, models that are able to estimate value based on the aggregation of identified value drivers are a better means for valuing firms which make large investments in knowledge assets (section 7.2.4).

7.2.4 Triangulation of Results

The combined use of literature review, case studies and questionnaire survey for data collection and logit and regression modeling methodologies has provided a strong and robust process for identifying, specifying and estimating the key value drivers in this exploratory research. The results provide convergent evidence that key value drivers exist in each sector and the inferences that can be drawn from the literature and the analysis in Chapter 5 and Chapter 6 are consistent with the findings that pervasive value drivers specific to each industry aggregate to the value of firms operating in that particular industry. A summary of findings under each method is provided in Table 7 below:

Sector	Pervasive Value Drivers from Literature Review and Case Studies	Logit Value Drivers	Multivariate Regression Value Drivers
Biotech	1. Profitability 2. Uniqueness of Innovation. 3. Reputation of research team & firm. 4. Growth prospects. 5. Quality of management.	1. Quality of management. 2. Risks 3. Uniqueness of innovation. 4. Government support.	1. Uniqueness of innovation. 2. Quality of management. 3. Risks 4. Research and development.

	6. Economic Factors. 7. Risks 8. Patent protection. 9. Productivity		
Infotech	1. Profitability 2. Uniqueness of Innovation. 3. Reputation of research team & firm. 4. Growth prospects. 5. Quality of management. 6. Economic Factors. 7. Risks 8. Patent protection. 9. Productivity. 10. Cost effectiveness.	1. Reputation of research team and firm. 2. Growth prospects. 3. Cost effectiveness. 4. Economic factors.	1. Quality of management. 2. Economic factors. 3. Growth prospects. 4. Research and development.
E&E	1. Profitability. 2. Uniqueness of innovation. 3. Reputation of research team & firm. 4. Growth prospects. 5. Quality of management. 6. Economic factors. 7. Risks 8. Patent protection.	1. Quality of management. 2. Productivity 3. Economic factors. 4. Productivity.	1. Growth factors. 2. Quality of management. 3. Productivity 4. Research and development.

	9. Productivity. 10. Government support. 11. Cost effectiveness.		

Table 7 Summary of Findings under Each Method

From a wide range of value drivers identified from literature and case studies, statistical analysis of the questionnaire survey (Chapter 5) had been successful in focusing the key characteristics of each industry that yield value. The multivariate regressed value drivers show a high degree of similarity with the logit-analysed value drivers, which provides a high level of robustness and credibility to the final AMTVM model for each of the industries in the study.

7.2.5 Relating Literature to Findings

It was stated in the foregoing sections of this thesis (Chapter 1, section 1.4; Chapter 2, section 2.11) that the application of currently available economic and accounting models to be used for valuation of intellectual assets had revealed fundamental inadequacies. However, a vital necessity for business investments to occur is conditional upon accurate economic measurement of such opportunities because such investments are likely to provide a platform for growth, profitability and competitiveness.

The implications arising from investments in intellectual capital are abundantly clear. Benefits will be high for companies that expect to invest heavily in developing high technologies in the near future. Conversely, the sub-optimal or super-optimal investment programs will be costly. In other words, the optimal level of investment will be determined to a large extent by the application of valuation models. The problems of competitiveness and profitability in a knowledge economy can be surmounted if capital intensity is coupled with rapid growth and technological change, which may be estimated by appropriate and accurate valuation processes. Success requires a sequence of good investments, and getting even one of them wrong can be very expensive. Thus valuation must play a central role in the process of measuring investment opportunities in intellectual capital in order to achieve adequate investments for optimal results.

Literature review (Chapter 2, section 2.11) examined a slew of criticisms from several eminent researchers, practitioners, and investors about the problems and inadequacies of measuring intellectual capital from the standpoint of existing models (Akiva and Morikawa (1990), Eccles and Mavrinac (1995), & Sullivan (2000). This disaffection with traditional techniques and models spawned the development of a new research direction in valuation methodologies based on valuing intellectual capital on the basis of identified value drivers, which has been the central theme of this research. Section 7.2.1 of this Chapter has linked the literature to the findings of this research, and justified the AMTVM models specifically formulated to account for the idiosyncratic differences between the industries in the study.

Although the branch of research used in this thesis, that of value driver research, is relatively new, several significant studies of a similar nature have been carried out (Bennett, 1991, BCG 1993, McTaggart 1994), all of which underpin the findings of this study. However, there was a major difference between this and earlier research. Unlike the earlier studies, which attempted to formulate generic models for knowledge intensive firms, this research investigated three individual industries, arising from the belief, that there were idiosyncratic differences present in each industry, and that, to determine the value of each industry, there was the need to identify what these industry-specific value drivers were.

This is precisely what this research achieved: the 'uncovering' of specific and idiosyncratic value drivers for each of the biotech, infotech and E&E industries (section 7.2.4), which were then integrated into industry-specific valuation models. While some of the value drivers are the same, important differences are also evident, which presents management, investors and venture capitalists with different management and risk-bearing implications. Literature had described a wide array of value drivers which critics of traditional valuation techniques had researched (Chapter 2, section 2.11), and the findings of this research in terms of underlying value drivers is consistent with those. Where this study has made a significant contribution to knowledge is that it has been able to establish idiosyncratic value drivers in three different industries. This leads to the conclusion that in order to value knowledge intensive firms, it is important to model valuation on drivers that are industry-specific.

Chapter 1 (sections 1.1.1 – 1.1.3) had established that for knowledge economies, three industries were particularly important, which led to the biotech, infotech and E&E industries being selected for this research. These industries were not only important for the U.S economy, but for Australia as well (Chapter 2, section 4.2.2) The recognition of the role that intellectual assets play in creating national wealth had led several universities to establish research parks, of which La Trobe University's research establishment represented a microcosm of the scenario of challenges, imperatives and opportunities of investments in nascent technologies. Therefore, the knowledge contributed by the findings of this study is envisaged not only to benefit investors, venture capitalists and finance practitioners, but additionally, government departments which are responsible for directing investments into channels of development, which will contribute to growth and prosperity of a nation.

As stated earlier in this section, several studies based on value driver research have also concluded that shareholder value management through understanding the underlying value drivers in each industry is of strategic importance, particularly for firms which employ a large body of intangible assets, for example, intellectual capital. In one of the earliest examples of research in value-driver based valuation methodologies, Bennett (1991) declared that it was much superior as a method for valuing assets than other comparable means available. His research was conducted on several service-oriented firms operating in the ticketing, entertainment, travel and tourism, and hotel agency businesses. What emerged was that their competitive value was dependent on factors which were service quality, promptness of service delivery, speed of providing clients' final product, technical back-up facilities, catchment width of provider-firms, and professional training of staff. While revolutionary in nature, and contrary to the expectation that this changed paradigm would attract academic skepticism, further exploratory value-driver research was carried out by the Boston

Consulting Group (1993) into a broad array of firms with considerable intellectual capital in their employ. The type of business researched were those operating in the computing software, insurance, actuarial services, and engineering consulting services areas. What emerged from the research was that the market valuations of these firms were dependent on product innovativeness, distribution channels management, professional knowledge transfer mechanisms, and staff motivation management. The results established characteristics of service oriented firms which had a high correlation to their verifiable market value, but which were neither reflected nor explained by their balance sheets.

In more recent studies, McTaggart, et al (1994) emphasized the need to change directions in valuing firms which were employing large investments in knowledge assets because research into technology-intensive firms had exposed contemporary cash flow based models as being irrelevant from understanding what lay beneath the veneer that yielded value. In that study, knowledge acquisition strategies, innovative product development, and financial control of costs featured as major drivers of value. In a later study, Pratt (1995) researched closely held knowledge based companies, and arrived at the conclusion that what gave value to such companies were a complex set of factors which were neither reported in the traditional financial statements, nor easily understood as to the manner in which they acted as a cohesive force to create value for their owners.

These findings from similar earlier studies are consistent with the results of this research, which established, without doubt, the existence of value drivers which are pervasive idiosyncratically in the three industries investigated (section 7.2.4). As stared earlier, it is upon these identified value drivers that valuation models have been formulated and tested (Chapters 5 and 6), strengthening the foundations of the belief that, firstly, value driver research, while still in its nascent stages of development, provides a robust and reliable means for valuation modeling; and secondly, they have empirical application, which is important for a wide section of users including venture capitalists, risk investors, government science and technology departments, research parks and, most importantly, investors in the new globalised knowledge economy.

7.2.6 Implications for Valuation

The focus of this study has been to address the complexities of valuation when applied to intellectual capital, and the actual valuation process, which provides the economic foundation for the creation of intellectual assets. As stated in Chapter 2, Literature Review, at a nascent stage of their development, intellectual assets are difficult, if not impossible, to value, mainly because their commercial viability cannot be accurately determined by traditional methodologies.

