RECOGNISING SCIENTIFIC ENTREPRENEURSHIP IN NEW ZEALAND

by

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A thesis

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ABSTRACT

To increase wealth and well-being, New Zealand needs to both increase the productivity of its traditional economic base and grow new economic sectors in a competitive global marketplace. Innovation underpins both of these objectives and the combination of Research, Science and Technology (RS&T) and entrepreneurship has the potential to make a particularly potent contribution since it can create new, knowledge-based sectors with sustainable competitive advantage.

However, a review of the literature and documentary analysis of aspects of the New Zealand RS&T system shows that commercialisation tends to be based on mental models which conceptualise RS&T and entrepreneurship as separate realms and are more appropriate for existing economic sectors than for new ones.

The origins of these existing mental models are explained and they are critiqued from a human capital perspective. A subset of human capital theory is used to derive an alternative, competency-based model of *scientific entrepreneurship*.

The competency-based model is included in a methodological framework for interviewing key respondents engaged in the commercialisation of products and services arising from scientific research.

Using a grounded theory approach to analysis, an expanded *metacompetency* model of scientific entrepreneurship is developed and it is argued that adoption of this model will better enable recognition of scientific entrepreneurship, leading to its increased incidence and consequently higher levels of innovation in the New Zealand economy.

The implications of these findings for national innovation policy and the management of RS&T are discussed.

Conclusions are also drawn on the efficacy of the methodology used, both for the purposes of the current research and for other public policy questions. Finally, suggestions are made as to further avenues of research indicated by the findings.

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CHAPTER ONE:INTRODUCTION

1.1 Title

Recognising Scientific Entrepreneurship in New Zealand

1.2 The general problem to be addressed

1.2.1 *Strategic significance*

New Zealand is a small country in terms of its human population, but its land area is relatively large. Partly as a consequence of this mismatch, but also due to its temperate climate and historical factors, much of the country's economy is based on the primary production and export of goods derived from farming, horticulture, forestry and fishing. There are negative consequences of dependency on primary produce and to counter these various efforts have been made to diversify the economy, add value to exports and to be more innovative (Birks, 2001a). There are also exceptional sectors which have comparative advantage and are growing faster than average in fast growing world markets (Ballingnall & Briggs, 2002b). Overall however, the New Zealand economy shows low rates of productivity growth (OECD, 2003). The reasons for this low rate of growth are unclear and there is much speculation upon them, but the relatively small size of the economy and its distance from markets have been advanced as key factors (McMillan, 2004).

To achieve economic growth, it would seem logical to develop strategies which foster the growth of currently successful sectors and also aim to create new sectors which can grow in spite of New Zealand's geographical and other disadvantages.

Innovation and investment in Research, Science and Technology (RS&T) underpin both types of strategies.

Because most of the RS&T investment and performance in New Zealand is in the public sector there has been considerable policy attention paid to the role of publicly funded and performed RS&T in supporting innovation across the economy. As a consequence the RS&T system was considerably restructured in the 1990s, to focus more on the generation of socio-economic outcomes. It is a contention of this research that the restructuring was largely based on mental models which limit the potential for commercialising products and services arising out of scientific research.

In particular, chapter three sets out to show that the role of *human capital* in RS&T in New Zealand has received equivocal attention over the years. What policy work there has been on human capital has tended to focus more on quantitative measures of *stocks and flows* than on the increasingly important factor of *quality*. Furthermore, stocks and flows have been represented by traditional indicators such as qualifications or *codified knowledge* such as patents. While undoubtedly important (among other things, codification is essential for the creation of property rights required for commercialisation) these measures are not adequate for recognising the increasingly important *tacit knowledge* (Polanyi, 1967) and other attributes which underlie quality and are coming to assume greater significance within RS&T-based innovation. Section 3.4 shows that the focus on traditional, quantitative measurement has tended to be reprised at the operational level in research organisations.

One form of human capital comprising largely tacit attributes is expressed as *entrepreneurship*, a complex phenomenon which has a significant role in innovation, particularly in creating new economic activity where it has not previously existed

(Schumpeter, 1987; Workplace Productivity Working Group, 2004). Entrepreneurship is a potential source of diversification of the New Zealand economy.

Given that RS&T and entrepreneurship are key contributors to innovation, it might be assumed that a combination of these two factors would have an even greater impact, and it is this potential that adds relevance to research on *scientific entrepreneurship*¹. There is however a strongly prevailing view that because science and entrepreneurship exist in inherently different realms, their combination can occur only at a systemic level through means such as the assembly of teams of people with separate and mutually exclusive sets of attributes. It is in part this thinking that underpins a view of *technology transfer* wherein ideas are created by scientists and passed to others along a chain of increasing application and commercialisation. This approach is appropriate in some circumstances, but there is little allowance for the possibility that the desired attributes may be combined within the same individual(s) - *scientific entrepreneurs* - who can move with their scientific ideas into the marketplace.

The aim of this research is to find such people, and by better understanding them to build understanding of the wider process of scientific entrepreneurship. In turn, it is contended that the results of this study will underpin development of public policies and approaches to management to help increase the incidence of scientific entrepreneurship. The findings also have broader implications for understanding how to recognise and develop high-quality human capital for innovation.

¹ "Scientific" has been substituted for "RS&T-based" as it is less clumsy and in the sense used here, both the "R" and the "T" are included. That is, the term scientific entrepreneurship encompasses Research which is science based and has a strong connotation of applied science or Technology (see also the discussion in section 2.3)

While the focus and location of the research is in New Zealand and some of its implications are necessarily country-specific, the above points about the strategic importance of human capital, entrepreneurship and scientific entrepreneurship are equally applicable to other countries. From an academic point of view too, there is a gap to be filled, as discussed in the following section.

1.2.2 Academic significance

A number of special journal issues on the commercialisation of RS&T² touch on matters of human capital but leave key questions to be addressed (see section 2.8.2). More specifically, the concepts of scientific entrepreneurship or entrepreneurial scientists have not been commonly used in either the scientific literature or the entrepreneurship literature (Oliver, 2004: 584). The research reported on here seeks to help fill the gap through development of theory on scientific entrepreneurship. Its orientation is towards identifying implications for public policy and making a contribution to the research policy literature, although there are also findings reported on in chapter six that could be considered relevant to management theory.

The research adopts an overlapping human capital perspective, within which an even more unifying research framework is constructed using a competency-based approach. Chapter four describes how this research framework is designed and used in the research process. Indeed, chapter four opens up another stream of academic enquiry related to the efficacy of the selected methodology for addressing the research question and for generating findings that are of relevance in a public policy context. In this research as will be seen in section 1.4, chapter four and

² *Research Policy*. (May 2003). **32**(2); and (May 2004). **33**(4); *Entrepreneurship Theory and Practice*. (2007). **31**(6)

throughout, the methodology becomes entwined in the process to the extent that at times it takes centre stage and reflections on methodology are a key part of the conclusions to be found in section 6.5.

1.3 The research questions

Preliminary enquiries to locate respondents found few scientific entrepreneurs in New Zealand, defined as *individuals who have taken substantial and personal financial risk to commercialise a product or service based on scientific research, whether successfully or not*. These low numbers are not deemed surprising by those consulted in the research design process, and nor are they likely to be unique to New Zealand.

A question then arises as to *whether there are inherently low levels of scientific entrepreneurship within the population, or the levels are potentially higher but expression of the phenomenon is inhibited by some systemic failure*. If the former, better understanding of the underlying attributes of scientific entrepreneurship might help determine whether and what efforts might be made to promote their development³. If the latter, then it is presumed that the correction of systemic failures will lead to increased incidence of scientific entrepreneurship and consequently greater probability of RS&T-based innovation.

However, it is not possible to directly answer these higher order questions about levels of entrepreneurship, notwithstanding the development of a working definition of a scientific entrepreneur, without first being able to characterise scientific entrepreneurs and scientific entrepreneurship. The problem is, as shown in sections

³ Jenssen & Havnes (2002) go so far as to propose a formula for calculating the proportion of people in a population who become entrepreneurs.

2.7 and 2.8, that there is no consensus on these matters. There is no such thing as an average entrepreneur, let alone a scientific entrepreneur, and the entrepreneurial activities they engage in cover an extremely broad range. A key conclusion from the literature review (chapter two) is therefore that it is not productive for research to simply attempt to answer the question “what is scientific entrepreneurship”? Rather, an appropriate methodology is used to broaden the focus of the research and *to build understanding of the process by which scientific entrepreneurship is recognised*. This focus on the process of recognition is a way of generating a question that can be meaningfully researched and, as is explained in section 1.4 and section 4.7.4, also a way of operationalising the chosen methodology which is developed from a coherent ontological and epistemological base.

Recognition⁴ is taken to encompass a number of phases which may be iterative and *emergent* rather than the phases proceeding strictly in sequence. The research described in chapters four and five proceeds in a likewise manner in order to address the following research question, located in a particular national context:

How is scientific entrepreneurship recognised in New Zealand?

However, as already noted, the inclusion of a New Zealand focus does not mean that the research has no generalisable relevance to other countries, and more specific underlying questions which help to shape the research instrument used are:

- What is scientific entrepreneurship?
- What are the key attributes of scientific entrepreneurs?

⁴ Recognise: Identify a person or thing that is already known, know again; realise or discover the nature of; acknowledge the existence, validity, character or claims of; show appreciation or award; (followed by as, for) treat or acknowledge (New Zealand Oxford Dictionary 2005)

- What indicates the presence of those attributes?
- What means are used to detect the existence or non-existence of those attributes within the broader innovation system?
- What are the systemic responses to the presence or absence of scientific entrepreneurship?

These questions seek to simultaneously build understanding of both the phenomenon of scientific entrepreneurship and the process by which it is recognised. As will be seen, according to the precepts of the methodology, better understanding of one leads to better understanding of the other.

Figure 1.1 Relevance of research question

Later chapters show how scientific entrepreneurship operates at many levels from the individual scientific entrepreneur (even within-individual) to the wider innovation system, and there is interaction between all these levels. The methodology described in chapter four probes two main perspectives: firstly that of scientific entrepreneurs themselves; and secondly that of current policies and practices used within the New Zealand public sector to recognise and foster the attributes of entrepreneurship. Conclusions and recommendations are drawn in chapter six for

ways in which improved systemic performance might contribute to an increased incidence of scientific entrepreneurship in New Zealand, with consequential innovation outcomes⁵. But it must be stressed that the research focus is on a very small niche within the New Zealand national innovation system and does not pretend to evaluate system performance or to offer a magic solution to its problems.

1.4 Structure of the thesis

There are six major chapters including this one, which has introduced the research and reasons for it.

Literature review

Chapter two is a review of the literature on topics relevant to the research question, based on a logic described in section 2.1 and a framework with competencies as a core integrating concept (see figure 2.1). This core role of competencies runs like a backbone through the research methodology and the thesis as a whole, and there is a connection between figure 2.1 and other key figures (underlined below) which provides an underlying structure to the narrative.

Given the wider economic context, the beginning point of the literature review is a discussion of the key process and outcome of innovation. Within innovation, the nature and role of RS&T is then discussed, with particular reference to both traditional and alternative mental models of the relationship between science and its application. The concept of human capital is discussed in terms of economic theory, its role in the firm, and ways in which its content might be characterised and

⁵ In principle scientific entrepreneurs can be imported, or developed or “enabled” to perform domestically, or (more likely) drawn from a combination of these sources. Getting the right balance and matching of human capital to future needs are crucial challenges for public policy in a highly competitive, rapidly changing global marketplace for talent (Mahroum, S: 2001; NZ Treasury, 2001; Guellie & Cervantes 2002).

measured (or not). Competencies are a particular aspect of human capital and the literature on their origins and current status is reviewed, including international perspectives, research on their development and their potential pedagogical role in breaking down hierarchies and disciplinary boundaries (Reid, 2006). A key characteristic of competencies is that they exist only in a context, and there is a discussion of literature related to generic national and organisational context. Given the overall aims and focus of the research, the importance of the broader New Zealand public policy context is also recognised and a later chapter (three, see below) is devoted to its description.

The final two sections of chapter two focus on the literature related to the characteristics of entrepreneurship and entrepreneurs in relation to the chosen competency model (Boyatzis, 1982) figure 2.3. Then there is a drawing together of literature that is specifically relevant to the concept of scientific entrepreneurship so as to locate the competencies of scientific entrepreneurship and provide focus to the research (figure 2.6).

Public policy context

Chapter three places the research in a national economic context and clarifies the structure of the New Zealand science system and reforms that have taken place over the last two decades. Section 3.4 doubles as a report on one element of the overall research process, namely the analysis of a large number of policy documents and research organisation reports. This shows the shifting commitment to policies on human capital in RS&T policy over time, although there are signs that this situation may be changing in research organisations and across other parts of the more widely conceived innovation system.

Chapter four contains a comprehensive discussion of methodology and shows a close and coherent fit between the ontological and epistemological bases of the research and the research strategy and methods that are employed. The methodology, which is also potentially generalisable to other jurisdictions and research questions, is based on *critical realism* (Fleetwood & Ackroyd, 2004) and a strategy of *retroductive inquiry* (Downward & Mearman, 2007). A key element of retroduction is the use of *models* as *analytic frames* which help locate phenomena within whole, complex systems (as in the case of scientific entrepreneurship) and sensitise the researcher as to what to look for without predetermining what the investigation will find or conclude (Blaikie, 2000; Ragin, 1994). Indeed, a key feature of critical realism is that the nature of things emerges out of the things themselves, not from the way that researchers conceptualise them (Fleetwood & Ackroyd, 2004; Outhwaite, 1987).

In this case, the Boyatzis competency model is originally chosen because its layered structure allows for integration of all the levels of entrepreneurship, from deep personal traits and other attributes to visible behaviours to contextual elements such as organisational and national culture. The Boyatzis model also resonates with the layered critical realist ontology. However, the Boyatzis model has its limitations and it has thus been expanded to three dimensions, with both the horizontal and the longitudinal (time) dimensions added (see [figure 4.2](#)).

Understanding is developed through comparison of the unit of analysis which is the focus of the study (scientific entrepreneurs) and the expanded model within an overall research framework shown in [figure 4.3](#).

Method

As well as there being a close fit between critical realism and retroduction, the *Grounded Theory* of Glaser and Strauss (1967) and Strauss and Corbin (1998) is also very compatible and its precepts are used to gather samples and establish sample size. Accordingly 46 respondents are identified and interviewed and the transcripts of those interviews analysed using precepts of *constant comparative analysis* (ibid) and a software programme (NVivo) which is itself closely modelled on the application of grounded theory.

Chapter four also includes a discussion of the implications of my own position with respect to the research, for example the impact of my values and experience on the process. These are acknowledged and made explicit because in social research using the methodology described, there is an element of interpretation and *reflexivity* on the part of a *human-as-instrument* (Yvonna S Lincoln & Guba, 1985; D. Scott & Morrison, 2005). In general this thesis is written in the third person, but both at this point and in section 4.9 I offer a first person account. In summary, the role being occupied is that of *empathetic observer* (Blaikie, 2000) since there is a need to be able to understand the viewpoints of respondents while also aiming to achieve some degree of detachment and objectivity.

Findings and analysis

Chapter five contains a summary collation of the output of interviews held with the 46 respondents, analysed on the basis of themes coded and mapped onto the expanded competency model used as an organising framework. It is in this chapter that the voice of the participants comes through, although regrettably due to

considerations of space direct quotations are limited to a selection of the most illuminating and insightful.

Conclusions

Finally, chapter six draws conclusions from the research and describes their implications for innovation policy and management and outlines possible future research directions. Conclusions are also drawn from what has been learned about the efficacy of the methodology and suggestions made for further research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

There is a thread of connected outcomes and processes running through the rationale for this research, beginning with wealth creation that is underpinned by increased productivity. A way of achieving higher productivity is to innovate, and RS&T and entrepreneurship are two means (among others) of contributing to innovation. It might be assumed that these two separate factors would make an even greater contribution were they combined in some way, and indeed much public policy is aimed at achieving such a combination. However, as shown in section 2.3 and chapter three, RS&T and entrepreneurship are conventionally seen to occupy different realms and as a consequence, combining them is problematic. This research aims to explore the potential for alternative approaches to bringing them together.

The perceived separateness of RS&T and entrepreneurship, and the breadth of each of the two topics, present challenges for a review of relevant literature and the derivation of a focused research question. There needs to be some kind of unifying perspective and this is provided by literature on *human capital*, which can be seen to underpin both RS&T and entrepreneurship. But the human capital literature is also very broad, and does not in itself provide the basis for a research framework. Such a framework is however provided out of a subset of writings related to human capital – that to do with competencies.

The competency model that is identified in section 2.5 also provides a good fit with the research methodology described in chapter four. This is useful, since there have

been many limitations in approaches hitherto used to conduct research into entrepreneurship, as shown in the review of entrepreneurship literature (section 2.7).

There is also very little that is written about the particular subset of *scientific entrepreneurship*, but section 2.8 reviews some related literature and develops an academic rationale for this gap to be filled. Section 2.8 also develops further the idea of a competency-based framework for the research (developed further in chapter four) and there is recurring discussion how competencies might be *formed* since this is of relevance to conclusions drawn in chapter six.

In summary then, this chapter draws on the literatures related to Innovation, Entrepreneurship, RS&T, Human Capital and Competencies. Any one or a few of these could have been explored in greater depth and there are various component literatures such as Organisation Behaviour and Development, Leadership, Education, Child and Adolescent Development and the Philosophy of Knowledge. Herein lies a risk of being drawn too far into one of the literatures, with the loss of the breadth of perspective that will be shown to be essential. Conversely, too a broad an overview may be of insufficient depth to give confidence that real gaps in knowledge have been identified. However, the breadth of the review is of central importance in this research, since it maps out disparate but relevant areas of knowledge that are not always associated, then establishes connections and gaps between those areas in order to locate a new field of study and feed forward into the research design described in chapter four.

The structure of chapter two reflects the interrelationship of all the literatures reviewed, as represented by the stool metaphor shown in figure 2.1⁶. It is logical to describe the seat of the stool first of all, not least because it represents the overall desired outcome (innovation). The seat rests on the three legs of RS&T, entrepreneurship and human capital. A competency framework provides a reinforcing “backbone” and competencies (indeed the whole stool) exist within a number of contexts - hence there is a brief review of key concepts about context in section 2.6.

Figure 2.1 Structure of the literature review

⁶ Gilbertson and Gilbertson (1992b) also use the three legged stool metaphor to represent innovation. Their three legs are new product development, technology management and entrepreneurship, perhaps befitting their greater emphasis on firm-level processes

The stool metaphor not only represents the structure of the literature review, but provides the core of a structure for the whole following narrative. This structure is represented in a number of figures which are “nested” in each other as follows:

- Figure 2.1 (above - the stool model with competencies at the centre);
- Figure 2.3 (p 70 - the original Boyatzis competency model incorporating “horizontal” and “longitudinal” dimensions);
- Figure 2.6 (p 114 - the Venn diagram showing the location of competencies of scientific entrepreneurship);
- Figure 4.2 (p 194 - the extended competency model); and
- Figure 4.3 (p 198 - the high level research framework which links the competency model to the unit of study and to the methodology).

2.2 Innovation

2.2.1 *Economic theory*

A wide range of literature indicates that the wealth and well being of nations is largely (but not entirely) affected by their rate of economic growth (Healy & Côte, 2001; Workplace Productivity Working Group, 2004). There is also a considerable, long-standing consensus that in modern, globalised economies, economic growth is in turn largely driven by innovation⁷ because it increases productivity (Cyert, 1991; OECD, 2001). The causes of venture growth are complex and there are individual, organisational and environmental (contextual) domains to consider. Research needs to consider the web of complex relationships among these domains rather than studying their multiple, simultaneous effects (Baum, Locke, & Smith, 2001: 299).