While the benefits of converting nascent technologies into commercial products and services can produce huge financial returns, if successful, the process itself is both complex and costly. Primarily, management must make continuous investments in intellectual capital because it is fundamental to survival against competition in the knowledge economy. However, given the riskiness of investments in knowledge, it is of paramount importance that investments must be optimal: that is, valued accurately to eliminate both sub-optimality.

Thus managers must primarily focus their decision making about investments, operations, and sources of financing on the creation of economic value for the company's shareholders. This is managed by making continuing investments in intellectual capital.

In terms of normal investment processes employed by firms, capital budgeting techniques, supplemented by payback analysis form the backbone of rational investment decision making. In the absence of historical cash flow figures which is often the hallmark of nascent technologies, the prediction of future values based purely on guesstimates often raise the riskiness of projects. This, in turn, incurs higher costs of capital, which often make projects too expensive. Thus, as Narayan (2001) points out, traditional valuation techniques based on accounting and economic models act decisively to deter investments in intellectual assets, hurting shareholder wealth-creating objectives of strategic management. While there are many interpretations as regards the word 'value', the basic approach underlying this thesis is that value is economic value, that is, the basic ability of invested capital to create shareholder value. Thus, if traditional valuation models are unable to meet the new paradigm of investments in the knowledge era, then it is imperative that a methodology should be developed. This is exactly what this thesis has achieved. The methodology, based on inherent underlying value drivers, applied by several researchers , and championed by Helfert (2000) has been able to formulate a model that is capable of calculating streams of future wealth to investors, firstly, reducing risks and uncertainties to managers and capital providers, and secondly, promoting and facilitating the investment decision processes. Furthermore, the models, developed upon a methodology which has included the rigours of qualitative and quantitative analysis, must afford a high degree of confidence to managers, investors and capital providers for use in critical decision making processes.

Furthermore, this study has been able to establish that different industries must be valued in accordance with their idiosyncratic value drivers. This has important implications of valuation. It clearly proves that standard valuation models such as accounting and discounted cash flow models which fail to differentiate between characteristic of values inherent in disparate different cannot be efficiently and confidently applied for rational investment decision-making processes. In section 7.2.4, the relative value drivers of the three industries have been tabulated, clearly proving that valuing biotech, infotech, and E&E industries must be carried out on the basis of their idiosyncratic value drivers.

This has another implication for management. In order to strategically manage value in their own firms, they must research and understand the value drivers in their own industries, before modeling them for valuation. This research provides the methodology for this onerous task.

Thus managers, investors and risk capital providers will now have a readily usable model for making crucial decisions about value in their own industries. Since economic value is very much a future-oriented concept, there is an inherent characteristic about predicting the future: risk. And in this risk lies the basic problem of valuation, and the basic opportunities to profit from it. And if it is assumed that value driver analysis of intellectual capital allows the identification of the firm's sources of value, then traditional valuation methodologies, based on predicting cash flows arising out of its assets, can be discarded. This, in turn, will enable managers to identify and systematically manage the firm's underlying value drivers, and establish its ability to earn a return on its capital in excess of the cost of capital, and one that exceeds that of its competitors.

7.2.7 Implications for Strategic Management

Contemporary literature clearly indicates that the importance of valuation as a strategic issue is being increasingly recognized by strategic level managers in the knowledge economy. Clearly, optimal investments in intellectual capital hold strategic implication for competitive advantage, shareholders' wealth maximization, profitability, and the overall health for firms.

Whether one views business strategy based on the 'competitive forces' perspective, or the resource based view of the firm, it is evident that in order to remain profitable in the knowledge economy, firms must create strategic advantage over their competitors by developing unique positions with their investments in, among others things, intellectual capital and capabilities. Innovations and scientific activities directed in developing these resources must therefore be viewed from a strategic standpoint, and firms must, in consequence of this recognition, make continuous investments in intellectual capital. Inherent in this view is the assumption that valuation of intellectual capital must be carried out with the greatest of accuracy in order to maximize the value of the firm.

Value based management has thus evolved as a critical focus for strategic management. Managing for maximizing shareholder value has become a key strategic objective for corporate managers. Many successful firms in the knowledge economy measure economic value creation for the company from a holistic viewpoint, and reward management teams accordingly. Thus, for strategy makers, understanding what drives value in their firms becomes imperative for creating shareholder value, and using reliable models to value intellectual capital become essential tools that attempt to quantify available objective data, in order to ensure that such investments in intellectual capital not only meet the pressures of competition, but are able to achieve returns in excess of their cost of capital. In this way, business strategy can provide wealth maximization to its shareholders.

Given the different value drivers identified in section 7.2.4, this would hold different implications for strategic management of firms. What clearly emerges that for firms operating in the Biotech industry, strategic management must ensure that products developed out of carefully channelled R&D programs are innovative enough to give firms a competitive advantage. Crucial in this is the need to pay attention to the educational qualifications, experience and outlook of senior managers who must be motivated to create value for shareholders.
Similarly, firms operating in the infotech industry must also ensure that senior managers are perceived of a sufficient quality to ensure that the knowledge creating processes are able to deliver products that can deliver market growth, which is seen to be a driver of value. Thus marketing managers in infotech firms must concentrate on market growth strategies in order to create the opportunities for profitability and value. However, strategic management must regulate investments in intellectual capital consistent with the economic environment of the nation, which promote value when conditions are good.

The implication for strategic management in the E&E industry is that research and development activities must be aimed at innovating products that that are proven to improve productivity of user firms. Thus, if firms are able to establish knowledge creating activities that allow firms to improve efficiencies in their operations, this will lead to market growth, profitability and wealth creation for stakeholders.

In summary, managing for shareholder value reaches beyond accounting reports: It requires an integrated set of management processes – a fusion of competitive strategy, investment analysis, valuation of investments in intellectual capital, and an understanding of the factors that create value which are idiosyncratic for the industry. Secondly, while the strategic challenge of shareholder value creation can be simply expressed - consistently exceeding the cost of capital in the performance of a firm's investment portfolio- the actual task of doing so is a very complex and vexatious process, but must include understanding the underlying value drivers that contribute to value. Finally, measures that gauge the degree of shareholder wealth creation are not always evident from financial reports, but increasingly knowledgeable investors are able to discern many indicators of value arising out of a wellspring of underlying value drivers in the firm.

7.2.8 Implications for Public Policy

In the foregoing Chapters, the point was made that with the emergence of the global economy, knowledge had become the major tool for firms to maintain competitiveness. The forces behind this new economic and social reality are the revolution in the creation of knowledge witnessed in industries such as biotechnology, information technology and energy and environment, among others. Goods and services have witnessed an exponential increase in knowledge intensity, as firms attempt to establish themselves in the global competitive hierarchy. Nations that are well placed to compete in the global economy would be characterized by a strong knowledge base, manifested by their ability to create and commercialise knowledge, the ability to produce competitive goods and services, and the ability to adjust to new technological and economic realities. In this new economic paradigm, a talented and skilled workforce, able not only to create knowledge, but to meet every challenge of managing firms in the knowledge economy, will determine a nation's economic success. This scenario demands two clear types of investments: continuing investments in creating knowledge, and continuous investments in commercializing that knowledge. However, the role of public policy is crucial in creating an atmosphere in which knowledge will be created and commercialized for a nation's economy to compete in effectively in a globalised economy.

In respect of the Biotech industry, public policy must promote and encourage the creation of knowledge that leads to products that are truly unique, and not just improvements to technologies that are currently available. Policy must also encourage the formation of high level management skills in the industry by encouraging universities to offer educational courses that leads to a steady supply of requisite skills to the industry. It may also hold implications for public policy on immigration which should be able to encourage the migration of management skills where shortages exist.

For the infotech industry, which has underpinned the opportunities of the 'global marketplace' public policy holds equally important implications. Primarily, the government must ensure the existence of factors in the general economy that promote investments in nascent information technologies. Growth prospects of the economy will encourage investments in the infotech industry, which, in turn, will make the industry profitable for shareholders and the nation alike. Further, public policy must also ensure that management skills are available for firms to optimize their research and development efforts, in order for their products to gain value from achieving market growth.

In respect of the E&E industry, the current awareness the global community of the importance of the ecology, environment, and energy to the wellbeing of society, must act as a guide to the formulation of public policy. It must promote the availability of specific management skills to the industry which should innovate and introduce products that increase productivity for user firms. It must legislate to induce changes in market structures that facilitate growth prospects for innovate products.

Whichever industry is considered, a proactive role of the government is critical in determining the economic wellbeing of a nation.

Given the intensity and magnitude of the social and economic changes in motion, the implications for public policy are clear:

- Building an intellectual capital structure for firms by which they will be able to accept, respond, and prosper in competition in a knowledge-based globalised economy. This will occur through facilitating infrastructure investments and financial incentives in creating knowledge. Nations such as Japan and the U.S. have made substantial gains over the past two decades in applying the benefits of science and technology to generate competitive commercial success. Public policy must put in place a continuous array of incentives for commercial development and exploitation of technology for the economic benefit of the nation. This is in recognition that to remain competitive in a global knowledge economy, it is essential to strengthen the development and commercialization of intellectual capital. One of the key ways to achieve this is through encouraging R & D, which must be supported by tax benefits in order to make it cost effective. Nevertheless, such benefits would be largely redundant unless firms were able to value their nascent technologies to ensure that scare resources found their way into channels that provided future windows of commercial viability.