Smith (2006: 3) identifies four significant “bodies of work” on the link between innovation and growth, three from different schools in economic history and one from the economics of growth, a field which is itself made up of four main approaches or theories. All of these four theories have concluded that technical change is the most important contributory factor, but there are strong differences between them, as summarised by David and Lopez (2001) and Smith (2006). The first theory of the four is the *neo-classical approach*, which is distinct in its focus on resource allocation, efficiency, the equilibrium properties of economic systems, and on physical capital accumulation as the drivers of economic growth. Smith (ibid) credits the work of

⁷ There are dissenting voices: Sheth (1981: 274) takes a contrary view to the notion that innovation is inherently good and is critical of this bias in literature, arguing that “the true innovators (the first 2-3 percent adopters) are more likely to be social deviants, abnormal in their epistemic drive, and adopt innovations indiscriminately rather than based on any rational choice calculus”. Sheth also advances other arguments against innovation e.g. negative social impact.

Solow (1957)⁸ and others for showing that there is a *residual factor* affecting economic growth which can not be ascribed to labour or capital inputs, and which has come to be attributed instead to technical change. This finding has led to considerable research on *growth accounting* for the impacts on growth of various separate factors - including technical change which is now seen as critical but still external (exogenous) to the economy. In this respect neo-classical theory differs from those that come later and hold that technology and innovation are produced within the economy or *endogenously* as follows:

Evolutionary models

The second of the four theories of economic growth is attributed to Joseph Schumpeter (1883-1950) who brings technological change to centre stage – indeed he attributes growth in capitalist economies to *creative destruction* wherein new technologies replace old, and to pervasive *carrier technologies* such as steam power, electricity, information and communications technologies (ICT) vehicles and so on.

Technology-gap models of growth

This theoretical approach compares countries at the boundary of technological change (e.g. the USA) and those who catch up by importing and diffusing technology (e.g. New Zealand). In both sorts of economies, for different reasons relating to their particular relationship to the boundary, investment in RS&T is of great importance. In New Zealand a national science capability is necessary to *spill in* research from overseas (Carnaby, Kelly, & Hill, 2006).

The differences between countries might also be explained in cultural or sociological terms, as does Weber (2002) who draws a link between capitalist behaviour and the

⁸ Solow, R. (1957). Technical change and the aggregate production function. *Review of Economics and Statistics*, **39**(3), 312-320

protestant ethos which is externally rather than internally focused and promotes the view that the purpose of life on earth (and the pathway to salvation) is work. Weber's model is not without criticism (Outhwaite, 1975) but cultural explanations in general are not easily dismissed (see section 2.6.2). Dunphy and Herbig (1994) list factors important in the adoption of innovation and their degree of cultural *boundedness* as an explanation of differences in innovative capabilities between countries. Watson (2005) finds it unsurprising that *pragmatism* should arise in America because:

The mechanical and materialistic doctrines of Hegel, Laplace, Malthus, Marx, Darwin and Spencer were essentially deterministic whereas for James and Dewey the universe - very much like America - was still in progress, still in the making, "a place where no conclusion is foregone and every problem is amenable to the exercise of what Dewey called 'intelligent action'" (Watson, 2005: 947)

Watson goes further in describing some key American thinkers and a particular view they had of ideas and how they might come about:

We can say that what these thinkers had in common was not a group of ideas, but a single idea - an idea about ideas. they all believed that ideas are not "out there" waiting to be discovered, but are tools - like forks and knives and microchips - that people devise to cope with the world in which they find themselves....And they believed that since ideas are provisional responses to particular and unreproducible circumstances, their survival depends not on their immutability but their adaptability (Watson, 2005: 934)

As will be seen, these points of Watson's echo some of the findings of the field research described in chapter five.

New growth theory

David and Lopez (2001) and Peters (2007) credit Romer⁹ as the principal initiator of the “new fashion” in growth theory which places considerable emphasis on a specific research sector generating new ideas and knowledge and *spill-overs* of knowledge through the economy. The *public good, non-rival, non-excludable* nature of knowledge (it can be simultaneously accessed by different parties without being privately owned or used up) mean that there is no limit to the increasing returns that can be achieved – the growth rate can be permanently raised by increasing the flow and use of knowledge.

2.2.2 Systems of innovation

The Organisation for Economic Cooperation and Development (OECD) appears to have drawn on all of the above history in theorising on the sources of growth, although one view is that new growth theory in particular became the underlying theory of the *knowledge economy* that was developed in the mid-1990s and also accepted by other development agencies such as the World Bank (Peters, 2007: 8). In any case the OECD has investigated innovation at great length and arrived at a simple definition for it:

The development, deployment and economic utilisation of new products, processes and services (OECD, 2001: 51)

Innovation is therefore both a process and an outcome. The OECD argues that:

By any number of measures, scientific advances, technological change, and innovation have become key drivers of economic performance. Some of the recent features of this

⁹ Romer, P. (1986). Increasing Returns and Long-Run Growth. *Journal of Political Economy* 94(5), 1002-1037

transformation are the growing impact of ICT on the economy and society; the increasing interactions between science and industry, leading to a more rapid development of new products and processes and a shift to more knowledge-intensive industries and services; faster technology diffusion; and rising skill requirements. The ability to harness the potential of new scientific and technical knowledge and to diffuse such knowledge widely has become a major source of competitive advantage, wealth creation and improvements in the quality of life (ibid)

Despite the clear linkages between innovation, productivity and growth, economic theory is not able to explain how innovation happens, and the more recent field of *innovation studies* has developed as a consequence:

Technology can be thought of broadly as the knowledge and learning necessary for new products and processes. Innovation is the commercialisation of product and process novelty. Innovation studies therefore focus on the structure and operations of learning, including science and Research and Development (R&D) as well as diverse non-R&D learning processes, and on the array of corporate activities involved in bringing innovations to the market (Smith, 2006: 13)

This view owes much to the *National Systems of Innovation* (NIS) approach where the ability to innovate is seen to be derived from a broad system that includes formal and non-formal education, business, research organisations, networks and other subsystems and ways of working. (Caputo, Cucchiella, Fratocchi, Pelagagge, & Scacchia, 2002; Dunphy & Herbig, 1994; Lundvall, 1998; Shekar, 2004; Whitley, 2002).

Tomlinson (2001a) identifies two different strands of work in the NIS literature. One, espoused particularly by authors from the United States, has tended to focus on the impact of national technology policies on firms' innovative behaviour, while the alternative:

Takes as its starting point the fact that important parts of the knowledge base are tacit¹⁰ and emanate from routine-based processes of learning-by-using and learning-by-interacting among firms. Correspondingly, the emphasis here is more on the efficacy of networks of firms and how they undertake innovative activity, than on formal activities related to the R&D system and the science base (ibid: 33)

Lundvall (1998) is a particular proponent of the NIS approach and criticises the neo-classical perspective on innovation with its emphasis on such things as rational choice (e.g. selection of R&D projects, allocation of R&D resources). Lundvall assumes instead that innovation is rooted in processes of interactive learning which do not thrive in pure markets. Thus the fundamental challenge in understanding innovation is

To understand what is happening to the creation, distribution and use of knowledge.... (and to this end)....there is a need for a broad multi-disciplinary, inter-disciplinary and cross-disciplinary effort where economists combine their efforts with sociologists and with experts in cognitive¹¹ sciences (ibid: 416)

Innovation springs from many sources. For example, two-thirds of OECD production and 70% of jobs are in services where innovation is less directly driven by R&D expenditure and is more dependent on acquired technology and the quality of human resources (OECD, 1999b). Service innovations remain a source of competitive advantage in the market for only short periods of time, because they are relatively easy to imitate and customers' needs and tastes are continually changing (Aranda & Molina-Fernandez, 2002). It is important therefore to recognise the difference

¹⁰ There is further discussion of tacit knowledge in section 2.4.3

¹¹ There are many approaches to the "cognitive sciences" and definitions of "cognition" (from the Latin cognoscere: "to know"). For the purposes of this review, and to maintain consistency with later discussion (see section 2.6.3) cognition (adj. cognitive) is defined as the process through which a system comes to know the outside world (Campbell-Hunt et al. 2001: 160). Cognition is distinguished from "affective" (emotional) and "conative" (motivational) domains (Miller, 1993).

between service-based innovation such as a new approach to retailing and science-based innovation leading to a new product, although these can be combined as with the Institute of Geological Science's use of GPS technology to create a guide to "Lord of the Rings" film sites¹². Service-based innovations are not the focus of this study but they remain contextually important.

Innovations can be either incremental or radical breakthroughs with the former more likely to arise from cumulative market-led improvements to existing products and services and the latter more likely to arise from scientists or *entrepreneurs* (Darroch & McNaughton, 2002; Durbin, 2004: iv; Jones-Evans, 1996). Investments which allow firms to identify and exploit RS&T build up what is called the *absorptive capacity* of firms. As innovation and absorptive capacity depend on past research and its foundations, such innovation is said to be *path dependent* (Carlaw, Devine, Pirich, & Tullett, 2003; Knuckey et al., 2002: 14).

Innovation is pervasive, occurring across all sectors, not simply in a group of high-tech, high-performing ones. What is different about low-technology sectors is that in terms of knowledge creation, they draw heavily on knowledge created outside the industry (Smith, 2006). This last point is a crucial one, as will be seen in later discussions of technology transfer in New Zealand (chapter three).

The OECD (2001) argues that a country's innovative capacity is more important to its economic growth - and to its ability to sustain growth over the long term - than is any particular technological breakthrough or industrial sector. Its view is that countries that experience the highest levels of growth are likely to be those that can most rapidly develop new products, processes and services based on these new

¹² <http://data.gns.cri.nz/shop/lotr/index.jsp>

technologies and apply them most efficiently to other sectors of the economy. Radical innovation by a few organisations, together with incremental technological and organisational innovation by an increasingly large number of firms, are essential to ensuring the sustainability of economic growth over the long term.

Incremental innovations meet immediate market needs and radical innovations lay the base for future wealth. There is a distinction between *yeast* and *mushroom* effects, where the former increase productivity relatively evenly across the economy, while factors such as a technological breakthrough or discovery suddenly mushroom to increase productivity more dramatically in some sectors than others (Harberger, 1998).

Consistent with the new growth theory approach OECD countries are placing an emphasis on developing and enhancing linkages between their knowledge production and the knowledge application systems. Common initiatives across a range of countries include centres of excellence, cooperative R&D centres, science and technology parks (Slaughter & Leslie, 1997: 56) incubators and other link programmes.

2.2.3 Firm-level innovation

The importance of innovation in the competitive success of firms has been widely canvassed in the management literature (Caputo, Cucchiella, Fratocchi, Pelagagge, & Scacchia, 2002). Chaston (1997) finds that successful small firms exhibit a proactive commitment to innovation as a means through which to sustain overall performance. However, it is not suggested that all growing firms are innovative or that all innovative firms are entrepreneurial. Nor, as with national systems, do all innovative or entrepreneurial firms derive their innovativeness from RS&T.

Radical innovations can enhance competencies¹³ or they can be competency destroying (Darroch & McNaughton, 2002; Gatignon, L.Tushman, Smith, & Anderson, 2002) which may be why they are less likely to be taken up by existing firms than by start-ups (Shane, 2004).

Depending on the type and style of innovation then, different competencies, management approaches and policies are required. McGrath and MacMillan (1995) contrast *platform planning* which is an extrapolation of an existing business, with a lot of known facts and few assumptions, and *discovery driven planning* which is the opposite, and more suitable for brand new ventures into the unknown. In a similar vein although using the term discovery in the opposite sense, Barney (2004) describes two types of entrepreneurship in the modern economy: *discovery* which is more systematic, orthodox and algorithmic (e.g. using Net Present Value calculations) and *creation* based on emergence, path dependence, learning over time and heuristics.

Barney (ibid) also identifies two types of government policies that might be chosen to favour one or both of the two types of entrepreneurship. *Industry picking* favours discovery (in his terms) by identifying specific industry or industry segments and providing incentives to invest. Alternatively, *setting the entrepreneurial context* favours both discovery and creation and consists of taxes on capital gains, bankruptcy laws, trade policy, free trade zones, technology centres, protection of property rights, and infrastructure development including education, transportation, life quality. Barney seems to overlook the NIS option espoused by Lundvall and discussed above.

¹³ Competencies are defined and discussed in detail in section 2.5

Breakthrough inventions are:

Contributed disproportionately by smaller independent entrepreneurs, while cumulative, incremental improvements are undertaken by larger firms with substantial R&D activities (Durbin, 2004: 38)

This does not mean that larger and older firms are not particularly innovative – indeed Grimes (2004) finds that it is these firms which have the scale to be innovative across a number of fronts on a consistent basis; large, old firms provide the ongoing engine of innovation and economic growth; while medium-sized young firms provide the spark of the new entrepreneur. If success continues for the latter group, they will eventually evolve into the former; if not, they may disappear. Both groups are crucial components of a dynamic growing economy.

In times of rapid technological progress, the *churning* process, whereby entrepreneurs quickly and easily enter and exit the market, is important for realising product and process innovation, and for driving higher productivity (OECD, 2001: 75). However, churn may not be healthy and there is a commonly-recurring tension here between the proponents of entrepreneurship as the engine of innovation and those who maintain that:

Firm survival is key and that professionals, rather than entrepreneurs, are more significant for sustained growth and economic performance. While entrepreneurs may be important in the early phases of growth and can “kick-start” the process, skilled professionals with high levels of education and training may be needed to implement and extend technological progress (ibid)

On the other hand the OECD also points out that high survival rates might point to high entry and/or exit barriers rather than good economic performance. The

cumulative nature of innovation capabilities may have the detrimental effect of *locking in* particular practices, leading to an inability to “move away from technologies that are in some sense less adequate than alternatives” (Smith, 2006: 16). Schumpeter writes of the stifling or assimilation of entrepreneurs by *rational* innovation where “innovation itself is being reduced to routine” (Schumpeter, 1987: 131-4). Lundvall (1998) suggests that once a dominating institutional pattern has become established, it tends to attract those industries most compatible with it and most search activities will be oriented toward problems emanating from the existing set of economic activities.

Innovation is closely linked to risk (Berglund & Hellstrom, 2001). Pursuit of radical innovation is particularly risky, and such a strategy may therefore suit a large system which is able to spread risk over a whole suite of products and technologies. The risks for an entrepreneur with a single innovation are qualitatively different, and small, innovative firms may suddenly find themselves the market leader, creating unexpected stresses in management (Department of Trade and Industry, 1998).

Durbin cites the OECD’s prescription for promoting economic growth through increasing product market competition so as to provide more scope for risk takers to explore new business opportunities, and stimulates the process of creative destruction (firm entry/exit). Here innovation is the primary means whereby rivals maintain their market share (Durbin, 2004).

Clusters of firms in close proximity can facilitate system-wide innovation. Silicon Valley in California is often cited as a case where successful innovation occurs because of clustering (Graham, 2006; Healy & Côte, 2001; Weston, 2004b). Mobility of skilled people is also important and this factor is discussed in more detail in

section 2.4.4. However, a dissenting voice on clusters finds that intra-firm cooperation is superior to inter-firm (Simonen & McCann, undated: 17).

The next section moves from a broad consideration of innovation at the level of national systems and firms to a key contributing factor: RS&T - and begins the process of narrowing down the scope of the research to a focus on scientific entrepreneurship.

2.3 Research, Science and Technology

2.3.1 Introduction

Innovation may derive from many different sources, but RS&T is seen as having particular importance from the point of view of national systems. The following review of relevant literature describing the nature of RS&T is of necessity a limited one because the history and philosophy of science alone are as old and as broad as humankind, even before one delves into approaches to research (of which there is some discussion in chapter four on methodology) and the nature of technology. All of these areas are controversial. Even the common use of the singular abbreviation (RS&T) to describe three components begs questions about their relationship to each other – for example are the three distinct and if so is there implied a linear progression from research (a process) to science (a body of knowledge) and technology (application)? Alternatively, research is often described in terms of its outputs and science, or at least scientific method, as a process that encompasses all three elements. Technology can also be seen as the embodiment of research and scientific knowledge. Research is often coupled with Development (R&D) which implies progression towards the creation of a technology that may be commercialised. The distinctions between research, science and technology are

increasingly blurred. The terms RS&T, S&T, R&D and science are often used interchangeably and this is the case in the literature that is reviewed here. Before going further to discuss models of RS&T however, it is first necessary to consider some of the literature on mental models in general.

2.3.2 *Mental models, paradigms and conventional wisdom*

The concept of *mental models* is developed and explained in depth by Johnson-Laird (1983). In this view, people do not perceive the world directly, but rather:

Our view of the world is causally dependent both on the way the world is and on the way we are. There is an obvious but important corollary: all our knowledge of the world depends on our ability to construct models of it (ibid: 402)

What is more, mental models are a basis for action:

They enable individuals to make inferences and predictions, to understand phenomena, to decide what action to take and to control its execution, and above all to experience events by proxy; they allow language to be used to create representations comparable to those deriving from direct acquaintance with the world; and they relate words to the world by way of conception and perception (ibid: 397)

According to Johnson-Laird, mental models can be of abstract phenomena as well as the “real world”. For example, social transactions only make sense in a conceptual world of social conventions which are created or acquired. When we talk about those conventions, our descriptions draw on the repository of knowledge that lies behind the models of discourse that we construct (ibid: 415-9). A mental model persists as long as it provides an explanation of the world - once it fails to do so it can be replaced by another.

The theory of mental models remains highly controversial. It has attracted admirers and critics in roughly equal numbers, and some of the criticisms have been vigorous if not downright hostile (Jonathan St., 1996: 321). However, the concept resonates with the writing of Gonczi (2002; see section 2.5.1) the notion of *structure determinism* (Campbell-Hunt et al., 2001; see section 2.6.3) and the *paradigm* enunciated by Kuhn (1996) in his description of the structure of scientific revolutions and how they come about.

Kuhn's theory was first formulated in 1962 and he foreshadows Laird-Johnson's mental models in describing an experiment with playing cards in which participants see a red spade as a black spade until they become aware of the anomaly. It is the perception of *anomaly*, or a phenomenon for which the paradigm has not readied the investigator, which creates the perception that something has gone wrong and provides the prelude for new discovery, and ultimately a change of paradigm. Thus the old paradigm is not necessarily to be denigrated, since it allows the degree of specialisation necessary and the backdrop against which anomalies can be perceived (ibid: 57, 64-5) often through a process of *serendipity* in which the scientist is prepared to make sense of a truer picture of the world.

Serendipity may be *courted* through the marriage of planned insight to unplanned events (Fine & Deegan, 1996). This may also involve "modelling the unfamiliar on the familiar" (Schön, 1983: 186).

Those who achieve the fundamental inventions of a new paradigm tend to be either very young or very new to the field whose paradigm they change, since they are not committed to traditional rules, are likely to see that those rules are no longer able to

“define a playable game” and are able to conceive a replacement set (Kuhn, 1996: 90).

Kuhn thinks that paradigm change is mainly relevant to the physical and natural sciences although he does allow that the same process might occur in the social sciences (ibid: 21). Mental models and dominant paradigms have a sociological dimension (see section 2.3.6) as implied by Galbraith (1969) when he writes from the field of economics about what constitutes *conventional wisdom*:

We adhere, as though to a raft, to those ideas which represent our understanding. This is a prime manifestation of vested interest. For a vested interest in understanding is more preciously guarded than any other treasure. It is why men react, not infrequently with something akin to religious passion, to the defense of what they have so laboriously learned. Familiarity may breed contempt in some areas of human behaviour, but in the field of social ideas it is the touchstone of acceptability.

Because familiarity is such an important test of acceptability, the acceptable ideas have great stability. They are highly predictable. It will be convenient to have a name for the ideas which are esteemed at any time for their acceptability, and it should be a term that emphasise this predictability. I shall refer to these ideas henceforth as the conventional wisdom (ibid: 7)

Schön (1983) also writes about *professions* which may include scientists and describes how professionals frame their roles and act from them, seeking to defend their own positions and attack the positions of their opponents. Different disciplines have their own way of viewing the world and teach distinct, discipline-specific vocabularies (Davies & Devlin, 2007: 10). Attempts to change are often de-railed by the intrusion of familiar, patterned responses - “the technique of the intricate defensive” (Snow, 1963: 67) or “automatic intercepts” (Schön, 1983: 312, 321) which cement in performance according to familiar routines:

The sources of dogma in science....are to be found in social organisation rather than in its metatheory (Outhwaite, 1987: 35)

Similarly, the concept of *bounded rationality* leads individuals to engage in *satisficing behaviour* wherein the inherent limitations on decision-making encourage people to behave according to well-established routines, patterns and rules, to seek predictability and certainty in organised or structured environments, and to be highly selective in the range of information upon which they draw in making choices. As the complexity and uncertainty of a situation increases, the greater the limits imposed on individuals by their bounded rationality (Boston, Martin, Pallot, & Walsh, 1996: 20).