- Furthermore, it would be necessary for public policy to nurture the creation and commercialization of knowledge in higher education systems. Since it is an established objective of universities to carry out activities consistent with the creation of fundamental and advanced knowledge, commercializing such knowledge should be seen to be a natural progression of research activities. La Trobe University's Research Park, which constituted part of this research, is an example of the cognizance of this policy.
- Providing adequate support through proactive programs to encourage an unimpeded flow of capital and resources to the creation and commercializing of knowledge. In this respect, various means are evident, in the form of grants to researchers, or the provision of risk capital to facilitate the creation of knowledge. But in every case, capital is forthcoming only on the basis that the value of the technology at the developmental phase can be predicted with some degree of certainty. In other words, the application of a reliable and accurate valuation model is essential to securing the necessary funding for the project(s).

Inherent in such support mechanisms is the assumptions that firms and universities are able to value their intellectual capital with accuracy and confidence, based on a model that is reliable and dependable, rather than on techniques and methodologies that were developed for a different nature of assets, in a different economic paradigm.

Thus valuation techniques and models have indisputable implications where public policy is concerned.

7.2.9 Implications for Equity Investment

Valuation of equity depends on several forms of security analysis. Technical analysis attempts to predict stock price movements on the basis of market indicators which include prior share price movements, transaction volumes, etc., while fundamental analysis attempts to evaluate the current market price relative to projections of the firm's future economic potential in terms of profits and cash flows, and includes business strategy analysis, accounting analysis, financial analysis, and prospective analysis related to forecasting and valuation. As discussed in Chapter 2, Literature Review, equity and business valuation of knowledge-intensive firms, made with a focus on financial reports have been supplemented in recent years by substantial amounts of non-financial data, because of the wide recognition among investors that published reports fail to project all relevant and necessary data to give a meaningful estimate of value. Thus, there has been an attempt to understand the underlying, pervasive factors that contribute to the value of equity, and integrate them in quantitative modelling (Palepu et. al 2000). These quantitative approaches have become quite varied as investors grapple with a wide variety of techniques to find one that gives them a reliable indication of equity values. Among them are statistical techniques such as regression analysis and logit analysis, which in concert with a given degree of market efficiency can yield generally satisfactory results of equity values.

Equity analysis attempts to evaluate the firm and its prospects from the perspective of a current or potential investor in the firm's stock, and includes combining individual securities into portfolios to maximize progress toward the investment objectives, which is to maximize wealth. Thus quantitative analysis based on factors which are not always reflected in financial statements (e.g., nascent technologies being developed by the firm) and which create value for investors, play a pivotal role in eliminating the overpricing of securities. More importantly it gives the strongest indications where wealth can be made, that is, where price is below the value of the security. But in order for this to occur, the quantitative modeling must incorporate underlying value drivers that are present and identified form one's analysis. Thus there is a clear implication that equity valuations in knowledge-based firms must include the ability to stay abreast of information in relation to underlying value drivers, and the ability to gather and interpret the kind of information which gives an indication of value.

In respect of Biotech firms, the need for correctly modeling the underlying values which determine the price of equities has been clearly demonstrated in recent years. The euphoria which accompanied the overestimated potential of biotech firms a decade ago witnessed dizzying price for their equities, which bore no relation to their true economic worth, nor their underlying value drivers. Deriving values from technical analyses was not possible simply because this industry was relatively new with no history of trading on the bourses. Establishing values based on fundamental analysis was impeded for much the same reasons. Thus prices were set which had no relationship to economic worth. Further, there were no mechanisms to feed information about the industry's underlying value drivers tabulated in section 7.2.5 to vary the equity prices. In such a situation, the emerging correction of a gradual long term decline in biotech equity values was inevitable, clearly proving that quantitative modeling based on underlying value drivers will probably eliminate the problems of overvaluation of biotech securities, and pave the way for rational investments in this critical sector.

The global euphoria in respect of knowledge based firms was not limited to biotech stocks. About a decade ago, infotech equities began clearly displaying irrational pricing tendencies. In the heady economic times of the middle 90's prices rose to extraordinary heights. In the vast majority of cases prices could not be proved to bear any relationship with underlying economic value. Fundamental analysis which showed rocketing P.E ratios, and plummeting D.Y ratios were ignored in the belief that the upward spiral of prices would continue. Inevitably, the corrections came, as witnessed by the collapse of the NASDAQ technology index, and with it the destruction of shareholder wealth.

Clearly, this research holds important implications for the infotech industry. Understanding and applying the models of valuation based on underlying value drivers will facilitate users to obtain accurate estimates of value, which will prevent the overpricing of securities and, importantly, allow the orderly and disciplined investment streams to be channelled into nascent infotech projects.

The E&E industry did not witness the global euphoria which accompanied both the biotech and infotech industries in the 90's. Nevertheless, value based modeling developed in this thesis is just as much important in this industry as for the others. Its continuing importance and role in the economic and social welfare of any nation is doubtless (Common 1998). Thus, it can be reasonably assumed that considerable wealth can be created from investments in nascent technologies in E&E. The implication that this thesis holds for equities in E&E is that value will be created for shareholders, risk-capital providers and entrepreneurs by modeling their investments on the underlying value drivers (section 7.2.5), preventing overvaluations and the destruction of scarce capital.

7.3 Conclusions

This section summarises the findings of this research, points out the limitations, and provides directions for future research.

7.3.1 Summary of Findings

This research sought to address a particular problem in valuation methodologies: formulating a model(s) to provide a basis of accuracy in valuing intellectual capital, to replace contemporary techniques which were appropriate for a different class of assets. It was believed that a generic model which could be used in all knowledge based industries would be difficult to estimate, since the theoretical basis of valuation used – pervasive underlying value drivers – could not be pervasively common in all industries. Thus three industries were selected for investigation, and the data was tested and compared empirically. The summary of the findings are as follows:

- There was the presence of pervasive underlying value drivers in each of the industries investigated, and this was consistent with the findings of similar research carried out by academics and consultants in other industries, as described in section 7.2.4.
- Each industry possessed some similarities, but the presence of idiosyncratic value drivers has required estimating individual models for each of the industries under investigation (Chapter 5 & 6, and section 7.2.5).
- Statistical analysis of the questionnaire survey supported the findings from the case study analysis, which provided the basis to estimate and test the logit models with empirical data (Chapter 5 & 6).
- The models for the biotech and infotech industries established a very good degreed of fit when tested against empirical data, but this was less evident for the En & Env .industry (Chapter 6).
- That value driver research has been proved to have both, a strong theoretical foundation as well as empirical support (Chapter 2 & 6).
- Thus, research could be extended to other industries, and models could be estimated consistent with their idiosyncratic underlying value drivers.

7.3.2 Limitations of Research

- The study was limited to three companies in the first phase of the study, and to three hundred firms in the second phase. By definition, this is a relatively small sample size, but the investigation was intended to be an exploratory pilot study of three industries only. In the circumstances, further research involving a much larger sample size would probably strengthen this branch of research
- This study addresses biotech value from the perspective of the organisation rather than the shareholders. The purpose of this study is to tease out the organisational value drivers and shareholders' interests are presumed to be represented by maximising value and maximising return. The situation of

information asymmetry and vagueness of early-stage innovation in new biotech firms gives the approach adopted in this research a degree of relevance in that it would be relatively more difficult for outside investors to fully appreciate the value aspects of the venture.

- The interactive influence of explanatory variables on biotech return may not have been fully understood and appreciated in this research such as the influence of each explanatory variable *A* on biotech return/explanatory variable *B* correlation. A more advanced study using "*partial correlation*" would provide a better insight into this aspect of the interactive relationships of the explanatory variables.

These limitations provide the opportunities for future research and improvement of the BVM.

7.3.3 Future Research

Since intellectual capital is central in importance to firms operating in the knowledge economy, future research should focus on valuations in every area of a firm's operations which underpin activities for knowledge creation. Not all aspects of intellectual capital has equal value, and the kind of nascent technologies which contribute to value depends on a range of underlying drivers that are, in a broad sense, idiosyncratic to individual industries, and in a narrow sense, unique to each firm. These idiosyncrasies and unique features present ample avenues for future valuation research.

Further, not all intellectual capital can be converted to profits, and future research could investigate how a value added framework is put in place by strategic intention by successful firms to understand, manage and create underlying value drivers, with the objective of maximizing value to shareholders. Such a framework would yield value by employing intellectual capital (unique capabilities) that competitors cannot imitate.

Valuations are as much important from a strategic management standpoint as it is from a financial management viewpoint, given that owners perceive a firm with its collective advantages as a vehicle for wealth maximization. Thus managers face a twin and challenging paradigm: creating a differentiated level of value for shareholders in the face of intense competition, and increasing globalization, which facilitates this competition. In this environment, intellectual capital provides the only means for managers to achieve their agency objectives. The implications for intellectual capital and its management are staggering. The situation suggests that intellectual capital is of such importance to wealth maximisation that firms must develop ways to nurture their ability to innovate and create value. While there is credibility in the proposition of Chaos Theory that the further one looks into the future, the more difficult it becomes to make predictions with accuracy, it could be argued, nevertheless, that using the forces of science and experiential factors, research in value driver research, with strategic implications for valuations of intellectual capital could make impressive contributions.

7.3.4 Conclusion

This research commenced with a vision: to extend the frontiers of knowledge in the complex and difficult environs of valuations; to contribute substantially to the horizons of valuation of intellectual capital in an economic paradigm that has shifted from one in which the dominant economic theory of diminishing return held sway, to the knowledge era, where investments in intellectual capital have the potential to achieve increasing returns. The implication for this is awe-inspiring as it opens up vistas of wealth creation that hitherto was unimaginable. Nevertheless, this rosy scenario must be tempered with several provisos, chief amongst them, that valuation of intellectual capital must be accurately determined in order to achieve returns in excess of the cost of capital, thereby maximizing shareholder wealth. Clearly, the question of the process and methodologies of valuation of intellectual capital assumes paramount importance. At the commencement of this investigative journey, the question was posed if valuation models, developed for a different economic era, were suitable for use in the knowledge age. In this, the concluding stage of the journey, it may be asserted with confidence, that given the results of this research, value driver valuation processes produce significantly better understandings of the worth of intellectual capital in the knowledge economy.

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Interview Script

Name of interviewee ______________________________

Name of organisation ______________________________

Location of Organisation ______________________________

Date/Time of Interview ____________________ Length of Interview __________

SECTION A – About the Company

1. What is the type of technology your company engaged in developing?

____

2. Which of the following clearly describes the industry in which your company operates?

Biotechnology ☐

Information Technology ☐

Energy and Environment ☐

Other ☐

3. Is your business connected to a specific area within the industry you nominated in question 2?

Yes ☐

No ☐

If you answered 'no' how would you describe the specific area within the industry that you operate in

____

____

4. What are your business objectives?

Sell the technology when it has reached the commercialisation stage ☐

Patent the technology ☐

Transfer the technology ☐

Commercialise the technology within your organisation ☐

Others ☐

____

____

SECTION B – Value Creators in Nascent Technologies

Please indicate the degree of importance of the following factors, which in your opinion, affect and create value in respect of the nascent technology/technologies you are developing.

1. The possibility of profiting from the good reputation of the user firm of the technology.

2. Reputation of the technology developer for defending its invention and for technology protection.

3. Manufacturing, management and marketing capability of the technology recipient.

4. Capital, marketing talent and other values invested by the technology recipient/licensor.

5. The ability of the technology recipient/licensee to significantly increase their profit margin by using this technology.

6. Ability of the technology recipient/licensee to roll out the products quickly.

7. The amount of the technology recipient/licensee's expected cost savings, risk savings, and other burden saving which follow using this technology.

8. The reputation of the firm developing the technology.

9. A lower risk of technological obsolescence.

10. Strategic alliances entered into with other firms to ensure the profitability of the technology.

11. The technology is a pioneering technology, not just a mere improvement.

12. With reference to question 3 in section A, this area of innovation would produce a higher differentiated value.

13. Non- reliance on the state of the economy and the effect of trade cycles.

14. A low possibility of the demand for the technology being depressed by unemployment, union attitudes etc. in the main markets for the technology.

15. The degree of economic and industrial development, the labour and capital availability and cost, etc. in the technology recipient's country.

16. Availability and cost of capital and labour.

17. With reference to question 4 in Section A, the costs associated with this option.

18. A low possibility of product liability suits.

19. The ability of the technology recipient/licensee to use clauses protective against product liability suits, particularly in connection with trademark licenses.

20. Low risks and costs of litigation in product liability suits.

21. Low financial and other risks arising from a failure to police patent infringements.

22. Proactive Government policies in respect of the technology being developed.

23. Lack of legal restrictions on the technology being developed.

24. Lack of ethical and environmental issues connected with the technology

25. The stage of the technology's technical and market development (commercially proven).

26. The intrinsic quality of the technology as a marketable quality, safe, stable technology.

27. The perceived utility by the buyer or user of the technology or its product, in terms of increased productivity.

28. The lack of ability of competitors to develop around the technology, or patent, or independently duplicate the secrets, in terms of the burdens of cost, time, quality, and risks of a legal, technological, environmental ethical nature.

29. Size of the total relevant market (local, national and international), and the licensee's likely share.

30. Low price sensitivity of the potential market for the technology.

31. Lack of intense competitive activity in the target market(s).

32. The potential of the technology to deliver differentiated products to the target segments, or deliver price and non-price competitive edge to the user of this technology.

33. The potential of the technology to allow technology recipient to achieve increased market reach.

34. High barriers to competitors developing the same or competitive technology by their own effort.

35. The scope and reliability of the protections of the technology, be it patent, trade secret, trademark, or copyright.

36. Low risk arising from non-protection of the technology.

37. The potential for achieving financial growth by the user adopting this technology.

38. The potential for export and/or export growth for adopters of this technology.

39. The availability of government or other grants for the adopters of this technology.

40. What other factors do you consider are important as value creators in respect of nascent technologies?

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SECTION C – Valuing Nascent Technologies

1. What valuation method do you use for valuing the technologies that you are developing?

   Formal ☐

   Informal ☐

2. If you use a formal method for valuing nascent technologies, what are these methods?

   Cost based method

   ____

   ____

3. Value based on expected revenue during the technology's life cycle

4. Value based on Discounted Cash Flow Projections

5. Value based on the Adjusted Present Value (APV) Method

6. Value based on Options Pricing Model(s)

7. Value based on any other traditional valuation model

8. If you do not use a formal valuation model, what valuation method, if any, do you use?

A. ______________________________

B. ______________________________

C. ______________________________

D. ______________________________

9. In respect of the technology(ies) you are developing, are there any other points that you would like to make?

(a) Regarding value creating factors in nascent technologies

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____

(b) Regarding valuing the techology(ies) you are developing

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Technology Valuation Questionnaire

Name of organisation (optional)______________________________

Location of Organisation___________________________________

SECTION A – About the Company

1. What is the type of technology your company engaged in developing?

____

2. Which of the following clearly describes the industry in which your company operates?

Biotechnology ☐

Information Technology ☐

Energy and Environment ☐

Other ☐

3. Is your business connected to a specific area within the industry you nominated in question 2?

Yes ☐

No ☐

If you answered 'no' how would you describe the specific area within the industry that you operate in?

____

____

4. What are your business objectives?

Sell the technology when it has reached the commercialisation stage ☐

Patent the technology ☐

Transfer the technology ☐

Commercialise the technology within your organisation ☐

Others ☐

____

____

SECTION B – Value Creators in Nascent Technologies

Please indicate the degree of importance of the following factors, which in your opinion, affect and create value in respect of the nascent technology/technologies you are developing.

1. **The possibility of profiting from the good reputation of the user firm of the technology.**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

2. **Reputation of the technology developer for defending its invention and for technology protection.**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

3. **Manufacturing, management and marketing capability of the technology recipient.**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

4. Capital, marketing talent and other values invested by the technology recipient/licensor.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

5. The ability of the technology recipient/licensee to significantly increase their profit margin by using this technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

6. Ability of the technology recipient/licensee to roll out the products quickly.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

7. The amount of the technology recipient/licensee's expected cost savings, risk savings, and other burden saving which follow using this technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

8. The reputation of the firm developing the technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

9. A lower risk of technological obsolescence.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

10. Strategic alliances entered into with other firms to ensure the profitability of the technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

11. The technology is a pioneering technology, not just a mere improvement.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

12. With reference to question 3 in section A, this area of innovation would produce a higher differentiated value.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

13. Non- reliance on the state of the economy and the effect of trade cycles.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

14. A low possibility of the demand for the technology being depressed by unemployment, union attitudes etc. in the main markets for the technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

15. The degree of economic and industrial development, the labour and capital availability and cost, etc. in the technology recipient's country.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

16. Availability and cost of capital and labour.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

17. With reference to question 4 in Section A, the costs associated with this option.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

18. A low possibility of product liability suits.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

19. The ability of the technology recipient/licensee to use clauses protective against product liability suits, particularly in connection with trademark licenses.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

20. Low risks and costs of litigation in product liability suits.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

21. Low financial and other risks arising from a failure to police patent infringements.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

22. Proactive Government policies in respect of the technology being developed.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

23. Lack of legal restrictions on the technology being developed.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

24. Lack of ethical and environmental issues connected with the technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

25. The stage of the technology's technical and market development (commercially proven).

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

26. The intrinsic quality of the technology as a marketable quality, safe, stable technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