2.3.3 *The linear model of RS&T*

The origins of the *linear model* for RS&T in modern times are often attributed to Vannevar Bush, who was Director of the US Office of Scientific Research and Development during the Second World War. Bush was charged by President Roosevelt with recommending ways to extend to the post-war world the extraordinary gains made by science in wartime. Bush makes a distinction between basic research performed without thought of practical ends, and applied research which solves practical problems. He sees basic research as providing scientific capital which is drawn upon to ultimately generate new products and processes. The connection with applied research is a “numbers game”, where the more investment there is in basic research the more likely there is to be a useful, practical outcome (Bush, 1945).

The identification of a significant gap between “pure” and “applied” science might also be attributed to Snow (1960) although he acknowledges that:

This complex dialectic between pure and applied science is one of the deepest problems in scientific history (Snow, 1963: 68)

But Bush is further accused of advancing a view that basic and applied research cannot co-exist:

Applied research invariably drives out pure if the two are mixed (Stokes, 1997: 3)

This quotation attributed to Bush cannot be found in his report (Bush, 1945) but having set up his straw man Stokes knocks it down and proposes an alternative model, including research in *Pasteur's Quadrant* that is driven by *consideration of use* rather than knowledge for its own sake (Bohr's Quadrant); or application without knowledge (Edison's Quadrant) – see figure 2.2. Yet according to Etzkowitz (1998: 826) even Pasteur did not believe in crossing the boundary between science and business.

Figure 2.2 Quadrant model of scientific research (Stokes, 1997: 73)

Research is inspired by:

		Considerations of use?	
		No	Yes
Quest for fundamental understanding?	Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
	No		Pure applied research (Edison)

Stokes describes the systemic consequences of the respective models of understanding: one that recognises Pasteur's Quadrant:

The experience of a number of scientific fields supports the view that scientists involved in fundamental use-inspired research will play a role in the technological return from the resulting knowledge, enhancing the likelihood that the nation investing in the basic science will share in the technological return (Stokes, 1997: 105);

and one based on the separation of basic and applied research:

Whatever its surface logic, however, this arrangement loses the creative insight of the bench scientist in helping to define societal need. It also runs the risk of creating a bifurcated funding system with substantial conflict between those who are asked to judge scientific promise and those who are asked to judge social value (Stokes, 1997: 116)

Just as all innovation does not derive from RS&T, Stokes (1997) points out as does Ziman (1984) that not all technological innovation is rooted in science. A great deal has originated from a reverse flow, from technology which preceded and often informed the development of scientific theory – for example the engineering of the steam engine which anticipated the science of thermodynamics (Stokes, 1997: 19-21; Ziman, 1984: 116-7)¹⁴. In the modern day, there are similar examples in transistors/semiconductors, superconductivity and genetic engineering:

(t)he acceptance of dualisms such as patents vs publication and basic vs applied research goals were the surface expressions of a theory of knowledge based on an underlying dichotomy that placed scientific advance, i.e. development of theory, in opposition to technological advance. In an apparently growing number of scientific fields, this dualism is no longer a valid picture of what happens (Etzkowitz, 1998: 827)

Schön (1983) and Stokes (Stokes, 1997: 37-34) both describe how the separation of technology and pure science was institutionalised in 19th Century German research institutes and Universities, upon which American Universities were later modeled. Among the consequences of this separation is:

A hierarchy in which “general principles” occupy the highest level and “concrete problem solving” the lowest....the researcher’s role is distinct from, and usually considered superior to, the role of the practitioner (Schön, 1983: 24, 26)

This hierarchy flowed into systems of education and perpetuated the perception of gaps between thinking and action (Gilbert, 2005: 160).

¹⁴ On the other hand, Ziman (1984: 166-7) also points out that the development of nuclear technology proceeded from science, with little consideration, on the part of some researchers, of the use to which it was to be put

But German industry was progressive in many respects. Ziman (1984: 127) notes that in the 1860s, German dyestuffs manufacturers set up their own company laboratories, staffed by fully qualified academic scientists employed to carry out research that would lead to the development of new products and processes. A parallel development also took place in various government agencies. These non-academic enterprises gave rise to an alternative sociology of science, with different incentives and rewards for the individual. Nevertheless:

In spite of the radical transformation of the social relations of science and technology in the past few decades, a distinction between “pure” and “applied” science still lingers on....(a)s the epithet “pure” suggests, this distinction is essentially ideological...(which is) no longer a valid distinction in the collectivised R&D system of today. The institutional forms, the internal sociology and the societal relations of the elements of this system can no longer be classified by their positions along the traditional axis from pure science to its applications....but even when the research is essentially “applied”, and the institutional framework is essentially “industrial”....epistemologically speaking, all S&T takes its cues from academic science, and is therefore steeped in its role models, its ethos and its institutional traditions. That is why we keep coming back to the internal sociology of this form of science in all our efforts to understand science and technology in their social context (Ziman, 1984: 129-30)

The sociology referred to by Ziman may be changing. Latterly, large surveys of scientists have concluded that the distinctions between basic and applied research are no longer central:

Basic and applied were as likely to describe levels of prestige and sources of funding as they were a fundamental distinction between two types of research....historians and sociologists of science are beginning to consider basic science as a social and economic construct through which university-based scientists have claimed autonomy and resources (Slaughter & Leslie, 1997: 179, 181)

There is further discussion of the sociology of science in section 2.3.6, but in general it can be seen that there are a number of questions that might be asked of conventional models of the relationships between science and its application. These questions are taken further in the next section.

2.3.4 Technology transfer

Mental models which hold scientific research and its application to be distinct activities naturally underpin a linear process of research producing academic knowledge which is then turned into intellectual property (IP) and transferred into the commercial market (Evans, Kersh, & Sakamoto, 2004: 223; Slaughter & Leslie, 1997: 141). The foregoing discussion would suggest this conception of technology transfer is beset with three major problems. One is the perception of a disjoint between basic and applied research which several writers dispute. Secondly, the relationship between research, science and technology is not unidirectional. Historically, progression has also been in the opposite direction. Thirdly, the interaction between the three elements is not linear - it is far more complex and messy than that. Johnson et al. (2002) also argue that the dichotomy between codifiable and non-codifiable knowledge is problematic since it is rare that a body of knowledge can be completely transformed into codified form without losing some of its original characteristics.

Nevertheless the linear model is convenient to use, particularly for the purposes of making policy, and there is still a considerable literature and no little effort dedicated to overcoming its conceptual and practical problems. As will be seen below, there is probably more focus on making the model work than on finding a new one altogether, although Stokes (1997) has tried and Kline and Rosenberg (1986) have developed

the *chain linked* model which recognises more fully the complexity of the process by which science is commercialised.

2.3.5 *The changing role of Universities*

In the traditional view of technology transfer, it also follows that the skills and knowledge required of scientific researchers are distinct from those who are involved in commercialisation. In post-industrial economies, product innovation almost always depends on University-educated personnel (Slaughter & Leslie, 1997: 30; Williams, 2005: 17) and internationally, technology transfer often occurs from a University or research institute to industry.

Etzkowitz (1998: 825) describes four categories of industry-academia linkages, from those modeled on the “hydraulic assumptions of knowledge”, with reservoirs of basic research flowing through dams and gateways, to those where firms outsource their R&D efforts to academia. Considerable efforts have been made to increase these linkages (e.g. Group of Eight, 2005; Higher Education Funding Council for England, 2003). Government policies have also been designed to facilitate the movement of IP from one agent or sector to another. For example Carlaw et al. (2003) focus on the interface between the innovative (research) and absorptive (business) capacities of an economy. In the USA, the Bayh-Dole Act of 1980 vests IP arising from publicly-funded research in the recipient research organisations, with the intention that the organisations will then be incentivised to commercialise that IP. In Britain a third stream of funding for Universities has been introduced, on top of funding for teaching and research, to address a lack of UK experience in commercialisation, managing IP and handling venture capital, when compared to the US or Canada (Weston, 2004a).

Various institutional mechanisms have been designed to facilitate the technology transfer process, for example the Innovation Centre (Caputo, Cucchiella, Fratocchi, Pelagagge, & Scacchia, 2002) or the Technology Transfer Office which enables scientists to choose their level of involvement with (or detachment from) the transfer process (Etzkowitz, 1998: 831). *Spinouts*, or the creation of a company to commercialise IP coming out of a University or other research institution, are also regarded as useful vehicles, but the overall rate of success of technology transfer efforts tends to be very low:

In 2003 Australian Universities declared \$2.7 billion in revenue from fee-paying domestic and international students and \$635 million from consultancy and contract activities. These revenues compared to just under \$35 million in income declared from activities directly related to the commercialisation of research....even the world's leading commercialising Universities only generate between 3 and 5 per cent of total revenues from research commercialisation activities....of the 850 invention disclosures Yale University made between 1982 and 1996, 1 per cent produced 70 per cent of revenue, 4 per cent accounted for 90 per cent of revenue, while 88 per cent of disclosures failed to cover their management costs (Group of Eight, 2005: 2-4)

A New Zealand survey finds that the relative productivity of New Zealand Universities is much higher than this (Canterbury, 2006) but the monies generated by *academic capitalism* are still small as a proportion of total University income (Slaughter & Leslie, 1997-8).

University spin-offs remain relatively rare, even in the US although the Bayh-Dole Act has brought about an increase in spin-off activity (Shane, 2004: 17; Siegel, Waldman, & Link, 2003: 28). Some types of technology are more amenable to this mechanism than others: those that are radical, tacit, early stage, general purpose, have significant customer value, are a major technical advance and have strong IP

protection. Technologies licensed to established firms (an alternative to spinning out) are more likely to be incremental, codified, late stage, specific-purpose, have moderate customer value, be a minor technical advance and have a weak IP position (Shane, 2004: 103). Within entrepreneurial technology firms, two kinds of risk tend to be inversely related, mirroring the above criteria. Investments in developing highly uncertain technologies are usually undertaken when appropriability risks (that another party will be able to take up the technology) are limited, while firms developing innovations that are more open to such risks tend to focus on more cumulative and predictable technologies (Casper & Whitley, 2004: 91).

Gibbons (1998) maintains that the values of technology transfer will have to be brought from the periphery of Universities, where they reside at the moment, to their core. In part to overcome the limitations of the classic linear model, Gibbons proposes an entirely different mode of organisation for Universities (Mode Two) compared to the current, outdated Mode One structure and processes, as shown in table 2.1:

Table 2.1 Comparison of characteristics of “mode one” and “mode two” universities

Mode One	Mode Two
Problems set & solved in a context governed by the (largely academic) interests of a specific community	Knowledge is produced in a context of application
Disciplinary	Transdisciplinary
Relative homogeneity of skills	Relative heterogeneity of skills
Hierarchical, forms resistant to change	Flatter hierarchies, transient forms
Accountability to discipline	More socially accountable and reflexive
Narrow quality control based primarily on peer review	Still peer review, but quality control also includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localised context

As with concerns about the supposed neo-classical basis of human capital theory (see section 2.4.2) there are objections to connections between education and business (e.g. Hornblow, 2007; Peters, 2007) but the change Gibbons hopes for may be further advanced than he allows: the Massachusetts Institute of Technology (MIT) and Stanford University are perceived as being very good at training academic researchers in an atmosphere of innovation and risk-taking, enabling transfer of ideas into business (P. David, 1997).

Duberley & Cohen (2007) note the emerging reciprocal relationship between producers and users of knowledge, and report that some scientists found the combination of business and academic activity as mutually enriching and the pursuit of competitive funding can alter the ethos of departments and entire Universities (Slaughter & Leslie, 1997: 137-8).

Shifts in practice at the institutional level have tended to be encouraged by changes in national policies. Funding for Universities from traditional sources has diminished and there has been increasing access to funds at the periphery though the efforts of *academic entrepreneurs* (ibid). On the demand side, globalisation and consequent loss of market share have driven multi-nationals to invest in new technologies and increasingly turn to research Universities for science-based products and services to market. Academic capitalism and hence most external revenue have become concentrated in applied science departments and engineering, which have also tended to be interdisciplinary. Professors in fields close to the market are most able to accrue prestige and resources, and as a result of their increasing intersection with the market, a new hierarchy of prestige and privilege is emerging within Universities (ibid: 141). This finding is supported by another that US faculty members with tenure are more likely to engage in patenting activity and that older faculty are more likely to engage with industry (Allen, Link, & Rosenbaum, 2007). It is interesting to compare

this finding with the view of Kuhn (1996; see section 2.3.2) that change is more likely to come from younger scientists although there would be no inconsistency if it were the case that academic entrepreneurs were engaged in incremental innovations.

2.3.6 *The sociology of science*

“The way science is done” is of relevance to later discussion (and findings) about the differences and similarities between science and entrepreneurship, and the dominant early figure in developing the related field of sociology of science is R. K. Merton (Storer, 1973: xi). Ziman (1984, 1994) has also written extensively about the topic and discounts ethnographic (detached) study of the sociology of science, preferring instead a hermeneutic (empathetic) approach (1984: 7).

Ziman argues that scientists need traits of imagination, self-criticism, diligence, curiosity, devotion to truth and respect for the public literature (see Merton’s *norms* for science in table 2.3). Scientists tend to be motivated by the science itself, rather than by external rewards. However, Ziman also notes that the traits of scientists have been so idealised and eulogised that some of the other traits that are inseparable from the role have been ignored:

Such as narrowness of view, to gain mastery of a speciality, and egoism, to concentrate on a topic, and to prevail against competition (Ziman, 1984: 175)

Ziman dismisses what he calls the simplistic, linear chain of discovery in science, partly because it does not recognise the communal nature of research (Ziman, 1984: 3). Like Schön (1983: 325) Ziman (1984: 3-7) suggests that the membrane separating discovery from application is largely an illusion.

Science is a collective, social activity (as is business) but its output belongs to a world of public knowledge (Ziman, 1984: 56) unlike business where knowledge is owned privately. This implies a different sort of continuum, from public to private ownership. A need to make public the results of research and communication is a core scientific process (Callaghan, 2004: 38; Ziman, 1994).

Within the world of science there is a lengthy process of peer review, publication and accreditation before widespread recognition - another highly social process - is achieved. Recognition comes in the forms of credentials, awards and measures such as citation rates for publications (bibliometric measures) although these suffer from a number of limitations which are discussed in depth by Whitehead (2003). Scientists are rewarded by these non-economic returns for sharing knowledge – in effect the bargain that is struck for making knowledge freely available.

As a proxy for quality as well as productivity, bibliometric analysis shows that scientific papers produced by teams tend to have more impact than those produced by individuals. With the exception of a few individuals who attract very large numbers of citations, the research of the team also has much more impact per person for the same number of papers. Impact is proportional to team size (Whitehead, 2003). When the publication outcomes of two teams within a multi-University scientific alliance are compared, the productivity increase is highest for the more heterogeneous team (Porac et al., 2004).

The high degree of competition for recognition drives and shapes academic science. Recognition tends to come from extreme specialisation and is bestowed from above, rather than by election from below. In this sense, the traditional structure of academic science is notably undemocratic (Ziman 1984: 72-79) and:

The freedom of the academic scientist within the republic of learning is....heavily qualified.
Certain types of egocentric or idiosyncratic behaviour would not be consistent with the
maintenance of this internal social structure (ibid: 81)

However:

The search for some link between disjoint theoretical domains has been a powerful agent
of scientific change....a detailed study of the history of science will always reveal a tense
dialectic between conservatism and radicalism (ibid: 98)

2.3.7 *Management of science*

Also important in making comparisons with the world of business are the
management processes that are used in science, for example to provide incentives
and rewards and manage careers (Duberley, Mallon, & Cohen, 2002) or life stages
(Janson & McQueen, 2003; Rae, 2000). A frequent *cri de coeur* of scientists is that
they are:

Individuals, not resources to be managed (Ziman 1984: 175)

This plaint may be at odds with the organisational requirements of much modern *big science*, which is conducted within large, complex teams using considerable amounts
of expensive infrastructure (ibid: 44-52). Whether in industrial or academic settings,
the realities of corporate existence militate against the idealised view of scientific
autonomy (Ziman, 1994: 189).

Nevertheless any research organisation requires generous measures of: social
space for personal initiative and creativity; time for ideas to grow to maturity;

openness to debate and criticism; hospitality towards novelty; and respect for specialised expertise (Koslow, 2005: 3; Ziman, 1994: 276).

Gibbons (1998) states that so far, the emphasis in Universities – and this is a consequence of the disciplinary structure – has been on individual performance and little, if any, attention is currently given to the challenge of teaching people to be *creative* in a team situation. In what he sees as the new context, a significant adjustment will have to be made in developing structures which promote and reward group creativity. To avoid wasteful duplication, an ethos developed on teamwork and, more importantly, on sharing resources will need to be developed at the centre of institutions' policies.

Adler and Zirger (1998) discuss structural barriers to innovation which often exist within larger organisations, and give examples of both firms and the barriers they have faced. The latter include differences between R&D and product development departments in status, incentives, rewards and culture. The authors propose as an alternative a matrix-style *virtual* organisation with a lot of mobility of personnel.

According to Schön (1983) the way to bridge gaps that may exist between thought and action is based on the interactive framing and reframing of problems, use of *generative metaphor*, reflection in action and use of design:

The roles of practitioner and researcher will have permeable boundaries, and research and practice careers will intertwine as a matter of course, eventually leading to institutional redesign (ibid: 325)

2.3.8 *Summary*

The potential for RS&T to contribute to innovation is complicated by a range of factors such as mental models, organisational design and performance and its internal sociology. All of these are essentially human elements and another approach to understanding RS&T (and entrepreneurship, as will be seen in section 2.7) is to adopt a “human capital” perspective. Thus a consideration of literature on human capital follows in the next section.

2.4 **Human Capital**

2.4.1 *What is human capital?*

In simplistic terms, human capital is that which is not physical capital such as plant and equipment, or financial capital. It is defined by the OECD as:

The knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being (Healy & Côte, 2001: 16)

The composition of human capital is thus wider than skills and knowledge alone. As the definition implies, what is also important is how individuals integrate and apply their skills and knowledge to generate outcomes. There is a clear consensus from all the reviewed literature that human capital has greatest value when it is used within a relevant context.

The contribution of human capital to national wealth is recognised and discussed in great detail in macroeconomic literature (Becker, 1975; Keeley, 2007; Schultz, 1971)

while at the level of the organisation, there is also considerable discussion about its contribution to innovation and the development of competitive advantage (e.g. Campbell-Hunt et al., 2001; Hamel, 1991). However, the way in which human capital contributes to productivity improvements is still something of a “black box” (Durbin, 2004) and most attempts to measure human capital depend on proxy measures (see the discussion on measurement in section 2.4.7).

Generally, human capital is regarded as being distinct from, although linked to, social capital¹⁵ and it appears that social and human capital are mutually reinforcing (Hipkins, 2006: 105).

2.4.2 Economic theory and human capital

Over the last century, the share of Gross Domestic Product (GDP) attributed to physical capital has dropped markedly in modern economies, while that earned by human capital has increased, leading to the concept of the knowledge economy (Keeley, 2007).

All forms of capital have traditionally been regarded as inputs to the processes by which goods and services are produced, but the role of human capital as a simple input is now seen as much more complex. Modern theory holds that human capital has the inherent capacity to modify both itself and other inputs, and it is this property that leads to a permanently dynamic economy. Human capital is the only factor of production capable of creating new and improved production processes and goods, and in addition promotes their diffusion through the economy (P. A. David & Lopez, 2001).