27. The perceived utility by the buyer or user of the technology or its product, in terms of increased productivity.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

28. The lack of ability of competitors to develop around the technology, or patent, or independently duplicate the secrets, in terms of the burdens of cost, time, quality, and risks of a legal, technological, environmental ethical nature.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

29. Size of the total relevant market (local, national and international), and the licensee's likely share.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

30. Low price sensitivity of the potential market for the technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

31. Lack of intense competitive activity in the target market(s).

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

32. The potential of the technology to deliver differentiated products to the target segments, or deliver price and non-price competitive edge to the user of this technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

33. The potential of the technology to allow technology recipient to achieve increased market reach.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

34. High barriers to competitors developing the same or competitive technology by their own effort.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

35. The scope and reliability of the protections of the technology, be it patent, trade secret, trademark, or copyright.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

36. Low risk arising from non-protection of the technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

37. The potential for achieving financial growth by the user adopting this technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

38. The potential for export and/or export growth for adopters of this technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

39. The availability of government or other grants for the adopters of this technology.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5
☐	☐	☐	☐	☐

40. What other factors do you consider are important as value creators in respect of nascent technologies?

____

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____

SECTION C – Valuing Nascent Technologies

1. What valuation method do you use for valuing the technologies that you are developing?

   Formal ☐

   Informal ☐

2. If you use a formal method for valuing nascent technologies, what are these methods?

   Cost based method

   ____

   ____

   ____

   ____

3. Value based on expected revenue during the technology's life cycle.

   ____

   ____

   ____

   ____

4. Value based on Discounted Cash Flow Projections.

   ____

   ____

5. Value based on the Adjusted Present Value (APV) Method.

6. Value based on Options Pricing Model(s).

7. Value based on any other traditional valuation model.

8. If you do not use a formal valuation model, what valuation method, if any, do you use?

   A. ____

   B. ____

   C. ____

   D. ____

9. In respect of the technology(ies) you are developing, are there any other points that you would like to make?

   (a) Regarding value creating factors in nascent technologies.

   (b) Regarding valuing the techology(ies) you are developing.

Biotechnology:(4: strongly agree, 3:agree, 2: not sure 1: disagree, 0: strongly disagree)

Q1:	4	4	3	3	3	3	3	3	4	3	3
	4	3	3	3	3	3	3	3	3	4	4
	4	3	3	4	4	3	3	4	4		
Q2:	4	4	3	3	3	4	4	3	4	3	4
	4	3	3	3	3	3	3	3	3	4	4
	3	3	3	4	4	4	4	4	4		
Q3:	4	3	4	3	4	3	3	4	4	4	4
	4	3	4	4	2	3	4	4	4	4	3
	3	4	4	3	3	4	3	4	4		
Q4:	3	4	4	3	4	4	4	3	4	3	4
	3	3	3	3	3	3	4	3	3	3	4
	4	4	4	4	4	3	4	4	4		
Q5:	4	4	3	4	3	3	4	3	4	4	4
	2	3	3	4	3	4	3	3	4	3	4
	4	3	3	4	4	3	4	3	3		
Q6:	3	4	3	3	3	3	3	3	3	3	3
	3	3	4	3	4	3	4	4	3	3	4
	4	3	3	4	4	3	4	3	4		
Q7:	4	4	3	3	3	3	4	3	4	4	3
	3	4	3	3	3	4	3	3	4	3	4
	3	3	4	3	4	4	4	3	4		
Q8:	4	4	3	3	3	3	3	3	3	3	4
	4	3	4	4	3	3	4	4	3	4	4
	3	4	3	3	3	4	4	4	4		
Q9:	3	4	2	3	3	3	3	4	3	3	4
	3	3	3	3	4	4	3	3	3	3	3
	3	3	3	4	3	3	3	3	3		
Q10:	3	3	3	3	4	3	3	4	3	3	3
	3	3	4	4	4	4	3	3	3	3	3
	3	3	3	3	4	3	3	3	3		
Q11:	3	4	3	3	4	4	4	4	4	4	4
	3	3	4	3	3	3	4	3	4	4	3
	3	4	4	3	4	4	4	4	4		
Q12:	4	3	4	4	3	4	3	4	4	3	4
	4	3	4	2	3	3	3	4	3	3	4
	3	3	4	3	4	4	3	4	4		
Q13:	4	4	3	3	3	3	3	3	3	4	3
	3	4	3	3	3	3	4	3	3	3	3
	4	3	3	4	3	3	3	4	4		
Q14:	4	4	4	3	3	3	3	3	3	3	3
	2	3	3	2	3	4	3	4	3	3	3
	4	3	3	4	3	3	4	3	4		
Q15:	4	4	4	3	3	4	4	3	3	4	3
	3	4	4	2	4	3	4	4	4	4	3
	4	3	4	3	4	4	3	3	4		

Q16:	3	4	3	3	3	3	3	4	4	3	3
	3	3	3	3	3	3	4	4	4	3	3
	4	3	4	3	3	4	4	3	4		
Q17:	3	3	3	3	3	3	3	3	3	4	3
	3	4	3	3	3	4	3	3	3	3	3
	3	3	3	4	3	3	4	4	4		
Q18:	3	3	4	3	3	3	4	3	3	4	3
	3	3	4	4	3	3	3	4	3	3	3
	3	4	3	3	3	3	4	4	4		
Q19:	4	4	4	3	4	2	3	3	4	4	4
	4	3	4	4	3	4	4	3	3	3	3
	4	4	3	4	4	4	4	4	4		
Q20:	3	4	2	3	4	3	4	4	3	3	3
	3	4	3	4	3	4	4	3	4	4	4
	3	3	3	4	4	4	4	3	4		
Q21:	4	4	3	4	3	3	4	4	4	3	3
	3	3	3	1	3	4	3	3	3	3	4
	3	3	3	4	3	4	4	3	3		
Q22:	3	4	3	3	3	4	4	3	4	3	3
	3	4	4	3	3	4	3	3	3	4	4
	4	3	3	4	3	4	4	3	4		
Q23:	4	4	3	4	3	3	3	3	3	4	4
	2	3	3	1	3	4	3	4	4	4	4
	3	3	3	4	4	4	3	3	4		
Q24:	3	4	3	3	3	3	3	4	4	3	3
	3	4	4	4	4	4	4	3	4	3	4
	4	3	3	4	4	4	4	4	4		
Q25:	3	3	4	3	3	4	4	3	4	3	3
	3	3	2	4	3	4	3	3	3	3	4
	3	3	3	4	3	4	4	3	3		
Q26:	3	3	3	3	3	4	4	3	4	3	3
	3	4	3	2	3	3	3	3	3	3	4
	3	3	4	4	3	4	4	3	3		
Q27:	4	4	3	3	3	3	3	3	4	4	3
	3	3	3	4	3	3	4	3	3	4	4
	4	3	4	4	3	4	4	4	3		
Q28:	3	3	3	3	3	4	4	4	4	3	3
	4	3	3	4	3	3	4	4	4	3	4
	3	4	3	4	3	4	4	4	4		
Q29:	4	4	3	3	3	3	3	3	3	3	4
	3	3	3	4	3	3	3	3	3	3	3
	3	3	3	4	3	3	4	4	4		
Q30:	3	3	3	3	3	3	4	3	4	3	4
	3	3	3	3	3	3	3	3	3	4	2
	4	3	3	4	3	3	3	4	4		
Q31:	4	4	3	3	3	3	3	3	4	3	3
	3	3	3	3	3	3	3	3	4	4	4
	4	3	4	4	3	4	4	4	4		

Q32:	3	4	3	3	3	3	4	4	3	3	4
	4	3	4	4	3	3	3	4	3	3	4
	3	3	3	4	4	3	4	4	4		
Q33:	4	3	4	4	4	4	3	3	3	3	4
	3	4	4	3	4	4	4	3	3	3	2
	3	4	3	3	4	4	3	4	4		
Q34:	4	4	4	3	3	4	3	4	3	3	4
	4	4	3	3	4	4	4	3	3	3	3
	3	3	4	4	4	4	3	3	4		
Q35:	4	4	4	4	3	3	4	4	3	3	4
	4	4	3	3	3	3	3	3	4	3	2
	4	4	3	3	4	4	3	3	3		
Q36:	3	4	3	3	3	4	3	3	3	4	3
	3	4	4	3	3	4	4	3	4	4	3
	4	3	4	4	4	4	4	4	4		
Q37:	3	4	3	3	3	3	4	3	3	3	4
	3	3	4	3	3	3	4	4	3	3	2
	3	3	4	4	4	3	4	4	4		
Q38:	3	4	3	3	3	3	4	3	3	3	3
	3	3	3	3	3	3	3	4	3	3	4
	3	3	4	4	4	3	4	4	4		
Q39:	3	4	3	3	3	3	4	3	4	4	3
	3	3	3	3	3	3	4	3	4	3	4
	4	4	4	4	4	4	4	4	4		