¹⁵ Social Capital is defined as “networks, together with shared norms, values and understandings that facilitate co-operation within or among groups” (OECD, 2001a)

Human capital has therefore come to be regarded as essential to innovation and, by extension, to economic growth and well being. Becker (1975) Schultz (1971) and others have shown that growth in human capital can explain the residual, i.e. the difference between the amount of growth in national income and the amount of that growth that can be attributed to growth in physical capital. There is also evidence (not conclusive) that the level of human capital in different countries can explain differences in income between those countries – suggesting that national systems have some role in influencing economic outcomes through the way human capital is developed and deployed (ibid: 161). This view of the contribution of human capital needs to be placed alongside the explanation that technological change is the residual factor contributing to growth (see section 2.2.1) but there is complementarity rather than inconsistency between the two, given that technologies may be seen as embodying forms of human capital and that *technological learning* is critical to the innovation process (Winsley, 1997).

There is a countervailing view which regards human capital as an almost pejorative term and a manifestation of the worst excesses of neoclassical economic theory (treating people as mere commodities to be invested in, bought and sold). Ellstrom (1997) for example criticises human capital theory on the grounds that it is wrongly informed by a rationalistic perspective which does not readily lend itself to the study of learning processes within firms and their role in the promotion of social innovation. The criticisms of Ellstrom and others may have some merit (see also Benade, 2007) but human capital theory does seem to have evolved past pure rationalism and neoclassicism and it provides some useful insights which are complemented by other literatures. It has certainly become a relatively benign core element of OECD thinking (Keeley, 2007).

All the same, human capital theory takes a life-cycle view of investment with decisions made rationally (at either the individual or aggregate level) on the basis of expected returns over time, compared to returns that might be expected from alternative investments. The field of behavioural economics has called into question this notion of *homo economicus* (Levitt & Dubner, 2006: 198) but investments in human capital generate high public and private benefits and are worth analysing. For an individual, spending longer in education carries a cost, but it produces a return in terms of increased personal income (Keeley, 2007: 33-4) and possibly other benefits such as improved health (G. Johnston, 2004).

Attempts to maximise benefits at a national level have from time to time led to the identification of particular sectors where future demand for human capital is likely to be, and where investment would generate the greatest returns (Rowarth, 2005; Tomlinson, 2001b). This *workforce planning* approach has had mixed success, given the rapidity and unpredictability of changes in requirements for particular types of human capital.

At the aggregate level there is some contention as to whether higher investment in education and training drives growth or whether growth drives higher investment in education in training (Krueger, 2000) and competence acquisition or enhancement might be regarded as an outcome of innovation rather than vice-versa (Gatignon, L.Tushman, Smith, & Anderson, 2002). A linked question is whether expenditure on human capital formation¹⁶ should be treated as consumption or as an investment. In reality it is probably mix of both.

¹⁶ Human capital is said to be both “created” anew and “developed” from an existing base. “Formation” incorporates both of these processes

While the basis upon which investments are made, or the relative returns, or equity of access or outcomes, are not the focus of this review, it is useful to note that there are higher rates of return from earlier stages of education, and the cost of later training increases due to higher rates of income foregone (Nerdrum & Erikson, 2001; Schultz, 1971). Much human capital development, particularly in the sciences, is also cumulative, i.e. each new element builds on what has gone before (Ziman, 1984: 49, 60), and tends to move incrementally rather than in leaps and bounds. The implication is that it is expensive to add on human capital later in life to people who are highly trained in another field. In purely investment terms, is better to embed desired attributes as early as possible in the life cycle (Durbin, 2004; Keeley, 2007). This is particularly the case with cognitive development as shown in a longitudinal study of New Zealand young people which has found that quality early childhood education (among other factors) has a positive and lasting effect on the development of key competencies although other attributes may be formed at later stages (Wylie, 2004; , 2006; Wylie, Ferral, Hodgen, & Thompson, 2006; Wylie & Hodgen, 2007; Wylie et al., 2006).

2.4.3 Human capital at the level of the firm

The resource-based view of the firm (RBV) is that human capital has significant value (Rylatt, 2003) and is a vital contributor to firm-level innovation, competitive advantage and success (Bontis & Fitz-enz, 2002; Campbell-Hunt et al., 2001; Hamel, 1991; Hitt & Ireland, 2002).

Schultz (1971) and Becker (1975) comment on a useful concept which resonates throughout different literatures on human capital (e.g. Boyatzis, 1982; Oates, 2001): the difference between *generalisable* and *specialised* education and skills. The former being more transferable into different settings and the latter being more

related to a particular job (and firm). In terms of career resilience in a rapidly changing labour market, it makes sense for an individual to invest in and persist with their own general education for as long as possible. For individuals, to hold only specialised skills may be a risky strategy when demand for them changes (Casper & Whitley, 2004: 92). Employers on the other hand have an interest in investing in the development of specialised skills through on-the-job training, and an incentive to ensure that human capital is made concrete (codified) so that it can be owned through such devices as manuals, patents etc. This is particularly so in an economy where knowledge has great value (Boussouara & Deakins, 1999).

A product advantage can come and go but if a firm commits early to building a complex and deeply embedded capability it is difficult for others to catch up. There is therefore more incentive than was previously the case to invest in human capital which difficult to reproduce and of high strategic value, such as that associated with RS&T. Such investment affords a firm an opportunity to increase innovation, create and/or build a competitive advantage and to increase firm value (Hitt & Ireland, 2002). Yet this brings new challenges, as the imperative to invest in specialised skills must be balanced against the risk of losing that investment through worker mobility. The power relationship within firms has shifted, and the growth of the field of knowledge management is a response (Kakabadse, Kouzmin, & Kakabadse, 2001; Peters, 2007).

Tacit knowledge is particularly difficult to manage, because it is known but not able to be explained (Polanyi, 1967: 4) or codify. Rather, it is embodied within an individual or group. Polanyi also implies that other attributes, apart from knowledge, may also be tacit – he refers to the “tacit power of scientific and artistic genius” and considers that knowing covers both practical and theoretical knowledge (ibid: 6-7).

2.4.4 *Mobility*

Tacit knowledge is transmissible only by engagement with or movement of those people who have it (Corolleur, Carrere, & Mangematin, 2004; Murray, 2004) and significant mobility of highly educated or innovation-important workers ensures diffusion and increases innovation (Graversen & Friis-Jensen, 2001: 45):

In the US, knowledge management is closely related to human resources management: mobility in early careers is encouraged since it allows knowledge circulation and renewal. In France, knowledge transfer and human resources management in R&D are treated as two distinct topics, which may explain why R&D seems sometimes more sluggish in France than in the US (Gaughan & Robin, 2004: 579)

The diffusion of technology is the prime mediator in the relation between human capital and growth (P. A. David & Lopez, 2001) although there is still insufficient understanding of how this diffusion works (SPRU, 2000). It may even be that the channels through which knowledge is spread are as important as the knowledge creation itself (Graversen & Friis-Jensen, 2001).

A high mobility rate can indicate that the research environment cooperates with the surrounding economy (Graversen, 2001: 123). The social value of the production and mobility of researchers is usually far above the corresponding private value and one of the most important channels for knowledge diffusion is through candidates from Universities (Graversen & Friis-Jensen, 2001: 47). University researchers who have prior experience of the private sector have much more positive perceptions of the opportunities it presented than those who never leave the University setting (Duberley & Cohen, 2007: 490).

However, while mobility of highly educated labour is perhaps the most obvious mechanism of knowledge transfer (Nås, Ekeland, Svanfeldt, & Åkerblom, 2001: 72) it is not the only one as noted in the discussion on technology transfer in section 2.3.4. Neither should it be automatically assumed that high mobility is optimal, since knowledge accumulation takes time (Graversen, 2001: 123).

In spite of this cautionary note, it is likely that the mobility of people has been crucial to the success of the New Zealand Dairy Industry (J. Smart, 2003) and the OECD sees the mobility of workers between sectors and firms as particularly important for innovation:

Not only because of the productivity gains that can result from a more efficient allocation of labour, but also because of the effect on the diffusion of knowledge and technology. Mobility can also foster renewal of R&D organisations through new recruitment (OECD, 2001: 75)

There is a considerable literature about the value of skilled migration between countries which has been reviewed but not fully reported on (e.g. Laafia & Stimpson, 2001; Mahroum, 2001) since the focus of this research is on movement within a single innovation system. However, it is interesting to note that entrepreneurs are at the “high end” of mobile populations and to reflect on some of the *push* and *pull* factors that are operating: for example the importance of working conditions, notably the autonomy given to young researchers rather than hierarchical systems where senior researchers control resources and choose projects; the availability of financial support for academic research; and the presence of knowledge-intensive clusters and top researchers in a given discipline (Guellic & Cervantes, 2002).

2.4.5 Classifying human capital

Various writers (e.g. Bontis & Fitz-enz, 2002; Burr & Girardi, 2002; Thomas N. Garavan, Morley, Gunnigle, & Collins, 2001; Hitt & Ireland, 2002; Nerdrum & Erikson, 2001; Snell, Lepak, & Youndt, 1999) have developed taxonomies of the relationship of human capital to other forms (e.g. organisational capital, structural capital, intellectual capital, relational capital). There are also a number of taxonomies describing the composition of human capital itself (Boussouara & Deakins, 1999; P. A. David & Lopez, 2001; Ellstrom, 1997; Lundvall, 1998) but the thinking behind them is hardly new – Johnson et al. (2002) describe a similar taxonomy developed by Aristotle¹⁷. What is useful though is their contribution to the construction of a framework for research. David and Lopez (2001) for example identify two major forms of human capital – *tangible* and *intangible*. Tangible forms include: Longevity, Physiological Condition and Health, which are not the focus of this study, although it is interesting to view them from the perspective of building a total innovation system.

Intangible forms are of more interest and David and Lopez further divide these into three main groups of capabilities (sic)¹⁸:

- **Psycho-motor based skills** (know how, can-do)
- **Procedural capabilities** such as
 - creativeness, innovativeness
 - social capabilities e.g. diligence, loyalty, cooperativeness, trust (know how, know who)
 - flexibility, multi-task performance, re-trainability

¹⁷ Aristotle distinguished between *episteme*, knowledge that is universal and theoretical, *techne*, knowledge that is instrumental, context specific and practise related; and *phronesis*, knowledge that is normative, experience based, context specific and related to common sense ("practical wisdom")

¹⁸ David's definition of the term "capability" differs from that used in this study – see section 2.5.1

- problem-solving, leadership, managing complex tasks
- **Cognitive capabilities** (know why, know what)

David's taxonomy echoes the pure-applied hierarchy of knowledge which has been criticised in section 2.3.3 but it is still useful for the purposes of discussion and the model that is developed later on (figure 4.2) restores synthesis.

2.4.6 Developing human capital

Each set of David's capabilities is important and requires attention if national human capital is to be developed to its full potential. However, traditionally as far as intangible forms are concerned, emphasis has been placed on the development, assessment and recognition of cognitive capabilities through schooling and tertiary study, or psycho-motor skills through trade training, apprenticeships and so on (Menzies & Barwick, 2000; Reid, 2006). These remain important but there is evidence to suggest that many of the attributes most relevant to entrepreneurship are procedural in David and Lopez's terms (see sections 2.7 and 2.8). Furthermore, procedural capabilities are forms of "tacit attributes" which are developed through both formal and non-formal systems (Wylie, 2006: 44) families, not-for-profit organisations and communities (Evans, Kersh, & Sakamoto, 2004: 238).

The process of forming all the elements of human capital is an extremely complex one, and for this to be optimised requires a coordinated approach across a range of sectors (Keating, 2001). By concentrating only on the role of formal education in human capital formation, there is a danger of erroneously crediting to education some of the contribution made by these other sources (Schultz, 1971: 40).

2.4.7 *Measuring human capital*

Human capital is hard to measure. Any individual measure can only tell us so much. For a fuller picture we need to combine a number of different indicators, but even then we need to understand the limitations of our understanding....single-index measures of human capital need to be complemented with more specific measures based on direct measurement of knowledge and skills in organisations (Keeley, 2007: 116)

Within national economies

Given the importance of human capital for RS&T and innovation policy, it is perhaps surprising that up until recently there has been a relative scarcity of research in this area, mainly through lack of adequate data (Ekeland & Smith, 2001b: 17). As a response, the OECD Secretariat, together with the European Commission and the Group of National Experts on S&T Indicators, initiated work on a statistical framework that resulted in the so-called *Canberra Manual*, published by the OECD and Eurostat in 1995. The emphasis of the Canberra Manual is on measuring stocks and flows of human capital.

The stock of formal knowledge is used as an indicator of the innovation potential of the economy and the mobility rates of workers are assumed to reflect knowledge circulation and exchange. Similarly, the flow or mobility rates between the research sectors and the remaining sectors are used to describe the way in which knowledge spreads from the "towers or pyramids of wisdom" to the rest of the economy (Graversen, 2001: 116)

However:

In addition to formal education, tacit and informal knowledge gained through experience and on-the-job training during the individual's working life adds to his ability stock....this informal, specific knowledge or ability is an unknown part of human capital. In practice, it is difficult to formalise

and measure tacit knowledge, particularly in terms of entire populations, and the formal level of education is often used as a proxy for these 'hidden' abilities, especially for the higher educated (ibid: 115)

This invisibility of key attributes represents a serious difficulty for the measurement of the human capital that is essential for growth within modern economies, and chapter four proposes an alternative approach to addressing this problem.

Economists are aware that conventional measures of human capital are indirect. Accordingly, some have argued that the only relevant way to measure economic talent is by results such as earnings (Schultz, 1971)¹⁹ or by comparing wage data and earning differentials between those with different education and/or skills (Salganik, Rychen, Moser, & Konstant, 1999). But much of the variation in earnings is unexplained by an individual's years of schooling, labour market experience and parental characteristics. Human capital is multi-dimensional, and other behavioural traits appear to be influencing employment and earnings outcomes. Employer surveys have ranked non-cognitive characteristics like attitude, motivation and communication more highly than technical skills (Bowles, Gintis, & Osborne, 2001).

The relative ease of collection and current availability of data has a bearing on what is used to measure human capital. Statistics New Zealand draws upon a number of sources to produce data relating to the national stock including levels of educational investment, participation in different levels of education, attainment of qualifications, and earnings. Most of this measurement focuses on the supply side. Partly because market signals are often poor, demand for human capital is not readily susceptible to measurement (OECD, 1999a).

¹⁹ Citing Weisbrod, B. (1961). The Valuation of Human Capital. *Journal of Political Economy*. 69 425-436

Attempts to address the lack of demand information may be made at a sectoral level. For example a survey carried out with the aim of addressing future needs for human capital in the biotechnology sector, although once again using a mainly quantitative approach to measuring stocks and flows of human capital (Biotenz, 2003)²⁰.

Most of the measures described above are aimed at establishing the *quantity* of human capital at an aggregate level. They measure *quality* of human capital only indirectly.

Another indirect approach has been to assess the effect of the *quality of investment* in human capital formation. Much attention has been given to such measures as student/teacher ratios, class sizes, teacher salaries and per student funding. These are input related, and only indirectly related to outcomes but Statistics New Zealand also provides data on literacy levels of workers in different industries, sourced from the International Adult Literacy Survey (IALS – now ALL).

The IALS/ALL measures are in line with international trends towards measuring the quality of national human capital by assessing what people are actually capable of doing and the degree of matching of those abilities with future needs. The OECD in particular has given priority to developing direct measures of a range of individual attributes and has expanded on this approach through the DeSeCo project (Definition and Selection of Key Competencies) whose mission is:

Understanding the skills and competencies needed to lead a personal and socially worthwhile life in a modern democratic state (Salganik, Rychen, Moser, & Konstant, 1999)

²⁰ Even so, key skills “deficits” identified are general ones in the area of management and commercialisation etc rather than sector-specific

While the DeSeCo project has a non-commercial, schools and participation focus, some of its findings are of relevance to a consideration of human capital in innovation and another OECD programme (PIAAC) to be administered for the first time in 2011 will aim to:

Assess the level and distribution of adult skills in a coherent and consistent way across countries. It will focus on the key cognitive and workplace skills that are required for successful participation in the economy and society of the 21st century.... PIAAC will also gather a range of other information including the antecedents and outcomes of skills, as well as information on usage of information technology and literacy and numeracy practices generally (OECD, 2008)

Other activities in the same “family” are the Programme for International Student Assessment (PISA) commissioned by the OECD in 31 participating countries to report how well 15-year olds are performing on reading, mathematical and scientific literacy and Trends in International Mathematics and Science Study (TIMSS) a series of international assessments carried out in countries around the world to measure trends in mathematics and science learning at middle primary and lower secondary school levels.

Within organisations

Notwithstanding its value to organisations, of all value adding inputs human capital is often the most neglected by management, largely because it is difficult to manage and to measure (Knuckey et al., 2002)²¹. If it could be achieved however, there would clearly be considerable benefits in establishing the causal linkages between investment in human capital and its actual development and deployment to deliver outcomes.

²¹ Citing Barker, B. (2001). Manufacturing best practice and intellectual energy. *Integrated Manufacturing Systems* 12(1) 7-14

As with national systems, there are proxies for measuring human capital creation or the outcomes of its use at the firm level. For example, in 1995 IBM bought Lotus for \$3.5 billion, 14 Times its book value. That signalled that marketplaces put immense importance on the value of intangible assets such as intellectual property and know-how (Rylatt, 2003). But despite considerable efforts the accounting profession still cannot accurately represent human capital on a balance sheet, and it can certainly not assess future value with any confidence (Bontis & Fitz-enz, 2002). Nor can it take into account the fact that human capital depreciates through disuse and, unlike physical capital, appreciates by being used.

There have been some attempts at qualitative measures. For example Birchfield (2003) assesses New Zealand managers' management capability based on eight major, weighted drivers (but doesn't say how these are derived). Another survey measures the gap between managers' expectations or stated importance of key management practices and their perceptions of their actual current performance and practices (ibid).

Within individuals

The OECD definition of human capital implies firstly, that because human capital is embodied in individuals, the bedrock unit of account is the individual. Secondly, the focus of the measure is on a range of characteristics (knowledge, skills, competencies and attributes) that facilitate particular outcomes (the creation of personal, social and economic well-being). The noted characteristics are goal directed and therefore are only relevant to the extent that they are instrumental in facilitating the stated outcomes.

..the primary focus for measurement of human capital should be on individual characteristics that are instrumental in facilitating personal, social and economic well-

being, without necessarily pre-judging how these objectives might be defined
(Stroombergen, Rose, & Nana, 2002: 36)

There is however a risk in frameworks focused on the individual as the main unit of analysis since they downplay the important role of organisations (OECD, 1999a) and indeed the wider context. Because of disciplinary heritages, it is often difficult for scientists to think simultaneously about factors that impact on populations and processes that affect individuals (Keating, 2001) and one level of analysis or the other tends to be preferred. Both, however, are essential to a conceptual framework on human competencies. A complex set of factors is involved in developing, identifying, measuring and deploying human capital and consideration of one part of the overall system will only tell part of the story (Baum, Locke, & Smith, 2001).

In the past, measuring intelligence has been used as a predictor of performance in general and economic success in particular. Perspectives on intelligence have been further expanded through the introduction of concepts of other kinds of intelligences (Gardner, 1993) some echoing David & Lopez's (2001) procedural capabilities, and various other taxonomies of intelligence.

However the fact that intelligence cannot be directly observed, controversy over the validity of measures and insufficient correlation between measured intelligence and life outcomes led to the development of a competence "movement" (Brophy & Kiely, 2002) and there is a logic which suggests that identification and direct measurement of observed behaviours and their underlying composition and effects in particular situations (together comprising competencies) are key elements in building understanding of the role of human capital in a modern innovation system.

But before proceeding it is necessary to sound a cautionary note. While the conceptual link between competencies and desired outcomes has been established in human capital theory it has not been empirically determined (Rychen & Salganik, 2002). There is a notable lack of theoretically integrated and empirically substantiated research in this area, which has had a limiting effect on practice (Ellstrom, 1997). Depending largely on how they are defined, competencies are not any easier than other aspects of human capital to measure. Indeed, in some respects they present even more difficulties and so altogether different approaches are required (see chapter four).

2.4.8 Summary

This review of literature on human capital shows its connection to economic innovation and sets out to locate a particular subset of literature on competencies, reviewed in the following section. Competencies can be used as a framework to understand both RS&T and entrepreneurship and as will be seen, the review of the literature on this topic helps narrow the field of inquiry (section 2.8) and also informs the construction of a research framework in chapter four.

2.5 Competencies

2.5.1 What are competencies?

Despite their ubiquity, the concepts of competence and qualification are often poorly defined in the literature, and a general consensus on their meaning seems to be lacking (Ellstrom 1997). Matters are further complicated by the inconsistent use of the terms competence and competency. Sometimes they are interchangeable, and the plural of competence is written both as competencies and competences. What is

more, the terms *capacity*, *core competence*, *capability* and *qualification* have been used with sometimes complementary, sometimes identical meanings. Capacity and capability are also often used to denote potential rather than actual performance. But the heterogeneity of competenc(y) terms is in many cases illusory since the same aspects of performance are described in different language (Oates, 2001).

There is though a persistent element of hierarchy among terms (Ellstrom, 1997) albeit once again the terms used in different parts of the hierarchy may differ. For example one or more competencies may contribute to a *capability* (Eishenhardt & Martin, 2000: 1107) – a term in prevalent usage in the New Zealand public sector. RS&T capabilities may also be combined to contribute towards a technology *platform* (Kirpatrick, 2003; J. Smart, 1997).

Competence or competency might be seen as a characteristic of a job or an organisation (Ellstrom, 1997; Hamel, 1991; Lawson, 2004) or of an individual. For the purposes of this study, a competency is regarded as being individually focused (befitting a study of the characteristics of entrepreneurs) while capability is more relevant to a wider consideration of organisations and systems of innovation. However competencies and capabilities meet, overlap and interact. When combined with additional resources, a competency may become a capability. For example in a University, an academic staff member will have a competency in a particular discipline, but it is only when extra resources are added to free up time and allow opportunities to be addressed that a capability is activated.

Two principal approaches to competencies can be described (Brophy & Kiely, 2002). The predominant US approach defines competency as the underlying attributes of a person. It is largely an input-based approach, defining what is needed in order to be able to demonstrate competent performance.

In contrast, the UK approach sees competency in more strictly behavioural terms as a set of performances and standards. A group of mostly English authors propose that competency is best used as a measure of learning output (ibid). This approach focuses on training and assessment of performance, leading some writers to see the term competencies as synonymous with skills and to criticise the minimisation of key elements such as knowledge (Gilbert, 2005: 145-50). However while competencies may have come out of the language of vocational training they have now crossed into the world of management (SHL, undated) and education (Reid, 2006) and they have been reshaped by educators to fit within a teaching curriculum framework. Reflecting their mixed parentage, there still remain very different conceptions of the purpose and representation of competencies:

There seems to be at least two broad approaches to key competencies. The first has a utilitarian economic focus and is organised around an intention to develop competencies for the workplace and the new economy. The second has a liberal humanist focus and is organised around an intention to develop competencies, in every individual, for civic and personal as well as economic life (Reid, 2006: 8)

This dichotomy is also articulated by Ellstrom (1997) who describes adaptation versus developmental views of competence. In the functionalist, adaptation perspective, occupational competence is defined and evaluated in relation to the successful performance of certain given or predetermined tasks, i.e. tasks that the individual is neither allowed nor expected to try to change and improve. In contrast, the developmental perspective strongly emphasises that people have a capacity for self-management, and that they also are allowed and expected to exercise this capacity. Thus, in this perspective individual competence is defined as a capacity to

reflect and to act on the (work) environment, and shape it into what the individual wants it to be.

Ellstrom (ibid) goes further in identifying the different research traditions underpinning the adaptation and developmental approaches. According to him, the first perspective has its roots in cognitive science and cognitive psychology while the latter belongs to a more humanistic research tradition as espoused by Schön (1983). However, the two perspectives are proposed by Ellstrom to be complementary rather than mutually exclusive.

The developmental perspective takes a wider view of the formation of competencies for innovation since:

A “shaping principle” of human resource development²² seems to presuppose a broad conception of occupational competence and qualification including cognitive and meta-cognitive components (e.g. theoretical knowledge and intellectual skills), but also non-cognitive components related to values, interests, personality traits and social skills (Ellstrom, 1997: unnumbered)

As with human capital, what is common among definitions of competencies is that they are seen as comprising more than simply knowledge and skills, and they always have an aspect of application within a context. But the context is not simply a passive background. Hipkins (2006) describes views of learning which distinguish between situated knowledge and distributed knowledge where competence emerges in the context rather than being seen as the property of an individual. Rychen and Salganik (2002) go further to say that it is the demand, task or activity which defines the internal structure of a competenc(y). Gonczi (2002) points out what he considers

²² In this instance, “Human Resource Development” seems to equate to “Human Capital Development”

to be flaws in reductionist thinking about competencies based on a body-mind dichotomy and refers to developments in neuroscience which have shown that there is instead an integration of body and mind, emotion and reason. There are also converging ideas from cognitive science, learning theory and philosophy which challenge the traditional view of knowledge (reflected in David and Lopez's taxonomy in section 2.4.5) that there is a distinction between knowing *that* and knowing *how*.

Gonczi relates how cognitive science formerly conceptualised memory as retrieval from a container. It assumed that cognition is centralised, that the body is outside the process and that the environment is a problem to be overcome. Recent research instead sees memory as the recreation of patterns in a decentralised way across the brain. The environment is an active resource which helps the learner to solve problems and the body is part of the computational loop. It is not that the patterns are stored in the mind, rather they are in the environment and that the brain interacts with the environment to produce the appropriate pattern – i.e. to act intelligently/competently. These thoughts resonate with thinking on the interaction between organisations and their environments (section 2.6.3).

Gonczi and his colleagues adopt a relational approach to competence (sic) - one which links attributes of individuals (knowledge, skills, dispositions, values) to the demands and tasks and activities which individuals undertake in some aspect of their lives. Competence and its underlying attributes, they argue, is able to be *inferred* from performance and not directly observable. This approach to competence brings together the generic and the specific and Gonczi argues for an apprenticeship approach to learning since competence is essentially a result of social rather than individual activities. Oates (2001) cites Lave and Wenger²³ who in a number of studies of learning through apprenticeship-type situations postulate that knowledge is

²³ Lave, J., & Wenger, E. (1991). *Situated learning – legitimate peripheral participation*: Cambridge University Press

in effect built through participating in a group, the members of which already have competence and who are willing to allow the learner to become progressively part of the core of their community. In short:

The development of competence is a holistic activity involving individuals and groups acting in and on the world in an cognitive affective somatic fashion (Gonczi, 2002).

Oates (2001) also reports on more recent, adapted models of situated cognition which suggest that the contexts in which competence is developed affect/condition the extent to which individuals are able to adapt to new contexts and demands. This is the notion of "skills of transfer" (ibid: 21) or the ability to apply skills developed in one setting to another, new setting. Transfer of skills of communication, number and so on is facilitated by the use of conscious strategies to enhance transfer – i.e. deliberate reflection on the skills which the learner has and the contexts in which (s)he has used and developed them and reflection on the extent to which a new context resembles one in which the skills were previously used.

Oates (ibid) goes on to pose the question as to whether there are *root competences* (sic) or components of effective performance which are the building blocks of situated competence - *generative* elements which can explain effective performance in a wide range of settings – and argues for adaptability as a root competence.

In a management setting, competence-based analyses of managerial work provide a potentially useful descriptor of those management behaviours that are assumed to be causally related to effective and/or superior job performance (Sadler-Smith, Hampson, Chaston, & Badger, 2003). Competencies are commonly used to assist in recruitment, selection, development and appraisal of staff. They are often based on psychological research with clusters of key behaviours including hierarchies of

nested, contributing behaviours. Nevertheless the importance of underlying skills, attributes, dispositions and abilities is also recognised (Sadler-Smith, Hampson, Chaston, & Badger, 2003; SHL, undated).

For managers a model of effective job performance based on fit between the individual, the job's demands and the organisational environment has been developed by Boyatzis (1982). Specific actions or behaviours are in the overlap between these three domains, all of which are represented in the model shown in figure 2.3. A job competency is defined as:

An underlying characteristic of a person which results in effective and/or superior performance in a job (Boyatzis, 1982: 21)

In Boyatzis' own terms an underlying characteristic (attribute) of a person may be a motive, trait, skill, aspect of one's self-image or social role, or a body of knowledge which he or she uses (although knowledge is not specifically included in Boyatzis' model of dynamic interaction of components of job performance and levels of competencies as shown in figure 2.3 – presumably this is an oversight). The existence and possession of the above characteristics may or may not be known by the person who has them - i.e. they may be tacit. This idea seems to owe much to Polanyi (1967) but Boyatzis does not acknowledge such a link.

As discussed above there have been two schools of thought as to whether competencies are characteristics of a job (or role) or of an individual. The value of the Boyatzis model is that it recognises both sets of elements and their interaction, and integrates them in a context which enables holistic thinking and research.

Boyatzis' model offers the basis of design for the current study and is frequently referred to from here on. It also provides a core component of the broader model derived as part of the framework for research in figures 4.2 and 4.3.

Figure 2.3 Boyatzis' competency model

2.5.2 Developing competencies

Competencies have an observable component and are therefore susceptible to some degree of measurement, but there is a complex set of underlying controversies about how competencies are structured, which components are innate and which able to be learned and what are the best methods of learning (Thomas N. Garavan, Morley,

Gunnigle, & Collins, 2001). The truth is probably that individual competencies are derived from a mix of inheritance and the impacts of environment and individual experience.

Boyatzis identifies required competencies which he sees as being useful for the purposes of staff selection, job design, training and performance management and so on but does not go far in speculating how they are formed. There are however a multitude of programmes seeking to develop the knowledge and skills of management and entrepreneurship (Turner, 2005). In National Innovation Systems:

Emphasis is beginning to shift to take on board not only the R&D system and the interactive learning processes between firms and other institutions, but also what might be called “competence-building systems” (Tomlinson, 2001a: 33)

There has been relatively little work on studying these systems, yet one of the major reasons why National Systems of Innovation differ is connected to the people they contain and the building of competencies. Indeed:

While it may be argued that the science part of National Innovation Systems has become increasingly globalised, education systems and labour markets remain more closed and labour specific (ibid)

The discussion in section 2.4.7 about efforts to develop international competency benchmarks tends to contradict Tomlinson on this point, albeit at the level of outcomes, but it is an interesting one nevertheless.

Within New Zealand, a longitudinal study of school children is tracking the development of nine competencies, including five key attitudinal competencies: communication, perseverance, self-management, curiosity and social skills. There

are very strong correlations between performance in these five areas in general and the links between the “two core twins” of perseverance and communication are particularly strong (Wylie, 2006: 38). Attitudinal competencies also support the development of cognitive ones such as in reading and mathematics (Wylie, Ferral, Hodgen, & Thompson, 2006: 74) and these feed into each other in *spirals of growth* as opposed to circles of isolation, resentment or defeat (Wylie, 2006: 40). The development of key competencies is promoted by good learning environments and teaching practice, home support, supportive friendships and early engagement in *interests* or activities that can extend the student and include: interaction, language, symbols, patterns, goals and challenge; ask persistence and concentration; give rewards, provide enjoyment and experience of “flow”; and build confidence (ibid: 44-50). Wylie acknowledges the difficulties involved in assessing competencies, and proposes some suggestions including self-assessment and the use of exemplars and matrices (ibid: 47).

The longitudinal study finds that there is variation in the rates of retention of attitudinal competencies compared to cognitive ones. The cognitive competencies are more strongly related to what is in place by age five: for example innate aptitude and level of family advantage, reflected in opportunities for early learning and development of dispositions; whereas the attitudinal competencies appear more strongly related to the students’ current situation: the current family income; peer pressure; and school culture (Wylie & Hodgen, 2007: 17). Overall, patterns of competency development over time show a reasonable consistency in student performance through their schooling years. However they also show that performance does change: individuals respond to changing experiences, opportunities, and relationships, and build on what they achieve. Sustained improvement of performance is likely to occur gradually, rather than through sudden large leaps (Wylie & Hodgen, 2007: 23). Where students become disengaged from

learning, they tend to do so before age 12, with the lack of engagement escalating in adolescence and at secondary level (ibid). This finding has significant implications for the conclusions on influencing life histories (see sections 2.8.2 and 6.2.1).

Reid (2006) describes a potentially subversive role for competencies in breaking down the dominant, discipline-based and hierarchical curriculum model which depends on teaching *of* subjects and instead teaches through knowledge *for* capabilities (sic):

The dominant curriculum is hierarchical, with those subjects comprising what Connell calls the competitive academic curriculum enjoying a reputation as the most rigorous, and being taken by those pursuing a University pathway. Non-academic subjects are relegated to the margins, invariably populated by the 'weaker' students. For decades now, curriculum designers have pursued the holy grail of 'purity of esteem', urging that subjects are treated equally, always without success. The fact is that 'subjects' have become the battle grounds of education, with turf wars being fought by subject guardians. Those subjects at the top of the pile refuse to concede ground.

Competencies may be the Trojan horse needed to destroy curriculum hierarchy. If competencies were taken seriously through being consciously and systematically taught, assessed, and reported on, they would assume an importance currently assigned to subjects. This would result in subjects becoming the vehicles through which competencies are achieved, rather than as ends in themselves. The first steps in reducing the cause of curriculum hierarchies will have been taken (ibid: 12).

It might also be noted that the approach mooted by Reid would help resolve arguments about the merits of disciplinary versus interdisciplinary and multi-disciplinary approaches to learning. However it has to be acknowledged that Reid's paper is quite theoretical and skates over some difficult practical issues such as assessment and moderation of the teaching of competencies.

Further questions arise as to what is the mix of cognitive abilities, traits and behaviours within competencies, whether they can be separated and which is key (D. T. Smart & Conant, 1994). Whereas in the adaptation view described by Ellstrom (1997: see section 2.5.1) it may be possible to break down a competency into its smallest parts, in the developmental perspective the notion of a competency is a holistic one, and it is unlikely that a single competency could ever be disassembled like a car engine or even dissected like an animal or plant. Similarly, a competency cannot be separated from its context and a holistic consideration requires some attention to literature on context, as in the following section (2.6). This review has particular emphasis on contexts for entrepreneurship, as a precursor to the review on that specific topic in section 2.7.

2.6 Context

2.6.1 Introduction

The availability of human capital may be necessary but is surely not sufficient by itself to ensure a firm connection between invention and economic growth. This requires, in addition, a set of powerful incentives, such as the free market provides, to ensure a continuous flow of inventions and their transformation through the innovation stage into a direct contribution to productivity and output growth (Baumol, 2002: 247)

As the foregoing discussion seeks to make clear, competencies are embedded within a context upon which they act, and which acts on them. As well as the incentives identified by Baumol above, context(s) can include wider culture, business and government policy environments, organisational structures, informal frameworks and practices of management and leadership.

2.6.2 National context

There has already been reference to the general effects of culture on innovation systems and entrepreneurship (see section 2.2.1). A New Zealand study describes gateways and barriers to innovation which are mostly contextual in nature (Gilbertson & Gilbertson, 1992; Gilbertson, Gilbertson, & Andrews, 1992) with the main barrier being a cultural one (Gilbertson, Gilbertson, & Andrews, 1992: 49 - 50). However there are positive aspects of New Zealand culture that are expressed in a *kiwi* way of doing things. As reported in Campbell-Hunt et al. (2001) these are perceived to support innovative or entrepreneurial behaviour, for example:

Angus Tait thinks we are good at doing more with less - but it is being bred out of us....in another generation or so we won't be very much smarter than the rest of the world because the isolation that gave us the advantage of doing more with less is going away....it is the product of a particular combination of geographical and historical circumstances in which isolation has forced us to "do more with less" (ibid: 135)

There are also considered to be other components of kiwi ingenuity such as "all roundness" and "having a go at doing that ourselves; being prepared to listen and learn" and cutting across conventional professional boundaries and a willingness to take risks (ibid: 136-40). There is little more than anecdotal evidence for these attributes and ways of doing things. They may be true, but they may also reflect national myth making and should be treated with scepticism (Carden & Murray, 2007: 229).

However the central point, that cultural context is important, still stands:

Most studies place that proportion (of a society's innovative capacity) influenced by culture at between 30% and 50% (Dunphy & Herbig, 1994: in abstract)

Three structural factors are conjectured which account for the innovative differences seen between the United States and the rest of its Anglo cousins (including New Zealand):

1. Ease and acceptability of entrepreneurial activities; (including capital markets, taxation, IP regimes, connectedness of R&D etc);
2. Huge size of the American marketplace (population and economy); and
3. Much less social rigidity in both bureaucracy and social system (ibid: 52)

There are also effects arising from differences in institutional frameworks between Co-ordinated Market Economies (CMEs) such as in Sweden and Germany and Liberal Market Economies such as in the UK and US (Casper & Whitley, 2004). For example there is less risk of negative effects arising from failure where there is a plethora of other opportunities for new jobs or business (ibid: 94; McCrone, 2007).

Carden and Murray (2007: 112; 143) take a broader systems view in describing how innovations rarely emerge either from systems with high degrees of order and stability or completely chaotic systems. The key is to find a point between these two states, “at the edge of chaos” where the system is able to adjust constantly to a turbulent world but without traumatic upheaval. Adaptable societies must have cultures and institutions that facilitate freedoms, especially freedom to experiment on a small (or large) scale.

2.6.3 Organisational context

Organisations such as firms exist within the wider context described above, and provide an intermediate context within which many people work. There is interaction between these levels, within the additional context of rapid change in the nature of business (Gibbons, 1998). The creation of organisational knowledge or intellectual capital is driven by the interplay of human capital (employee knowledge and skills) needed to meet product or customers' needs, structural capital (organisational capability to respond to market demands) and customer capital (the strength of a customer base). Creation and testing of knowledge is a social activity and, as such, requires environments that provide extensive opportunities for communication and experimentation (Kakabadse, Kouzmin, & Kakabadse, 2001). It is not possible to encourage creativity and innovation in an organisational environment which itself is rigid, heavily hierarchical, and run on top-down management lines and so the

question of organisational or institutional design is a critical and central aspect of knowledge management practices (Peters, 2007).

Structure produces behaviour, beliefs regarding structures produce behaviour, beliefs regarding the beliefs that others have regarding structures, project behaviour....people can get caught in systems (organisations) that serve nobody's interest (Hämäläinen & Saarinen, 2004: 12)

In traditional systems theory, systems such as organisations are controlled through the external control and measurement of inputs, variables and outputs, but this does not account for what is invisible. An alternative is *Systems Intelligence* wherein a system can adapt if it is able to learn and accommodate changes in its parameters by itself (ibid: 31).

Echoing Gonczi's (2002) view of the interaction of individuals with their environments (see section 2.5.1) it is possible to describe a biological perspective of the evolution of firm-level competitive capability. Campbell-Hunt et al. (2001) describe two perspectives on cognition – the process through which a system comes to know the outside world. The classic open systems perspective is one in which cognition is largely taken to be an information-processing activity carried out by a goal-directed system that has direct access to, and can extract information from, the external world. A system constructs a model of the outside world which is then used to compute behaviour that is adequate to ensure survival (i.e. this is *cognitivism*). However this is not how strategic management works. Although successful businesses are goal directed, their success is often serendipitous and path dependent (as are innovation and some scientific processes - see sections 2.2.2, 2.3.2 and 2.3.3):

Some seem to follow a haphazard and indeterminate evolutionary path, rather than any cognitivist road map...The cognitivist/viable systems model concentrates on the roles, not on the real people who might occupy them, and emphasises rational decision processes, downplaying the importance of intuitive forces and emotion. ...Several managers spoke to us about the credence they give to intuition and "gut feeling" in making decisions (ibid: 168)

This is the logic of *structure determinism*, according to which the world we human beings see bears the imprint of our own structure: what we see depends as much on us as it does on what might be taken to exist externally. The structure of the system itself determines which external forces can perturb it and what the outcome of that will be. Opportunities and threats do not, as cognitivist logic has it, exist "out there". Instead they exist only if there are processes at work within the company that 'bring them forth'.