The degree of agreement:
0.838709677419355487
0.870967741935483887
0.895161290322580633
0.887096774193548388
0.862903225806451622
0.838709677419354877
0.862903225806451622
0.870967741935483877
0.790322580645161255
0.806451612903225766
0.903225806451612888
0.870967741935483877
0.822580645161290377
0.806451612903225766
0.887096774193548388
0.838709677419354877
0.806451612903225766
0.830645161290322622
0.903225806451612888
0.870967741935483877
0.822580645161290377
0.862903225806451622
0.838709677419354877
0.895161290322580633

0.82258064516129037
0.81451612903225812
0.86290322580645162
0.87903225806451613
0.81451612903225812
0.80645161290322576
0.85483870967741937
0.86290322580645162
0.87096774193548387
0.87903225806451613
0.85483870967741937
0.88709677419354838
0.83870967741935487
0.83064516129032262
0.87903225806451613

Appendix 5.2 Information Technology Input Data

(4: strongly agree, 3:agree, 2: not sure 1: disagree, 0: strongly disagree)

Q1:	3	3	4	4	3	3	3	2	4	3	3
	4	4	3	4	3	4	3	3	4	2	3
	3	4	4	4	4	3	2	2	4	3	4
	4	3	2	4	3	4	3	3	4	4	
Q2:	3	3	4	3	4	3	1	2	3	3	3
	3	3	2	3	3	3	2	2	3	3	2
	3	3	3	3	4	4	3	2	4	3	4
	4	4	2	3	3	4	3	4	4	3	
Q3:	2	4	3	3	4	2	3	3	3	3	3
	2	3	2	3	3	2	3	3	2	3	3
	3	3	3	3	4	3	3	3	4	4	3
	3	3	3	4	4	4	3	3	4	3	
Q4:	2	4	3	3	3	4	4	3	3	4	3
	2	3	3	3	3	2	2	3	3	3	2
	3	4	3	3	3	3	4	3	3	3	4
	4	4	3	4	3	3	4	4	4	4	
Q5:	2	3	4	3	4	4	4	3	4	3	4
	4	4	4	3	4	4	4	4	4	3	4
	3	4	3	4	3	4	4	3	4	2	3
	3	3	3	3	3	3	3	3	3	4	
Q6:	4	2	4	3	3	4	3	4	3	2	4
	4	3	3	3	4	4	4	4	2	3	3
	4	3	3	2	3	2	3	4	3	3	2
	3	4	3	3	4	4	3	3	4	4	
Q7:	4	2	3	4	4	4	4	3	3	2	4
	4	4	4	2	3	3	4	3	4	3	2
	3	3	2	4	4	3	3	2	4	2	3
	4	4	3	3	3	3	4	4	3	2	
Q8:	4	2	3	4	3	4	4	3	4	3	3
	4	4	4	3	3	2	3	4	4	3	2
	2	3	2	3	3	3	3	3	3	4	4
	3	3	3	3	4	4	4	3	3	4	
Q9:	3	3	2	2	4	4	3	2	4	4	4
	3	4	3	4	2	4	4	3	4	3	4
	2	2	4	3	3	3	4	4	3	3	4
	4	3	3	4	3	3	3	4	4	4	
Q10:	4	2	3	3	3	3	3	1	4	3	
	4	4	4	4	3	4	3	4	3	3	3
	3	2	2	3	4	4	4	4	3	4	3
	3	3	2	3	3	4	3	4	3	3	
Q11:	4	3	2	3	4	3	3	3	4	3	3
	3	4	3	3	3	3	4	4	2	4	4
	3	2	1	4	3	4	4	4	4	3	4
	2	4	2	3	3	3	3	3	4	3	
Q12:	3	3	2	3	3	2	3	3	3	3	3
	4	3	3	3	4	2	2	3	4	4	4

	3	3	3	4	3	3	3	3	3	3	3
	4	3	3	4	4	3	4	4	3	2	
Q13:	3	3	3	4	4	3	2	3	4	3	3
	4	3	3	4	2	4	4	4	4	4	4
	4	3	4	4	3	3	4	4	4	3	3
	4	4	3	3	3	4	3	3	3	3	
Q14:	3	3	4	4	3	3	3	3	3	3	4
	3	4	4	4	3	3	4	3	4	4	4
	4	3	3	3	4	4	3	2	3	3	3
	3	3	3	3	4	4	3	3	3	4	
Q15:	2	2	4	3	3	3	2	4	3	3	3
	3	4	3	3	4	2	2	4	4	2	3
	4	4	3	3	3	4	3	4	4	3	4
	4	3	2	4	3	3	4	4	4	3	
Q16:	4	2	3	3	3	4	2	4	3	3	2
	3	3	4	3	3	3	3	4	4	3	4
	3	4	3	4	3	4	2	3	3	4	4
	4	4	2	3	3	4	3	4	3	4	
Q17:	2	3	3	4	4	2	3	3	4	4	4
	4	3	4	4	2	4	4	4	4	4	4
	4	4	3	2	3	4	4	4	4	3	3
	4	3	1	2	3	3	3	4	3	4	
Q18:	3	3	4	3	3	2	3	2	3	4	4
	3	4	3	4	2	4	3	4	2	2	3
	4	3	4	3	3	3	3	4	4	3	3
	3	3	2	3	4	4	3	3	3	3	
Q19:	4	2	3	2	3	2	3	2	3	3	3
	3	4	3	3	2	3	3	3	3	2	3
	3	3	4	3	3	3	4	3	4	3	4
	3	4	2	3	3	3	4	4	4	4	
Q20:	4	2	2	3	3	2	3	2	3	4	3
	3	3	2	4	3	2	3	4	3	4	3
	3	3	4	4	2	4	2	3	4	4	3
	3	3	2	3	4	3	3	3	3	3	
Q21:	4	3	4	3	4	2	1	2	4	4	4
	4	4	4	4	4	4	4	3	4	3	3
	3	4	3	4	3	4	4	4	3	4	4
	3	3	1	3	3	4	4	3	4	3	
Q22:	4	3	3	3	4	2	4	3	3	4	4
	3	4	4	4	4	3	4	2	4	4	4
	4	4	4	3	4	3	3	4	3	4	3
	3	4	3	3	3	3	3	4	3	4	
Q23:	4	3	3	4	4	2	2	3	4	3	4
	3	3	3	4	4	2	4	2	3	4	3
	3	3	4	3	3	3	3	3	4	3	4
	3	4	1	3	4	4	4	3	4	3	
Q24:	4	2	2	3	3	2	4	2	4	3	3
	4	2	4	4	3	2	3	2	3	4	3
	3	3	3	4	3	4	3	3	3	3	3
	4	3	1	3	3	4	3	4	3	4	

Q25:	4	2	4	3	4	2	4	3	4	4	4
	4	4	3	4	4	4	4	4	4	3	4
	4	3	2	3	3	4	4	4	3	4	3
	4	3	3	3	2	4	3	3	4	2	
Q26:	4	3	4	2	3	3	4	3	4	4	4
	4	4	3	4	3	3	4	4	3	2	4
	3	4	3	3	3	3	4	3	4	3	3
	4	4	3	3	3	3	3	3	4	3	
Q27:	4	3	4	4	4	4	2	4	3	3	3
	3	3	4	3	3	2	3	3	2	2	3
	3	3	3	3	4	3	4	3	3	4	4
	3	3	3	4	3	4	4	4	3	3	
Q28:	3	3	3	4	3	2	4	3	3	3	3
	3	2	3	4	4	2	3	2	4	3	3
	3	3	3	4	3	3	3	3	4	3	3
	3	4	2	3	3	3	3	3	4	4	
Q29:	3	3	3	4	3	4	4	4	4	3	4
	2	4	3	3	4	4	4	3	4	3	3
	4	3	4	4	3	4	4	3	4	3	3
	4	2	3	4	3	4	3	4	3	3	
Q30:	1	3	3	4	4	4	4	3	4	3	4
	3	2	3	4	3	4	3	4	3	3	4
	3	3	3	4	3	2	2	3	3	3	3
	3	3	1	4	3	2	3	3	4	4	
Q31:	2	3	4	4	4	4	1	3	4	3	4
	2	3	4	3	3	4	3	4	4	3	4
	3	3	3	3	4	3	1	4	4	4	3
	4	3	1	4	4	3	3	4	4	3	
Q32:	4	3	3	4	4	4	4	3	3	3	3
	3	2	3	4	3	3	3	3	4	3	3
	3	3	3	4	3	4	3	4	3	3	4
	4	4	3	4	3	4	4	3	2	4	
Q33:	2	3	3	4	4	4	2	3	4	4	4
	2	3	4	3	4	3	4	4	4	3	3
	3	4	3	2	3	2	4	4	4	3	3
	4	3	3	3	3	3	4	3	3	3	
Q34:	1	3	4	3	4	4	3	4	4	3	3
	2	3	3	4	3	4	4	3	3	3	4
	4	4	3	3	3	3	4	4	3	3	3
	4	3	1	3	3	3	3	4	4	4	
Q35:	3	3	3	3	4	3	4	2	4	3	3
	2	4	3	3	3	3	4	2	3	2	4
	4	3	3	2	4	4	4	3	4	4	3
	4	3	2	3	4	4	3	4	3	3	
Q36:	3	2	4	3	3	3	0	3	3	3	3
	3	4	4	3	3	3	4	4	4	1	3
	4	3	3	3	3	4	3	3	3	4	4
	4	3	2	3	3	4	4	3	4	4	
Q37:	4	3	2	4	3	3	3	3	4	3	4
	3	3	3	4	4	3	4	4	4	4	4