To understand the business environment then, strategists must first understand the factors within the company which are empowering or restricting people's ability to identify opportunities and threats:

....the substance, direction and/or timing of organisational change can arise from an external perturbation acting on "fertile ground" (ibid: 177)

This is very much like the description of scientific serendipity provided in section 2.3.2. Clearly looking in only one direction, whether from the inside towards the outside or the reverse, limits understanding of how organisational systems work. Following Gonczi (2002) the same would apply to individuals since they are also systems. This discussion of structure determinism also resonates with that on mental models in section 2.3.2.

2.6.4 Leadership and management

There are four areas of critical difference between firms which are described as *leaders* and those that are *laggers*: Leaders have a greater commitment to the *softer* dimensions of business development; deeper relationships with all stakeholder groups when planning and developing products, services and processes; and recognise the need to promulgate company values. Leaders are more concerned with their employees' welfare and have developed more comprehensive systems for measuring and regarding staff performance, providing internal and external training and development opportunities, and assessing employee satisfaction (Knuckey et al., 2002).

Gilbertson (1992) finds a number of recurrent themes which explain the ability of some of New Zealand's most innovative organisations to "make ideas happen":

They are led by people who have a passion and vision for their innovation; and who lead from the front as opposed to administering and managing from an office on 'walnut row'; who have wide experience of jobs at various levels; have travelled overseas or have a perspective on cultural issues; have very explicit values - one in particular- that innovation and profit comes from people not structure and they tend to have well developed processes which enhance innovation in their organisations (ibid: 16)

Whether for good or for bad, individuals and organisations tend to find *fit* with each other and a study of the key influences on the development of human capability in some New Zealand workplaces finds that:

The most striking feature in the studies was that repeatedly workers recounted key capability development experiences in their lives, and those of colleagues, due to the efforts of particular employers, managers or supervisors....(t)he greatest impact of all, across all the industries studied, was reported to come from certain managers and supervisors who provided regular encouragement, support, coaching, and facilitated opportunities to expand the confidence and capability of workers (Bryson & Merritt: 10)

Janson and McQueen (2003) describe a pathway for the development of leaders which has seven growth stages. Movement across the transition points between each stage is greatly assisted by the role of enablers (individuals who assist leaders overcoming specific obstacles).

2.6.4 Linkages and collaboration

In terms of the construction of scientific careers, Duberley et al. (2002) confirm the importance of occupational communities, affiliations and contexts, both within and outside of the organisation, to which respondents orient themselves – from research teams within their departments to international collaborations and networks of friends and family which have little to do with science per se. This is confirmed by Bozeman & Mangematin (2004: 565). Johnson et al. (2002) note that, when interviewed about the background for their success as scientists, almost all Nobel Prize winners pointed to their interaction with other and more experienced Nobel Prize winners as a key element in their career.

Social Capital is clearly important and the social capital of academic scientists is critical to firms because it can be transformed into scientific networks that embed the firm in the scientific community through a variety of mechanisms (Murray, 2004).

For entrepreneurs too, Roberts (1991) highlights the importance of the general environment and of the snowball effect wherein success breeds success:

The greater the number of people who have already successfully founded new businesses, the less difficult it becomes to act as an entrepreneur. It is a matter of experience that successes in this sphere, as in all others, draw an ever-increasing number of people in their wake (ibid: 38)²⁴

Hunter (2007: 179) describes how historically:

The entrepreneur-centred network relied on the vision, energy, and talent of the central entrepreneur to coordinate and direct the resources of loosely aligned firms in a bid to exploit innovation

Entrepreneurs do not act in isolation – they depend on linkages with others, contrary to stereotypes of lonely “blokes in sheds” (Campbell-Hunt et al., 2001: 151) although Kennedy (1993: 24) describes a highly successful entrepreneur who was both a good leader and a “bit of a loner”.

2.6.5 *Entrepreneurial organisations*

Entrepreneurial firms are different from mature firms:

While many established firms innovate and compete under adverse market conditions, entrepreneurial firms must - simultaneously - build their internal infrastructure (Markman & Baron, 2003: 285)

²⁴ Citing Schumpeter, J. (1936). *The Theory of Economic Development*. Cambridge, MA: Harvard University Press

There is a difference between moderately dynamic markets where capabilities resemble the traditional conception of routines (more likely to be codified) and high-velocity markets where there are simple, highly experiential and fragile processes with unpredictable outcomes, like the creation of tacit knowledge. The ability to integrate competence and build new knowledge is especially important in high-velocity markets (Eishenhardt & Martin, 2000).

To Ravasai and Turati (2004: 6) learning in an entrepreneurial venture is higher level, *generative* learning, the outcome of which is not so much a change in routine behaviour (adaptive learning) as a change in the knowledge structures that sustain interpretation and action. Although the terms are used differently, these processes echo those described by Ellstrom (1997) at the level of individual competencies (adaptive versus developmental - see section 2.5.1).

There is also a model of growing organically into a new space in the market, in other words proceeding cautiously step-by-step, modifying plans depending on feedback and learning, and reinvesting to finance growth, evoking the historical New Zealand model of entrepreneurship described by Hunter (2007; see section 2.7.3) but in contrast to a model of rapid growth funded by venture capital (Ahn, Meeks, & Tkachenko, 2007). The following section reviews the literature on entrepreneurship in more depth.

2.7 Entrepreneurship

2.7.1 *Link to innovation*

As shown in section 2.2, there are many elements in the study of innovation, but subsumed within the wider process is the increasingly important “third leg” of entrepreneurship.

The word “entrepreneur” is a word that is borrowed from the French language, specifically the word “entreprendre” meaning “to undertake” or “to embark upon” (Hunter, 2007: 9).

Entrepreneurship is the focus of this section, which also includes a review of research on entrepreneurship in order to help create a rationale for the methodology described in chapter four. There is also consideration of how entrepreneurs are developed, showing the overlap with discussion of human capital, and the groundwork is laid for section 2.8 on scientific entrepreneurship, the topic where all the foregoing literatures connect.

Entrepreneurs are the economic mechanism by which technological knowledge is transformed into economic value and entrepreneurship is the key mechanism by which knowledge created in one organisation becomes commercialised in a new enterprise (Carlaw, Devine, Pirich, & Tullett, 2003)²⁵. Entrepreneurial firms are generally new and small, and a rising rate of new firm foundation (together with efforts to improve the performance of existing firms) can add significantly to economic well-being (Cromie, 1994). Small business in particular is best able to

²⁵ Citing Audretsch, D. (2002). *Entrepreneurship: A Survey of the Literature*. Prepared for the European Commission, Enterprise Directorate General

adapt to a changing environment and its structure allows it to adjust to technical change at a rate fast enough for survival (Thomas N Garavan & O Cinneide, 1994).

The importance of entrepreneurship in contributing to firm growth has been demonstrated (Baum, Locke, & Smith, 2001: 292; Sadler-Smith, Hampson, Chaston, & Badger, 2003). Within the European Union, there is a wider acceptance that:

Future prosperity hinges on the creation of vibrant indigenous businesses that are deeply rooted in the local economy. For this to occur, there is a need to expand the pool of local entrepreneurial talent (Thomas N Garavan & O Cinneide, 1994)

There are differences between entrepreneurs and other small business owners in general (Hansemark, 1998) although one international study defines entrepreneurs simply as those active in creating new firms (Reynolds, Bygrave, Autio, & Others, 2003: III). A useful conceptual distinction can be drawn between entrepreneurs, characterised by innovative behaviour and employment of strategic management practices, the main goals being profit and growth; and small business owners whose businesses consume most of their time and resources and provide most of their income (Thomas N Garavan & O Cinneide, 1994)²⁶.

Neither are entrepreneurs the same as managers (McCarthy, 2000: 5). The manager's role is to find ways of approaching production frontiers while entrepreneurship pushes out the frontier further (Baumol, 1993: 2-4; Durbin, 2004: 5-6). An outlier view is that management competence comprises both entrepreneurial judgement and organisational capability (Ghoshal, Hahn, & Moran, 1999). There is a

²⁶ With reference to Sexton & Bowman, (1984). Entrepreneurship Education: Suggestions for Increasing Effectiveness. *Journal of Small Business Management*, **22**(2), 18-25

whole literature on the evolution of firms past their entrepreneurial stages but this has explicitly been excluded from the current review.

Yu (Yu, 2001b) describes a Schumpeterian view of entrepreneurial discovery consisting of ordinary and extraordinary types and explains these in another paper:

In terms of mental constructs, ordinary discovery is a "backward" interpretation in a sense that the entrepreneur endeavours to exploit profit opportunities by doing some things better. This type of discovery largely promotes change within an existing situation (Yu, 2001a: in abstract)

Ordinary discovery may also involve entrepreneurs in simply conducting *arbitrage* or selling "for high prices that which he can buy for low prices" (Hébert, 1985: 274).

In contrast, extraordinary discovery is a:

Forward interpretation that involves a new dimension of interpreting events. In this case, the entrepreneur explores profit opportunities by doing some things drastically different from the traditional. This type of discovery enhances revolutionary change to the economy (Yu, 2001a: in abstract)

There are obvious similarities here with types of firm level innovation described in section 2.2.3. Extraordinary discovery perceives opportunities which are created by the entrepreneurial imagination. When a discovery brings major technological and organisational breakthroughs to the economy, it is termed Schumpeterian entrepreneurship, which encompasses three essential characteristics

First it can always be understood ex post; but practically never ex ante...second, it shapes the whole course of subsequent events and their long-run outcome. It changes social and

economic situations for good and creates situations from which there is no bridge to those situations that might have emerged in its absence. Third, the frequency of its occurrence has something to do with the quality of the personnel available in the society, with relative *quality* of personnel and with individual decisions, actions and patterns of behaviours (Yu, 2001b: 762)²⁷

Like innovation, entrepreneurship is a process that is risky (Berglund & Hellstrom, 2001). Perhaps for this reason the two are frequently confused, but innovation is a concept that tends to apply at the level of the firm or wider system whereas entrepreneurship is more likely to be practiced by individuals or small groups of individuals (Virtanen, undated). Virtanen provides a useful differentiation between the concepts of (1) *entrepreneur* who is an individual actor in the market (2) *entrepreneurial* which is a description of behaviour in the market and (3) *entrepreneurship* which combines the actor (entrepreneur) and the entrepreneurial behaviour.

The structure of the following discussion is loosely based - in reverse - on Virtanen's categorisation, beginning with the broader characteristics of entrepreneurship and moving deeper towards a description of the behaviour of entrepreneurs and their other attributes.

2.7.2 *Characteristics of entrepreneurship*

While the phenomenon is much discussed, has a long history (Hunter, 2007; D. T. Smart & Conant, 1994) occurs to some degree in all societies and all organisations and a number of common elements are recognised, there is a lack of consistent, universal theory of entrepreneurship (Virtanen, undated). An agreed definition has

²⁷ Citing Schumpeter, J. (1951). *The creative response in economic history*. In Clemence, R., *Essays of J.A. Schumpeter*. Cambridge MA. Addison-Wesley

not yet been found and is not likely to be. Nevertheless there are some consistent themes in the literature, and Smart and Conant (1994) have proposed a useful working definition based on their own comprehensive review:

Entrepreneurship is a dynamic goal-oriented process whereby an individual combines creative thinking to identify marketplace needs and new opportunities with the ability to manage, secure resources and adapt to the environment to achieve desired results while assuming some portion of risk for the venture (ibid: unnumbered)

Risk is a major recurring theme in the literature about entrepreneurship. As well, entrepreneurs often operate in situations of uncertainty – they don't always know what the probability is that a negative outcome will result from their activities. Entrepreneurs face four types of risk: financial; career; family and social; and psychological (McCarthy, 2000: 2)²⁸ but financial risk seems to be the most defining of entrepreneurial behaviour²⁹. Someone who takes other types of risks within an existing organisation may be known as an *intrapreneur* (D. T. Smart & Conant, 1994).

Numerous attempts have been made to measure the risk-taking attribute of entrepreneurs, but this is not just a function of personality. It also seems to reflect organisational context and history (McCarthy, 2000).

Entrepreneurship is a unique occupation characterized by fluid work roles, untried organisational structures and a myriad of requisite skill which many individuals with extensive experience of work organisations may misunderstand (Cromie, 1994).

²⁸ Citing Lises who defines risk as the probability of a negative outcome occurring from some course of action.. Lises, P. (1981). Who are the entrepreneurs? In Gorb, P., et al (eds) *Small Business Perspectives* (pp 33-50). London, Armstrong Publishing

²⁹ Although in Schumpeter's vision the entrepreneur is not the risk bearer - this role falls to the capitalist - the entrepreneur is more akin to a broker or arbitrageur and their flow of gains is temporary (Baumol 1993: 6-7)

Sadler-Smith, Hampson et al. (2003) explore the relationships among managerial behaviours (based on a competency model) entrepreneurial style and firm types (in terms of sales growth performance). From their own research and a summary of previous research they conclude that, while there are some shared competencies and behaviours, the principal differences between entrepreneurial management and non-entrepreneurial management include the following: (1) entrepreneurial managerial behaviours promote a culture of creativity and risk taking, create flat informal structures, and formulate strategy in order to take advantage of identified opportunities; (2) non-entrepreneurial managerial behaviours emphasise planning, control, monitoring, evaluation and formalised organisational structures (see figure 2.4).

Figure 2.4 Entrepreneurial and non-entrepreneurial competencies (Sadler-Smith, Hampson, Chaston, & Badger, 2003)

Global Competence Space		
Entrepreneurial managerial behaviours	Generic managerial behaviours	Non-entrepreneurial managerial behaviours
Managing Culture Managing Vision	Managing processes Managing stakeholders and environments Managing development	Managing performance
Entrepreneurial		Non Entrepreneurial

Research on entrepreneurship

Different disciplinary approaches to research on entrepreneurship have been used (McCarthy, 2000: 2; Virtanen, undated) including psychological, sociological, anthropological, behavioural, regional science and economics but:

Twenty-five years of characteristics and demographics-based research in the fields of psychology and sociology, which have attempted to discover cause-effect linkages between personality type or background, and the success of an entrepreneur, have met with failure (Mitchell, 1997: 123)

Rather than admitting defeat, Mitchell uses yet another methodology based on oral histories. The failings of initial investigations into the individual differences of entrepreneurs might have been due to a failure to take into account important contextual differences moderating the relationships between the characteristics of entrepreneurs and the performance of their new ventures (Wright, Hmieleski, Siegel, & Ensley, 2007: 792) but a considerable amount of research on entrepreneurship and its role in innovation does focus on contextual factors rather than on entrepreneurs themselves:

By the end of the 1980s opinion had clearly shifted away from explanations centred on the individual, towards theories that stressed the environment and the social backdrop to entrepreneurial behaviours (Llewellyn & Wilson, 2003: 341)

Smart & Conant (1994) criticise research efforts into the links between entrepreneurship and firm performance on the grounds that many entrepreneurial studies have failed to include organisational performance measures in their research designs, and much of the research on entrepreneurs completed in the last 40 years has been conducted by researchers in non-business disciplines. This deficiency is contrasted with the elevated status of the strategic management field, where strategy-performance linkages have been established.

Smart & Conant (ibid) cite Cunningham & Lischeron (1991)³⁰ who find four main approaches in entrepreneurship research. These include the study of personal

³⁰ Cunningham, J. Barton, and Lischeron, J. Defining Entrepreneurship. *Journal of Small Business Management*, (29)1. pp 45-61

characteristics, the recognition of opportunities, management and leadership styles, and intrapreneurship. Accompanying each of these areas is a set of specific beliefs about the nature of entrepreneurship, ranging from early thinking that entrepreneurs are great men with innate abilities, to viewing the entrepreneurial process as one of organisation and leadership. In broad terms, work in the area can be generally viewed as either trait-related or behaviour related.

Given the limited success and methodological difficulties inherent in pursuing the trait approach (discussed in more detail below) a behaviour or process-oriented approach has received increased attention in recent years. This looks at the entrepreneurial process in terms of the entrepreneur's activities rather than their specific individual traits. Smart & Conant (ibid) refer to Gartner (1988)³¹ who argues that the focus should be on what the entrepreneur *does* rather than on *who* the entrepreneur is. Virtanen (undated) suggests that entrepreneurship is more a process of *becoming* something than of *existing as* something i.e. there is a dynamic, time-based dimension.

A much-cited work describes the role of the Massachusetts Institute of Technology (MIT) in supporting technological entrepreneurs, using various case studies and considerable empirical research but only one of five “tracks” of research specifically on entrepreneurs themselves (Roberts, 1991). Other tracks focus on the firm, for example its financial base, strategy and growth. Roberts does however provide a useful taxonomy of influences upon success of technology-based companies made up of: *prefounding factors* such as family background, education, age and work experience, personality and motivation; *at founding factors*: technological base, degree of technology transfer from the source organisation; production orientation,

³¹ Gartner, W. (1988). “Who is the Entrepreneur?” Is the Wrong Question. *American Journal of Small Business*. (12)4. pp 11-32

financial base, initial capital; and *post founding factors*: market orientation, market interactions, marketing organisation and practices; financing; subsequent financing, managerial orientation, managerial skills acquisition and problem focus (ibid: 247). While all of these factors are linked, the focus of the current review is clearly on pre-founding factors in Robert's terms, and, notwithstanding the biases in research referred to above, there has been considerable study of these.

All research on entrepreneurship faces an inherent contradiction, which is:

How can we analyse and teach acts (*i.e. entrepreneurship*) whose nature is not yet known and whose effectiveness relies to a considerable degree on the difficulties others have in foreseeing them? (Baumol, 1983: 30)

It is however possible to identify indicators of entrepreneurial success, including contextual factors which may contribute to the formation of entrepreneurs or individual attributes that are required to underpin entrepreneurship. There is controversy as to whether the requisite individual attributes are innate or can be developed later in life. Many strong opinions are advanced, often on the basis of the holder's own experience or interests, as to whether entrepreneurs are born, or *made* (Anon, 2005; Fox, 2005; Thomas N Garavan & O Cinneide, 1994; Turner, 2005). Luck and timing can be crucial and some useful models of life stages have been developed (Janson & McQueen, 2003; Rae, 2000). Interestingly, speed of action or rate of change in the environment, both popularly assumed to be aspects of entrepreneurship, do not come through strongly in the literature as necessary factors in the process (even though they are often present).

2.7.3 Attributes of entrepreneurs

As with management competencies it is possible to assess differences in performance of various entrepreneurial skills among businesspeople with varying entrepreneurial orientation levels, for example using psychometric testing, and Roberts (1991: 86) reports using the Myers-Briggs type indicator test.

The defining characteristics of the entrepreneurial mindset are the passionate seeking of the best new opportunities with enormous discipline (i.e. not every option); focusing on adaptive execution; and engaging the energies of everyone in the entrepreneur's domain (McGrath & McMillan, 2000: 2-3).

Yet entrepreneurs are so different from one another that it is impossible to find an average one (Roberts, 1991: 26-9; Virtanen, undated; Welsch & Young, 1982: 50). McCarthy (2000: 5) identifies two main types of entrepreneurs: the charismatic type who is more inclined to be risk prone; and the pragmatist who is more risk averse. Different sets of motivations have also been identified (see below).

Rather than advance the case for either traits or skills and behaviours being of most importance in a consideration of entrepreneurship, all can be allowed for by using Smart and Conant's definition and Boyatzis' competency model. In their work on entrepreneurship, Baum et al. (2001) refer to Boyatzis (1982) but adopt a more disaggregated and dynamic view of the relationship between motives, traits and competencies. As operationally defined their research, an entrepreneur's traits interact with motivation, skills, strategy or behaviour and underpinning competencies as in figure 2.5.

Figure 2.5 The interaction of various factors of entrepreneurship (Baum, Locke, & Smith, 2001)

Entrepreneurial behaviour

It is possible to recognise entrepreneurs because they are:

True to themselves and their ideals; know time is a limited resource; are able to identify market opportunities; use time and money creatively; use their own skills and knowledge to advance themselves; honour all agreements; know responsibility goes with rights; establish their identity through their work; identify resources and critical priorities; improve on existing products and services and produce new ones (Fleming, 1988: 24-38)

Entrepreneurs “capitalise on *change*, or even create it” (Bagby, 1988: 5). McClelland (1961: 331) presents a picture of the entrepreneur as like the mythical Hermes - “forward looking, active, restless”.

Entrepreneurs are *hard working* and work harder when challenged and when the work to be done requires ingenuity rather than standard procedures. But they require concrete feedback in the form, for example, of production volume or profit as measures of how well or how poorly they are doing (Roberts, 1991: 48). Hard work can become “workaholism” wherein an individual’s entrepreneurial efforts become the focus of their lives and the demands of being successful are so great that there is little energy left to devote to personal relationships (Belt, 1990).

Entrepreneurs *make judgements or decisions* on the basis of imperfect information and in the face of uncertain situations and outcomes. They are *future oriented* in that they think ahead more in their decision making (Roberts, 1991: 48; Shane, 2000). Though luck and external forces play a part, successful entrepreneurs are the ones whose judgements prove to be correct (Hunter, 2007: 16). Busenitz and Barney (1997) compare the way entrepreneurs and managers make decisions, and find that entrepreneurs tend to use heuristics - simple decision rules that reduce the complexity of decision processes - more extensively than managers do.

Opportunity recognition is seen by many as a key behaviour of entrepreneurs (Baum, Locke, & Smith, 2001: 293; D. T. Smart & Conant, 1994) although to Shane (2000) who is a follower of the Austrian school of economics, opportunity recognition is driven more by the distinctive knowledge possessed by individuals than by their personality traits. This idiosyncratic information allows people to discover opportunities that others cannot see, even if they are not actively searching for them. *Discovery* - recognising an opportunity as it arises, is differentiated from *search* where someone knows what they are looking for. Great emphasis is placed on the importance of market knowledge and working backwards from market knowledge to discovery. Also:

People will be more likely to discover opportunities in sectors that they know well than in sectors that are "hot", because the investment in the information necessary to recognise opportunities is likely to occur long before a particular sector is popular. Therefore, potential entrepreneurs should look to discover opportunities in what they know rather than in what is popular with other entrepreneurs (Shane, 2000: 466-7)

The entrepreneur is not only ready and waiting when opportunity knocks; he or she knows where to wait! (Roberts, 1991: 103)

This applies to scientists as well. Bray and Perry (1994: 47) provide a good description of a technology platform while finding that:

The most commercially successful innovations arose in cases where scientists did not need to obtain industry support at the outset of the project because the innovation was targeted to a market that the scientist was already operating in....in both (successful) projects, scientists had research knowledge relevant to the potential commercial application of the investigations. They were also exploiting unique skills or resources that gave the technology a strong advantage over alternatives³²

Influential New Zealand entrepreneurs in the early days of the country's colonial history typically focused on their core knowledge and capabilities and were thus able to capitalise on opportunities for developing innovative products or services to meet new market needs:

The New Zealand entrepreneur's business strategies were not so much random choices as reflections of personal aptitudes and capabilities Hunter (2007: 236)

There seems to be a difference between having an idea which might appear from anywhere:

You'd think about it all day and night and you're in the shower in the morning, and it flashes out of the subconscious mind (Kennedy, 1993: 22);

and identifying an opportunity, which is the connection of idea with application. Then there is the *realising* of the opportunity (Ravasai & Turati, 2004: 5). This means that having identified an opportunity, the entrepreneur develops a feasible business idea,

³² The methodology used in this research has been heavily criticised by Winsley (1997)

validates it, acquires resources and designs structures to link the business concept to the needs of the consumer (see figure 6.2). Entrepreneurs often challenge existing wisdom and reconcile opposing forces, moulding external information with their individual decision-making processes. Socially marginal groups are often attracted to entrepreneurship because it enables them to avoid “selectors” who otherwise decide whether an individual is suitable for a particular job. Nevertheless entrepreneurs need a considerable amount of social and interpersonal skill to build and cultivate networks and other social capital that will enable them to glean the information and resources they need (Baron & Markman, 2000; Cromie, 1994).

Early New Zealand entrepreneurs traded in trust and built up social capital through membership of family and community networks and formal associations and donations to good works. This social capital was also drawn on, yet:

This was no mere corporate strategising or clever marketing, for these entrepreneurs it was part of their commitment to building an industrialised society that was economically and socially robust and viable (2007: 236)

Entrepreneurs have to be able to organise and lead others if their endeavours are to be successful. At the earliest stages, most will tend to be more or less creative, visionary, opportunistic, intentional, and controlling (D. T. Smart & Conant, 1994: 374). But while some researchers have explained firms’ founding processes as a series of simple, linear steps with logical foresight, Shane and Venkataraman (2003: 183) suggest that this explanation should be revised to one involving a more nuanced understanding of the process that involves enactment, incrementalism and path dependence – similar to Virtanen’s (undated) suggestion that entrepreneurship is a process of *becoming* and to the path dependency of organisational strategy discussed in section 2.6.3.

Motivation in entrepreneurs

McClelland (1961) is a seminal work on motivation which is cited in much of the literature ever since³³. McClelland identifies three main needs that drive behaviour – those for achievement, power and affiliation. The relative strength of each of these needs varies from individual to individual, and there are correlations with family, social, cultural and socio-economic background (McClelland, 1961: 43). Entrepreneurs have a particularly high need for achievement (*n-Ach*). Here McClelland draws on Max Weber's theories about the relationship between protestantism and capitalism (ibid: 47) although he sees a correlation between the two rather than a causative link - religion could have been adjusted to fit an already prevailing culture (ibid: 406). Driven by *n-Ach*, entrepreneurs thrive on the satisfaction gained from knowing that they have been personally responsible for a successful outcome (or even an unsuccessful one). Thus entrepreneurs are likely to undertake actions that have moderate risk characteristics, rather than those at either end of the risk continuum (Roberts, 1991: 48). Roberts describes the rationale for this as being that: in a situation with complete certainty as to outcome, the entrepreneur receives little satisfaction of his or her need for achievement because of the predetermined nature of the result; and in the pure chance situation, like winning a lottery, the individual again derives little satisfaction of their need for achievement because of the lack of influence of skill on the outcome. Failure is also more probable in extremely high risk settings and the entrepreneur would again be unlikely to attain his goals in such cases, thus frustrating a high *n-Ach*. Outcomes of decisions with moderate risk depend on a mixture of skill and chance and thus are

³³ Boyatzis (1982) is also clearly influenced by a 1973 study by McClelland which sought to determine which characteristics of managers are related to effective performance in a variety of management jobs in a variety of organisations

the situations most apt to satisfy the high n-Ach entrepreneur. This explains another key attribute of entrepreneurs, that of self-efficacy which is defined as:

People's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives (Bandura, 1994: 71)³⁴

People with high levels of self efficacy:

Approach difficult tasks as challenges to be mastered rather than as threats to be avoided. Such an efficacious outlook fosters intrinsic interest and deep engrossment in activities. They set themselves challenging goals and maintain strong commitment to them. They heighten and sustain their efforts in the face of failure. They quickly recover their sense of efficacy after failures or setbacks. They attribute failure to insufficient effort or deficient knowledge and skills which are acquirable. They approach threatening situations with assurance that they can exercise control over them. Such an efficacious outlook produces personal accomplishments, reduces stress and lowers vulnerability to depression (Bandura, 1994: 71)

Roberts (1991: 89) describes how in studies of *career anchors* a small number of entrepreneurs were found who:

Discovered early in life that they had an overriding need to create a new business of their own by developing a new product or service, by building a new organisation through financial manipulations, or by taking over an existing business and reshaping it in their own image....

The challenge of business initiation lies in the setting wherein the individual can measure for himself his "true worth" (Roberts 1991: 92-3)

³⁴ The implications of this are potentially quite profound – that rather than a strong sense of self efficacy *enabling* entrepreneurship, entrepreneurship is entered into *in order to enable entrepreneurs to express or experience self efficacy*. In a similar vein, Baum et al. (2001: 294) propose that traits affect competences (in their terms) because individuals practice what they like, and practice develops "skills". This supports the notion of "active learning" as a way of developing the competencies of entrepreneurship (see section 2.7.4)

The literature reveals that most entrepreneurs seek and experience personal autonomy, a sense of achievement and enhanced job satisfaction from proprietorship. While not the prime motivator, the potential to earn substantial sums of money acts as a powerful reinforcer of behaviour. Most business proprietors are keen to be in control of their own lives rather than accept the subordination frequently encountered in bureaucratic organisations. Putting a venture together and making a success of it requires a good deal of independent action on the part of the entrepreneur but it also affords a strong sense of accomplishment to those individuals who manage to do so (Cromie, 1994).

However shows that the owners of rapidly growing firms are motivated by the desire to exploit a market opportunity, not by the desire to gain autonomy nor by the desire to self actualise (Cromie, 1994)³⁵. McCarthy (2000) describes two types of entrepreneurs: the *craftsman* and the *opportunist*. The craftsman is motivated to set up a business in order to do the type of work that (s)he enjoys whereas the opportunist focuses on profit, growth and building a large organization.

Other descriptions of what motivates entrepreneurship include a critical “displacement event” or dissatisfaction with a work situation (Haynes, 2003: 114-5) or crisis (McCarthy, 2000: 6). McCarthy suggests that the underlying cause of crises seems to rest with the dominant personality of the entrepreneur (ibid: 8) but it might also be the case that such situations are triggers as much as fundamental motivators.

³⁵ Citing Storey, D., Watson, R. & Wynczyk, P. (1989). *Fast Growth Small Firms*, Department of Employment Research Paper. p. 67

Traits of entrepreneurs

A trait is a characteristic or typical pattern of individual behaviour, and combinations of traits are often used to distinguish personality types (Morris, Schindehutte, & Lesser, 2002: 35). Traits are constructs to explain regularities in people's behaviour, and help to explain why different people react differently to the same situation (Llewellyn & Wilson, 2003). Unlike values, traits can be inherited as well as learned. However, many traits imply the development of certain values. For instance, because of his or her sense of self-responsibility for events a person with a strong internal locus of control³⁶ might be expected to more highly value individualism. Further, traits can acquire values, such as the person who values being adventurous or being independent (Morris, Schindehutte, & Lesser, 2002: 35).

In psychology, the "Big Five" personality traits are five broad factors or dimensions of personality discovered through empirical research. These factors are Neuroticism (or Emotional Stability) Extraversion, Agreeableness, Conscientiousness, and Openness to Experience (Barrick & Mount, 1991). Each factor consists of a number of more specific traits. For example, extraversion includes such related qualities as sociability, excitement seeking, and positive emotions (Llewellyn & Wilson, 2003).

Dunette et al. (1996: 640, 651) query whether the big five are truly basic and also point out that they vary in breadth. Traits alone are insufficient to explain new venture success and some have suggested that the search for a distinct entrepreneurial personality is futile (McCarthy, 2000: 2; 8). Hellström et al. (2002: 268) also criticise the trait-based approach as being too *reified* and rigid and take

³⁶ "Locus of control describes a continuum of beliefs or expectancies ranging from internal to external. The internal end of the continuum refers to the belief that outcomes are a consequence of one's own behaviour, whereas external control represents a belief that events are independent of one's own behaviour and are the result of forces such as fate, luck and powerful others" (Welsch & Young 1982: 51)

more of a sociological view, encompassing past, present and future experiences, needs and wants of the subject embedded in a social setting.

Llewellyn and Wilson (2003) question whether the (extreme) rejection of links between personality traits and entrepreneurial behaviour is justifiable on the basis of the methodologies used, for example many studies were based on very small sample sizes and others centred on the use of narrow traits, especially risk taking, achievement motivation and locus of control (Ibid: 342).

In support of personality theories, Baum et al. (2001: 292) point to the importance of *personal predispositions* for venture success. They find that CEOs' specific competencies and motivations and firm competitive strategies are direct predictors of venture growth, and that traits and general competencies and the environment have significant indirect effects.

Several studies have shown a cluster of personality traits common among all successful entrepreneurs, including the previously-discussed need for achievement as well as persistence, innovative outlook, low need for conformity, high energy level, risk taker and efficiency (Belt, 1990). The factors for which empirical evidence for links to entrepreneurial success are strongest are: high self-efficacy; ability to spot and recognise opportunities; high personal perseverance; high human and social capital; and superior social skills (Markman & Baron, 2003: 287).

Zhao & Seibert (2006) use meta-analytical techniques to examine the relationship between personality and entrepreneurial status. Their results indicate significant differences between entrepreneurs and managers on four personality dimensions such that entrepreneurs score higher on conscientiousness and openness to experience and lower on neuroticism and agreeableness. No difference is found for

extraversion. This differs from Roberts (1991: 96) who finds technical entrepreneurs to be more introverted than the general population.

McCarthy (2000) finds that risk taking is related to several factors which include innate personality traits but also learning and experience of crisis; as well as business-related factors such as the type of venture founded and the nature of the industry environment.

Hansemark (1998) claims that only two psychological attributes (of all those that have been extensively studied) have shown any significant relation to entrepreneurship - need for achievement and locus of control. Many other researchers suggest that these are simply artefacts of cultural conditioning, with the latter comprising a mix of other dimensions of personality and cognition (Llewellyn & Wilson, 2003).

The more internal a person's locus of control, the more value that person attaches to utilising a variety of sources of information. Persons with low self-esteem place high value on professional sources (bankers, accountants, and lawyers), while those with high self-esteem tend not to seek out professional advice but to go directly to written and institutional sources without needing an intermediary to interpret the data. (Welsch & Young, 1982).

Other attributes

While considerable attention has been devoted to the personality traits of entrepreneurs, less has been given to values, especially outside of a Western context, and some have argued that entrepreneurship is largely a values based activity (Morris, Schindehutte, & Lesser, 2002). Values are related to but different

from personality. To have a value is to maintain an enduring belief that a specific mode of conduct or end-state of existence is preferable to the alternatives. Thus there is a close relationship between values and motives (Ibid: 36).

Values traditionally associated with entrepreneurship, such as risk, individualism, competitiveness, wealth generation and growth may be more consistent with Western cultures and conflict with closely held values within various ethnic subcultures. There is thus an ethnicity effect within entrepreneurship (Morrison, 2000). In an entrepreneurial context, where a value associated with economic innovation or individual success is inconsistent with the conventional traditions of a culture, the entrepreneur is likely to be frowned upon or even hated by others belonging to the cultural group (Morris, Schindehutte, & Lesser, 2002). While the reference here is to ethnic subcultures, presumably the same argument could be applied to other subcultures – for example in science or business:

As a function of “going it alone” an entrepreneur may feel distanced or isolated from society in a general sense, or from a particular group with whom they were once involved; someone leaving longstanding employment to start a business, for example. This sense of isolation may cause a disinclination to be creative, since that further tends to distance the individual. This has been described as “guilt” resulting from indulging in creativity viewed as a counter-normative pursuit (ibid: 157)

Creativity is another common theme in the literature, although there may be some confusion between creativity, opportunity recognition and problem solving. Researchers have identified several different aspects of creative thought, including: divergent thinking; attitudes and interests; personality traits; biographical inventories; and creative accomplishments. Some creativity is goal oriented and some is proactive or internally driven and as with the discussion of value conflict above, once again may create tension:

Creativity is essentially an individual act and serves to emphasise the individual characteristics of the creator. However, in thinking and acting creatively, the emphasising of individuating characteristics may cause a tension between that individual and the need for connectedness within the group (Walton, 2003: 153)

2.7.4 Developing entrepreneurs

It is clear from the literature that while entrepreneurship may be influenced through formal education or on-the-job training, its origins lie more widely and it is unlikely that the development of entrepreneurial attributes could be enhanced through traditional means alone. Thus a wider, more holistic view of their development is required (Berglund & Hellstrom, 2001; Rae, 2000) as is also the case with human capital in general (see section 2.4.6).

Apart from personality and motivation, there is considerable research available on the formation and contribution of other pre founding factors for entrepreneurship (Roberts 1991). Roberts concludes that entrepreneurs are very likely to have had self-employed fathers (Roberts 1991: 95).

Roberts' findings are biased towards fathers and sons but this gender bias reflects the reality of his findings and those of Scherer et al. (1990) and Allen et al. (2007) and the sample drawn for this research project (see section 4.11.2). The gender effect in entrepreneurship is probably changing (Wright, Hmieleski, Siegel, & Ensley, 2007) but its exact nature and its causes are not investigated here.

Other research describes how large numbers of practising entrepreneurs of both genders appear to have parents who have owned a business. This suggests that

social learning differences have a strong impact on shaping preference for an entrepreneurial career (Scherer, Brodzinski, & Wiebe, 1990).

However Roberts also finds that family background has no impact on entrepreneurial success and he is of the school of thought that successful entrepreneurs are made, not born. McLelland (1961: 403) thinks that the main way to influence the incidence of n-Ach is to focus on the family and child-rearing practices, and hypothesises that:

Technique-oriented courses may conceivably be less effective than goal- or fantasy-oriented courses in developing n-Ach (ibid)

Other researchers have found the links between early experience and entrepreneurial behaviour to be more tenuous. Westrup (1999) for example reports that peers have more influence on the formation of non-inherited personality traits than do parents.

Experience may be the major source of learning:

It is this ability to learn from mistakes that makes successful entrepreneurs....successfully coping with extreme difficulties while very young seems to set a pattern of resilience and ability not only to cope with, but also to learn from, adversity. It is this ability to learn from their experience which is, we suspect, the key attribute of these successful individuals (Sullivan, 2000: 163)³⁷

Garavan and O Cinneide (1994) are very critical of formal education and training programmes as means of developing entrepreneurs. Given that the three major features of innovators and entrepreneurs are their knowledge, skills and attitudes, in most formal education situations:

³⁷ Citing Cox, C. & Jennings, R. (1995: 9). The foundations of success: the development and characteristics of British entrepreneurs and intrapreneurs. *Leadership & Organization Development Journal*. (16)7

The first is treated thoroughly and in an analytical manner; the second receives sketchy attention and is harder to impart within formal educational systems; the third is hardly addressed at all. Yet this latter topic of attitudes, the psycho-social forces of the individual and the cultural context, is of prime importance in influencing innovative and entrepreneurial behaviour patterns. If entrepreneurship education and training is to be effective, the contention is that it must be so not only through factual knowledge and the limited skills acquirable in the classroom, but also through the stimulation of new ventures, the success of those ventures and the increasing capacity of the entrepreneur to pursue even greater success (ibid: 5)

Garavan and O Cinneide argue that the apparent rarity of the psychological and behavioural attributes which constitute entrepreneurship, the problems in establishing exactly what these attributes are (particularly at the psychological level) so that promotional strategies can be devised, plus the evidence that entrepreneurs may be apathetic towards education and training in most forms, all tell against entrepreneurial education and training interventions being resource-effective. They point out that management techniques tend towards order, rationality, predictability, tried and tested methods and the general depersonalisation of economic endeavour. This emphasis appears difficult to integrate into the more charismatic approach of genuine entrepreneurs without damaging their special potential (although as discussed above, it should not be assumed that all entrepreneurs are “charismatic”). It is suggested that the vital element of an educational programme for entrepreneurs is the inculcation of attitudes, values, psychological mind sets and strategies necessary for the subsequent taking on of the entrepreneurial role.

Garavan & Cinneide (ibid) argue for the use of more subtle methods like action learning and project management rather than reliance on technical approaches to teaching entrepreneurs – i.e. giving “a quick fix” programme in those disciplines

which the participants are not familiar with from their work experience, such as accountancy, budgeting, marketing, law and personnel management. While these aspects are very important if totally unknown, education and training in them accomplishes little more than giving a basic insight in single disciplines to enable the entrepreneur to talk to experts in each field. Teaching entrepreneurship skills needs to take account of the reality that entrepreneurship has to do with the management of loosely coupled systems.