	3	2	4	3	3	1	2	4	4	3	4
	4	4	3	3	3	4	3	3	3	3	
Q38:	4	2	3	2	3	3	4	4	4	4	4
	3	3	3	3	3	4	4	4	4	1	3
	3	3	3	3	3	3	2	4	3	3	3
	4	3	3	4	3	3	3	3	3	4	
Q39:	4	2	3	1	1	2	2	3	4	3	3
	2	4	4	4	2	3	3	3	4	3	3
	3	3	4	4	4	3	3	3	4	3	3
	3	4	1	3	2	4	3	4	4	3	

The degree of agreement:
0.83139534883720934
0.76162790697674421
0.76744186046511631
0.80232558139534882
0.86046511627906974
0.81395348837209303
0.80813953488372092
0.81395348837209303
0.83139534883720934
0.80813953488372092
0.80232558139534882
0.78488372093023251
0.85465116279069764
0.83720930232558144
0.80813953488372092
0.81976744186046513
0.84302325581395354
0.79069767441860461
0.77325581395348841
0.76162790697674421
0.85465116279069764
0.86627906976744184
0.81395348837209303
0.77325581395348841
0.86046511627906974
0.84302325581395354
0.81395348837209303
0.77906976744186052
0.86046511627906974
0.78488372093023251
0.81976744186046513
0.83720930232558144
0.81976744186046513
0.81976744186046513
0.80813953488372092
0.79651162790697672
0.82558139534883723
0.80232558139534882
0.76162790697674421

Appendix 5.3 Energy & Environment Input Data

(4: strongly agree, 3:agree, 2: not sure 1: disagree, 0: strongly disagree)

Q1:	3	3	3	4	3	3	3	3	4	3	4
	3	3	4	4	4	3	4	3	4	4	3
Q2:	3	4	3	4	4	3	3	3	4	2	3
	4	3	4	4	4	3	4	3	4	3	2
Q3:	3	4	3	3	4	4	4	4	4	2	4
	4	4	4	4	4	4	4	4	3	3	3
Q4:	3	3	4	4	4	4	3	4	4	2	4
	4	3	4	3	4	4	4	4	4	3	4
Q5:	3	4	4	3	3	3	3	4	4	3	3
	4	3	3	4	4	4	2	4	3	4	3
Q6:	4	4	3	3	4	3	4	4	4	2	3
	4	3	4	3	4	3	3	4	3	4	3
Q7:	4	4	3	4	3	2	3	3	4	3	4
	4	3	4	4	4	4	4	4	4	4	4
Q8:	4	2	4	4	4	3	3	4	3	3	3
	4	3	4	4	4	4	4	3	3	4	4
Q9:	3	3	4	4	4	3	2	4	3	2	3
	3	4	3	4	3	3	3	3	3	3	3
Q10:	2	4	3	3	3	4	3	4	3	3	3
	4	4	3	3	3	3	3	3	3	4	3
Q11:	3	2	3	3	4	3	3	4	4	3	3
	3	3	4	3	4	4	4	3	3	3	3
Q12:	3	4	4	4	4	4	3	3	3	2	3
	3	4	4	3	3	3	4	3	4	4	3
Q13:	4	3	4	4	4	3	3	4	4	3	3
	3	3	4	4	3	3	3	4	4	4	3
Q14:	3	2	3	3	3	4	3	4	4	2	2
	2	3	4	4	4	3	4	3	3	4	4
Q15:	4	3	4	3	4	4	3	4	4	3	3
	4	4	4	4	4	4	4	4	4	4	3
Q16:	4	3	4	3	4	3	3	3	3	3	3
	3	4	4	4	4	4	4	3	3	3	4
Q17:	4	3	4	4	4	3	4	4	3	2	3
	4	3	4	4	4	4	3	3	3	4	4
Q18:	3	4	3	4	3	3	3	4	3	2	4
	3	3	4	4	4	3	3	3	3	4	4
Q19:	4	3	3	4	3	4	3	3	3	2	3
	3	4	4	4	4	4	4	3	4	3	3
Q20:	4	3	4	4	4	4	3	4	3	2	3
	3	4	4	4	4	2	4	4	3	3	4
Q21:	2	2	4	3	4	3	4	4	4	2	3
	3	3	4	4	4	4	4	4	3	4	3
Q22:	3	1	4	3	3	3	3	4	4	3	3
	4	3	3	4	3	4	4	3	3	4	4
Q23:	3	1	4	3	4	3	3	4	3	3	3
	2	3	4	3	4	4	4	4	4	3	4

Q24:	3	1	4	3	4	4	3	4	3	3	3
	4	4	4	4	4	4	3	4	3	4	4
Q25:	4	4	4	4	4	4	3	3	4	2	3
	4	3	4	4	4	3	4	4	3	4	3
Q26:	3	4	3	3	4	3	3	3	3	3	3
	4	4	4	4	4	3	3	3	3	4	3
Q27:	4	4	3	4	4	3	3	3	3	3	4
	3	4	4	4	4	3	4	4	4	3	4
Q28:	3	4	3	4	4	3	3	4	3	3	4
	4	4	4	3	4	3	4	4	3	4	3
Q29:	4	3	4	4	4	3	4	3	4	2	4
	4	3	4	4	3	4	4	3	3	4	3
Q30:	3	4	4	3	2	3	3	3	4	3	4
	2	3	3	4	4	4	4	3	3	3	4
Q31:	4	4	4	3	3	4	3	4	4	3	3
	2	3	4	4	2	3	4	3	4	4	2
Q32:	4	2	3	3	3	3	3	4	4	3	3
	2	4	4	3	4	3	4	4	4	3	3
Q33:	4	4	4	4	4	3	3	3	4	2	3
	4	3	4	3	3	3	3	3	3	4	3
Q34:	4	4	4	4	4	3	3	3	3	2	3
	4	3	3	4	3	3	4	4	3	4	3
Q35:	4	4	3	4	4	3	3	4	3	2	3
	3	3	4	3	3	4	4	4	3	4	3
Q36:	4	1	3	3	4	4	3	4	4	2	3
	0	3	4	3	4	3	4	3	4	3	4
Q37:	3	4	4	3	4	4	3	4	3	2	3
	3	4	4	4	3	3	4	3	4	4	3
Q38:	3	4	3	3	4	3	4	4	3	3	3
	4	4	4	4	3	4	4	4	4	4	3
Q39:	4	2	3	4	4	3	4	4	3	3	3
	3	4	4	4	3	4	4	4	4	4	4

The degree of agreement:
0.8522727272727272729
0.8409090909090909094
0.9090909090909090906
0.9090909090909090906
0.8522727272727272729
0.8636363636363636365
0.9090909090909090906
0.8863636363636363635
0.7954545454545454541
0.8068181818181818177
0.8181818181818181823
0.8522727272727272729
0.875
0.8068181818181818177
0.9318181818181818177
0.8636363636363636365

0.8863636363636363635
0.84090909090909094
0.8522727272727272729
0.875
0.8522727272727272729
0.82954545454545459
0.82954545454545459
0.875
0.89772727272727271
0.84090909090909094
0.89772727272727271
0.8863636363636363635
0.8863636363636363635
0.82954545454545459
0.84090909090909094
0.82954545454545459
0.84090909090909094
0.8522727272727272729
0.8522727272727272729
0.79545454545454541
0.86363636363636365
0.89772727272727271
0.89772727272727271

Appendix 5.4 Dependent/Independent Variables Scores

Biotechnology		Information		Energy	
Dependent variable	Independent variable	Dependent variable	Independent variable	Dependent variable	Independent variable
0.8387	6	0.8313	7	0.8522	0
0.8709	0	0.7616	N	0.8409	0
0.8951	7	0.7674	N	0.9090	9
0.8870	7	0.8023	0	0.9090	9
0.8629	0	0.8604	0	0.8522	0
0.8387	7	0.8139	0	0.8636	9
0.8629	N	0.8081	7	0.9090	9
0.8709	6	0.8139	7	0.8863	0
0.7903	N	0.8313	0	0.7954	0
0.8064	N	0.8081	0	0.8068	N
0.9032	9	0.8023	0	0.8181	0
0.8709	0	0.7848	0	0.8522	0
0.8225	0	0.8546	8	0.875	9
0.8064	0	0.8372	8	0.8068	N
0.8870	0	0.8081	8	0.9318	9
0.8387	0	0.8197	8	0.8636	9
0.8064	0	0.8430	7	0.8863	9
0.8306	N	0.7906	0	0.8409	0
0.9032	7	0.7732	0	0.8522	0
0.8709	7	0.7616	0	0.875	0
0.8225	7	0.8546	N	0.8522	0
0.8629	7	0.8662	N	0.8295	0
0.8387	7	0.8139	0	0.8295	0
0.8951	7	0.7732	0	0.875	0
0.8225	0	0.8604	9	0.8977	6
0.8145	0	0.8430	9	0.8409	6
0.8629	0	0.8139	0	0.8977	9
0.8790	9	0.7790	0	0.8863	0
0.8145	0	0.8604	9	0.8863	6
0.8064	0	0.7848	0	0.8295	0
0.8548	0	0.8197	9	0.8409	6
0.8629	6	0.8372	7	0.8295	6
0.8709	0	0.8197	9	0.8409	6
0.8790	0	0.8197	9	0.8522	6
0.8548	0	0.8081	0	0.8522	0
0.8870	7	0.7965	0	0.7954	0
0.8387	0	0.8255	0	0.8636	0
0.8306	0	0.8023	9	0.8977	6
0.8790	7	0.7616	0	0.8977	N

Appendix 6.1 Biotech Sector Summary Output

Biotechnology Sector

	Biotech Return	Patents	('000) Mgt. Qlfns.	MRP	(A$m) R&D Exp.
1992	12.40	2538	79	10.2	66.78
1993	19.84	3013	97	10.11	78.95
1994	16.15	2816	103	10.04	95.86
1995	30.31	2926	108	9.86	98.07
1996	29.43	3897	118	9.55	101.66
1997	30.25	5412	141	9.9	122.45
1998	25.32	7834	155	9.92	123.98
1999	15.68	7796	162	10.05	144.65
2000	11.70	7005	174	10.55	191.34
2001	9.38	7732	191	10.84	210.12
2002	5.09	7763	200	10.77	220.48

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9248
R Square	0.8552
Adjusted R Square	0.7587
Standard Error	4.4069
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Signif. F*
Regression	4	688.3347	172.0837	8.8610	0.0108
Residual	6	116.5221	19.4204		
Total	10	804.8569			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Low. 95%*	*Upp. 95%*	*Low. 95.0%*	*Upp. 95.0%*
Intercept	144.7994	102.8252	1.4082	0.2087	-106.81	396.40	-106.81	396.40
Patent issued	-0.0055	0.0036	-1.5150	0.1805	-0.01	0.00	-0.01	0.00
Mgt. qualifications	0.7465	0.5145	1.4510	0.1970	-0.51	2.01	-0.51	2.01
MRP	-15.0301	9.2803	-1.6196	0.1565	-37.74	7.68	-37.74	7.68
R&D Expenditure	-0.3607	0.3037	-1.1874	0.2799	-1.10	0.38	-1.10	0.38

Appendix 6.2 Infotech Sector Summary Output

Infotech

Year	Infotech return	('000) IT qualifications	(A$m) GDP	(A$m) IT spending	('000) Sector Exp.
1992	21.0%	22.00	2239	9619	64.545
1993	16.2%	28.00	2430	12414	65.546
1994	18.9%	34.00	2918	12415	139.632
1995	20.1%	40.00	3436	22317	127.634
1996	19.4%	45.00	3849	22318	131.25
1997	14.1%	51.20	4267	27270	142.45
1998	16.9%	57.00	5120	27709	140.66
1999	8.6%	51.00	4495	27711	152.34
2000	5.9%	48.00	5541	21498	161.26
2001	7.3%	40.00	5404	16500	173.88
2002	6.8%	35.50	5384	18415	178.35

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.86
R Square	0.73
Adjusted R Square	0.55
Standard Error	0.04
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.0251	0.0063	4.0783	0.0621
Residual	6	0.0092	0.0015		
Total	10	0.0343			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.25543218	0.0560	4.5588	0.0039	0.1183	0.3925	0.1183	0.3925
IT qualifications	0.00309980	0.0040	0.7731	0.4688	-0.0067	0.0129	-0.0067	0.0129
GDP	-0.00005284	0.0000	-2.2483	0.0656	-0.0001	0.0000	-0.0001	0.0000
IT spending	-0.00000121	0.0000	-0.2038	0.8452	0.0000	0.0000	0.0000	0.0000
Sector Exp.	-0.00000747	0.0007	-0.0108	0.9917	-0.0017	0.0017	-0.0017	0.0017

Infotech

Year	Infotech return	(A$m) GDP
1992	21.0%	2239
1993	16.2%	2430
1994	18.9%	2918
1995	20.1%	3436
1996	19.4%	3849
1997	14.1%	4267
1998	16.9%	5120
1999	8.6%	4495
2000	5.9%	5541
2001	7.3%	5404
2002	6.8%	5384

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.79
R Square	0.63
Adjusted R Square	0.59
Standard Error	0.04
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0217	0.0217	15.4503	0.0035
Residual	9	0.0126	0.0014		
Total	10	0.0343			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.29801483	0.0415	7.1855	0.0001	0.2042	0.3918	0.2042	0.3918
GDP	-0.00003827	0.0000	-3.9307	0.0035	-0.0001	0.0000	-0.0001	0.0000

Appendix 6.3 Energy and Environment Summary Output

Energy & Environment

Year	E&E return	('000) Mgt. qualifications
1992	7.40%	51
1993	7.80%	54
1994	11.40%	56
1995	9.00%	61
1996	9.50%	63
1997	9.30%	71
1998	10.40%	79
1999	7.20%	87
2000	8.00%	97
2001	7.80%	104.6
2002	8.38%	113

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.29
R Square	0.09
Adjusted R Square	-0.02
Standard Error	0.01
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0001	0.0001	0.8372	0.3840
Residual	9	0.0016	0.0002		
Total	10	0.0017			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.1010	0.0153	6.5936	0.0001	0.0663	0.1356	0.0663	0.1356
Mgt. qualifications	-0.0002	0.0002	-0.9150	0.3840	-0.0006	0.0003	-0.0006	0.0003

Year	E&E return	($Mil) R&D spending	('000) Mgt. qualifications	Productivity	R&D Effectiveness
1992	7.40%	37.22	51	0.068	0.2603
1993	7.80%	40.23	54	0.062	0.2894
1994	11.40%	46.34	56	0.065	0.3862
1995	9.00%	47.88	61	0.069	0.3990
1996	9.50%	55.68	63	0.047	0.3712
1997	9.30%	56.98	71	0.058	0.4417
1998	10.40%	53.74	79	0.046	0.3559
1999	7.20%	59.16	87	0.049	0.3867
2000	8.00%	53.64	97	0.043	0.4470
2001	7.80%	55.71	104.6	0.042	0.3979
2002	8.38%	57.64	113	0.041	0.4059

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.62
R Square	0.38
Adjusted R Square	-0.03
Standard Error	0.01
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	0.0007	0.0002	0.9307	0.5049
Residual	6	0.0011	0.0002		
Total	10	0.0017			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.1247	0.0995	1.2532	0.2568	-0.1188	0.3681	-0.1188	0.3681
R&D spending	-0.0002	0.0014	-0.1644	0.8748	-0.0037	0.0032	-0.0037	0.0032
Mgt. qualifications	-0.0007	0.0004	-1.5493	0.1723	-0.0017	0.0004	-0.0017	0.0004
Productivity	-0.6736	0.9767	-0.6896	0.5162	-3.0636	1.7164	-3.0636	1.7164
R&D Effectiveness	0.1629	0.1393	1.1692	0.2867	-0.1780	0.5038	-0.1780	0.5038

Appendix 6.4 Correlation Between Industries

	S&P/ASX200	Biotech	Infotech	E&E	1651	
1992	-6.15%	12.40	21.0%	7.40%	1550	-6.15%
1993	40.24%	19.84	16.2%	7.80%	2174	40.24%
1994	-12.00%	16.15	18.9%	11.40%	1913	-12.00%
1995	15.18%	30.31	20.1%	9.00%	2203	15.18%
1996	10.06%	29.43	19.4%	9.50%	2425	10.06%
1997	7.91%	30.25	14.1%	9.30%	2617	7.91%
1998	7.53%	25.32	16.9%	10.40%	2813	7.53%
1999	12.05%	15.68	8.6%	7.20%	3153	12.05%
2000	1.70%	11.70	5.9%	8.00%	3206	1.70%
2001	6.74%	9.38	7.3%	7.80%	3422	6.74%
2002	-12.13%	5.09	6.8%	8.38%	3007	-12.13%

	S&P/ASX200	*Biotech*	*Infotech*	*E&E*
S&P/ASX200	1			
Biotech	0.45453231	1		
Infotech	0.130080642	0.623926167	1	
E&E	-0.285764114	0.445388316	0.456461874	1