Cope & Watts (2000) also argue in favour of experiential learning in order to create change in one's orientation or attitude.

In the education system, Gibb (1987) suggests that it should be possible, without abandoning some of the basic values, to move more flexibly towards encouraging students to develop their entrepreneurial potential by, for example:

- learning by doing;
- encouraging participants to find and explore wider concepts relating to a problem from a multi-disciplinary viewpoint;
- helping participants to develop more independence from external sources of information and expert advice, and to think for themselves - thus giving ownership of learning;
- encouraging use of feelings, attitudes and values outside of information; this, in general, will place greater emphasis on experience-based learning;
- providing greater opportunity for building up of networks and contacts in the outside world linked with their learning focus;

- helping participants to develop emotional responses when dealing with conflict situations, and encouraging them to make choices and commitments to actions in conditions of stress and uncertainty (ibid: 19)

Smeyers (2007: 7) also evokes the name of Wittgenstein in arguing that essential practices are learned foremost by doing rather than by teaching, and that a good deal of practical know-how is tacit, learned not through explicit representation and explanation but through unspoken processes of observation and emulation.

Garavan & O Cinneide (1994) are of the view that the portfolio of skills of many entrepreneurs is relatively narrow. They claim that it is unusual to find breadth and depth of knowledge at the same time - many entrepreneurs tend to be specialists rather than general managers, with in-depth knowledge in product development, organisation, design, or other areas but needing consulting expertise in other aspects, i.e. finance and sales. In this view, what is required is closely related to the ability to plan and to organise and the real entrepreneur is a person who can organise others and tap into the knowledge and expertise required on all aspects of establishment and start-up.

But reinforcing the lack of consensus on these matters, Durbin (2004) describes entrepreneurs as:

Jacks of all trades who may not excel in any one skill, but are competent in many (ibid: 7)

Data on alumni from Stanford Graduate School of Business also show that entrepreneurs are more likely to have held a number of prior roles, and taken a more dispersed set of courses and:

While part of the skill set of entrepreneurs is amenable to development through training (such as analytical ability), other elements may be innate (such as imagination and attitudes to risk), while others (such as foresight, or soundness of judgment) may be honed through learning-by-doing (ibid)

2.7.5 The match between research on competencies and entrepreneurship

As can be seen, there is a broad literature describing the requirements and attributes of successful entrepreneurs, entrepreneurial behaviours and entrepreneurship. Different descriptions contain many common elements, though they tend to reflect consensus-building in specific contexts and do not necessarily follow strict, formal, definitional constraints (Rychen, 2002). Oates (2001) is critical of such approaches where competencies have been identified through consultation and consensus rather than being theory or empirically based (see appendix one for examples).

Many of the sets of attributes that have been identified include items that are situated at different conceptual levels or have different levels of generality or follow different criteria of categorisation, reflecting the particular research framework and focus that has been applied. Nonetheless some common themes arise from this material, showing a remarkable propensity to being sorted into the *layers* of the Boyatzis' competency model as in table 2.2 suggesting that hitherto, each research approach has looked at only one part of the picture and reinforcing the conclusion that what is required is the more comprehensive and integrated view provided by a competency perspective, as developed further in section 2.8 and chapter four.

Table 2.2 Match between competency layers and entrepreneurship research

Layers of Boyatzis model	Commonly occurring themes in Entrepreneurship literature (successful entrepreneurship)
Cultural environment in which the job exists	Entrepreneurship highly valued Failure tolerated Supportive wider systems
Organisational environment in which the job exists Functional and situational demands of specific jobs	Untried organisational structures Multiple sources of information Multiple forces Loosely coupled systems Adversity Often minimal resources Conditions of ambiguity, uncertainty and chance Opportunities unseen by others
Specific action or behaviour demonstrated	Recognise opportunity Have Vision Take risks Integrate information Reconcile opposing forces Manage loosely coupled systems Use (often minimal) resources Develop business ideas Expose ideas to the marketplace Work flexibly Challenge existing wisdom Self-direction Self-expression Compete aggressively
Skills	Multiple High sensitivity to the environment High sensitivity to the market Interpersonal/social skill Creativity Planning Organising Synthesising insight and action Persuading others Ability to change
Self-image	High level of self-efficacy
Social roles	A variety of roles Outsider
Motives	Do new things Change Growth Profitability Autonomy Action
Traits	Extraversion <ul style="list-style-type: none"> • optimism Openness to Experience <ul style="list-style-type: none"> • unpredictable • dislike restraint, restriction, routine Conscientiousness <ul style="list-style-type: none"> • self reliance • perseverance • resilience • intentional

2.8 Scientific Entrepreneurship

(W)hen we reject the traditional view of professional knowledge, recognising that practitioners may become reflective researchers in situations of uncertainty, instability, uniqueness and conflict, we have recast the relationship between research and practice. For on this perspective, research is an activity of practitioners. It is triggered by features of the practice situation, undertaken on the spot, and immediately linked to action. There is no question of an “exchange” between research and practice or the “implementation” of research results, when the frame- or theory-testing experiments of the practitioner at the same time transform the practice situation. Here the exchange between research and practice is immediate, and reflection-in-action is its own implementation (Schön, 1983: 308)

2.8.1 *Locating competencies of scientific entrepreneurs*

In the introduction to this chapter (section 2.1) the metaphor of a three-legged stool is used to describe the organisation of the literature review that follows. The innovation “seat” cannot be studied without adopting a whole-of-system, multi-disciplinary approach to each of the contributing factors. However therein lies the risk of being overwhelmed by the sheer size of the overall topic, and some kind of organising principle is required. It is here that the competency concept proves its worth. Competencies grow out of a human capital perspective and provide a lens through which to view RS&T and entrepreneurship, while also including recognition of the essential role that context plays. Competencies link the three legs of the stool and provide reinforcing.

However it is both desirable and possible to focus even further. If we look deeper inside the competency circle of figure 2.1, we might see that there are specialised

competencies relating to the realms of RS&T and entrepreneurship alongside generalised other competencies. All these competencies overlap and partly complement each other. Some attributes might be unique to one realm and incompatible with others, while some are common, adaptable or transferable. It is possible to speculate on the types of behaviour in each area of overlap, and in particular in the central zone where scientific entrepreneurship is to be found. Figure 2.6 shows this location, and provides the desired further degree of focus for study. As will be seen, the Venn diagram shown in figure 2.6 is also nested in the extended competency model (figure 4.2) and the overall research framework (figure 4.3).

This section draws together literature that is specifically relevant to the concept of scientific entrepreneurship so as to locate the related competencies as shown in figure 2.6 and provide focus to the research.

Figure 2.6 Conceptual location of the competencies of scientific entrepreneurship

2.8.2 Similarities and differences

Although the importance of RS&T and entrepreneurship for innovation is well recognised, references to *scientific entrepreneurship* are not common in either the scientific or entrepreneurship literature (Oliver, 2004: 584). Roberts (1991) and others come close with *technical entrepreneurs* and Etzkowitz (1998: 824) describes *entrepreneurial scientists* but in terms of their abilities to write applications to funding

agencies. Slaughter and Leslie (1997) write of *academic capitalists* (see section 2.3.5) who are state-subsidised, do not want to face the market without government funds and turn to commercial partners because the risks of taking product to market on their own are great (ibid: 195; 203).

Given the knowledge required, it would seem logical that the commercialisation of scientific research needs to be more than mere arbitrageurship - buying at a low price and selling high. It is possible however that an entrepreneur could conduct a form of arbitrage by acting as a go-between or *broker* in bringing together the two sides of a combined scientific and business opportunity. Alternatively, a business person could reach into the world of science or a scientist could act as an entrepreneur.

But a question arises as to whether the ways of science are compatible with the ways of entrepreneurship. Oliver (2004: 584) identifies an inherent conflict between entrepreneurship as an individualised behaviour and research as a collaborative process. This would seem to misunderstand the mostly collaborative nature of true entrepreneurship as described in other literature but there may also be values conflict, for example between the information sharing of science and the secrecy of business. Finding the right balance between the two is a delicate challenge that not all can negotiate (Janson & McQueen, 2003: A 30). It is possible that scientists who are “insiders” may have to become “outsiders” if they are to become entrepreneurial and this comes with a personal cost (see section 2.3.6 and 2.7.3). Merton (1973) describes a famous set of *norms* for science first developed in 1942 and often taken as a point of departure in studies of knowledge validation (Mansilla, 2006: 18) Merton’s norms have been defined and updated by Ziman (1984) and are shown in table 2.3 along with some comparison with putative entrepreneurial norms.

Table 2.3 Comparing norms for science with those for entrepreneurship

Scientific Norms (Merton, 1973)	Definition*	Compatibility with entrepreneurship
Communalism	Science is public knowledge, freely available to all	<i>Low – Entrepreneurship aims to exploit knowledge for private gain (although it seeks to make applications as widely available as is possible)</i>
Universalism	There are no privileged sources of scientific knowledge. i.e. discovery claims and theoretical arguments should be given weight according to their intrinsic merits, regardless of the nationality, race, religion, class, age or scientific standing of the person who produces them	<i>Medium – entrepreneurship is dependent on broader social capital and is not as “neutral” as science claims to be, although markets may be tending this way</i>
Disinterestedness	Science is done for its own sake	<i>Low – entrepreneurship is done for the sake of practical outcomes</i>
Originality**	Science is the discovery of the unknown (scientific research results should always be novel)	<i>High – entrepreneurship is based on seeing opportunities that others cannot</i>
Scepticism	Scientists take nothing on trust	<i>Low – business depends on trust, although it is not naive</i>
<p>*From Ziman (1984: 84)</p> <p>** Somewhat ironically, originality is not one of Merton’s original norms. It is added by Ziman, who also proposes <i>curiosity</i> as a scientific <i>virtue</i> (ibid: 87)</p>		

Much scientific endeavour is pragmatic and aimed at prediction (Merton, 1973: 270)

but:

Pragmatic considerations do not fully cover the intellectual goal of science – that is understanding. Prediction is not the necessary and sufficient condition for scientific explanation (Ziman 1984: 44)

This is a major point and in Ziman’s view (ibid) explains a difference between the purposes of science (understanding and explanation) and business (prediction).

As with “ordinary” entrepreneurship there has been more of a focus in studying the *context* of what is often called technology entrepreneurship rather than on the human capital *content*. For example Murray (2004: 652) writes that the precise role that an inventor plays appears to be determined by a range of factors which include personal preferences but also: career stage; institutional barriers; professional norms and the incentives provided by the firm. Shane and Venkataraman (2003)³⁸ introduce research papers on technology entrepreneurship derived from a whole range of disciplines and using a range of methodologies, yet there is no emphasis on the role of human capital except that the authors end with the question: “(h)ow do the characteristics of firm founders influence the development of new technology companies?” Paradoxically, the same paper criticises the so-called person-centric nature of traditional literature on entrepreneurship. A second special issue³⁹ contains current thinking on scientific and technological human capital (STHC) but focuses on systemic and background factors and attributes such as the ability to source funding.

In yet another special issue⁴⁰, the role of human capital in technological entrepreneurship is examined. The editors note that there is little evidence in previous research on the nature of entrepreneurs and that across a number of special issues there has been relatively little attention to the role of human capital. They aim to extend the conversation on technological entrepreneurship by reaffirming the central role that individuals and teams play as the driving forces behind the development and growth of technology-based ventures (Wright, Hmieleski, Siegel, & Ensley, 2007: 792).

³⁸ *Research Policy*. (May 2003). **32**(2)

³⁹ *Research Policy*. (May 2004). **33**(4)

⁴⁰ *Entrepreneurship Theory and Practice*. (2007). **31**(6)

Markman and Baron (2003: 284) describe technology entrepreneurship in terms no different from the foregoing discussion of entrepreneurship in general. But Roberts (1991) sees differences between technical entrepreneurs and others. For example, technical entrepreneurs tend to be more highly educated than "ordinary" entrepreneurs although they tend to cluster around the master's degree educational level (ibid: 60, 111).

Entrepreneurs in MIT laboratory spin-offs are of an average age of 34 against a representative 38 years for their industrial and mixed source counterparts and typically have about 13 years of work experience before starting their own companies. The work experience of technical entrepreneurs differentiates them from other entrepreneurs. As opposed to the "school of hard knocks" they tend to get experience with one technology source organisation (Roberts, 1991: 65; 70-71).

Technical entrepreneurs come far more frequently from development work than from research; the key initial technologies of the new firms are transferred primarily from development projects carried out by the entrepreneurs at their previous employers; initial capitalisation is typically very small and provided from the entrepreneurs' personal savings. Multiple co-founders raise larger amounts of initial capital; prior supervisory, managerial, and especially sales experience by founders contributes to successful enterprises; multi-founder teams generally perform far better than single founders; and "founders diseases" are widespread but not universal, with two-thirds of the founders of successful technological enterprises being displaced before their companies achieve "super success" (Roberts 1991: 26-9).

Leaving aside the strong knowledge requirements for science, the literature seems to suggest that some attributes of scientists and entrepreneurs are similar - for example the desire for autonomy and creativity. Self-efficacy is more often mentioned with

respect to entrepreneurs, but there is no reason to believe this to be an attribute that high-performing scientists lack. However even those aspects which are superficially the same may be qualitatively different, for example scientific research does require a degree of risk taking but it is also subject to rigorous review processes which are painstaking and often slow. This does not discount the possibility of leaps in thinking but it does seem generally at odds with entrepreneurial processes wherein an individual acts on imperfect information, backs his or her own judgment and is judged retrospectively by results in the marketplace.

Research into the nature of technology-based entrepreneurship has suggested that there is a divide between scientist- or technician-based entrepreneurs and commercially-based (or opportunist) entrepreneurs (Jones-Evans, 1995, 1996; Roberts, 1991). The implications of this are that provision of commercial expertise might be most appropriate for the technically-based scientist seeking to commercialise new technology, while the commercially orientated entrepreneur may require technical assistance. However while it is theoretically possible for a businessman with substantial surplus capital and no technical experience to begin a new high technology business, most new high technology small firm founders are technical entrepreneurs (Boussouara & Deakins, 1999). Ravasai and Turati (2004) caution that:

In the absence of a related knowledge base, entrepreneurs may eventually be forced to abdicate their leading role in the development process and gradually lose the capacity to assess the levels of risk and return associated with the completion of the project. In this respect, our findings seem to discourage initiation of explorative ventures whose technological platforms are distant from the entrepreneur's core technological and scientific domains (ibid: 2-3)

This suggests that those without deep knowledge should not be commercialising technology. Their involvement might be resisted in any case, as Slaughter & Leslie (1997: 200) find that Professors involved in commercialisation resist efforts to shift entrepreneurial expertise away from them.

Etzkowitz (1998) does not see a divide between scientific entrepreneurship and other kinds, but acknowledges that:

As long as the traditional disjuncture between theory and invention is accepted, the emergence of entrepreneurial science is an anomaly, even a deviance from the shared normative role model of scientific behaviour (ibid: 826)

This comment echoes the discussion on RS&T in section 2.3.

Etzkowitz seems to mainly visualise the scientist as staying in their research post and moving back and forward between that and industry, rather than moving permanently with an idea and commercialising it. But:

Full integration of research and entrepreneurship occurs wherever scientists found their own firms to continue pursuing a particular kind of research from basic issues to concrete products for market (ibid: 828)

Many academic scientists are following this path whereas they would not have done so in the past, and are becoming rich as a result (Anonymous, 2006). However there is still a popular view that scientists cannot be entrepreneurs (Heeringa, 2003) and the increase of entrepreneurial activity within academia has raised concerns that the research orientation of Universities might become "contaminated" by the application-oriented needs of industry (Van Looy, Rana, Julie Callaert, Debackere, & Zimmermann, 2004). In reality no trade-off seems to have occurred between

entrepreneurial and scientific activities and it is concluded that it is indeed feasible to organise both scientific and entrepreneurial activities, without one jeopardising the other (ibid: 439). Slaughter and Leslie (1997) find that faculty members did not simply replace altruism with a concern for profit:

Rather, they elided altruism and profit, viewing profit making as a means to serve their unit, do science, and serve the common good (ibid: 179)

Both Etzkowitz (1998) and Oliver (2004) credit the new field of biotechnology with an increase in what might be described as scientific entrepreneurship. Oliver postulates that this is because biotechnology is a new and emerging field of science in which the R&D process is:

Based on tacit knowledge with little a priori understanding, and the process is exploratory and based on "learning by doing": (a) tightly coupled and reciprocal research process which is heavily based on integrated teams of interdisciplinary experts (Oliver, 2004: 584)

This nature of the R&D process in biotechnology-related fields is significantly different from developed sciences such as chemistry and can also be related to the characteristics of scientific entrepreneurs who function within an exploratory, tacit and limited knowledge base (ibid).

Developing scientific entrepreneurs

Janson & McQueen (2003) interviewed scientific leaders with powerful drives towards achievement and high standards of excellence, of whom:

Many report difficult transitions from scientific tertiary training to business thinking. However this was where early role models for entrepreneurship acted to support them....when leaders entered the business world after tertiary studies in disciplines such

as sciences, biology or engineering there were dominant feelings that their tertiary education had not prepared them adequately for the realities of business. Successful leaders are those who change their role during the company's development and transition from a science and technological focus to a commercial focus (ibid: 26)

The effectiveness of formal mentoring programmes in business and industry has been documented and can be useful in entrepreneurship (Scherer, Brodzinski, & Wiebe, 1990; Sullivan, 2000). Wright et al. (2007: 802) also stress the importance of role models but go further in suggesting the creation of primary school programmes to demonstrate to children and young adults the opportunity for careers that combine S&T with business management. They particularly argue for providing boundary spanning role models of females, who are generally underrepresented in the ranks of technological entrepreneurs.

Rubinstein et al. (2002) report that industry seeks *T-shaped* people, in whom the down-stroke represents depth and specialist knowledge in a discipline and the cross-stroke represents breadth and flexibility. The authors note that many science students learn such skills, but typically only in departments of social sciences and in business and management schools. They therefore make recommendations for changes in teaching to build requisite knowledge and skills such as teamwork. Wright et al. (2007: 801-2) also extol the virtues of University programmes which combine science and technology with business management.

The *Melbourne Model* at the University of Melbourne includes a stipulated emphasis on the production of *T* graduates by means of a proportion of each undergraduate degree being taken outside the students' core fields of study (Davies & Devlin, 2007). However the same authors point out that inter-disciplinary efforts seldom work if the

participants are not fully competent in their own fields. Disciplinary competence is sometimes at odds with broad interests and imaginative speculation (ibid: 12).

In a survey of recent New Zealand science graduates a distinction is made between *knowledge skills* including: analytic skills, subject specific knowledge and understanding; and *knowledge application*; problem solving, working independently, dealing with complexity and ambiguity and using information technology. The survey finds that in general, the latter are viewed as being of slightly more importance than the former (traditional knowledge group) but respondents reported receiving less of these skills during their degrees. In *social skills*, the largest skills deficits appear to be in the international area: understanding non-New Zealand cultures and a sense of confidence in international environment are rated as being moderately important, but respondents reported that they do not gain skills in proportion to their importance.

The survey shows that the most pressing skill needs involves a fourth factor, which relates to teamwork. The six items making up this factor relate to both communication and working with others. Both written and oral communication are rated as having high importance but the degree to which respondents felt their science qualification prepares them for such skills is less than needed. The gap between importance and performance is greater for oral than written skills. Also important are the ability to work with others, flexibility and adaptability, understanding of other points of view, and management skills. For all of these, the degree to which respondents gain these skills in their science degree is significantly less than their relative importance (Koslow, 2005).

The last group of skills contains a single skill, *commercialisation*, which respondents did not say is highly important, but they received little of this skill through their training, thus leaving a large deficit (ibid).

One implication of the competent learners project (see section 2.5.2) may be that largely because of their cumulative nature, a complete set of attributes for scientific entrepreneurship is unlikely to develop after the early years of life when cognitive competencies have already been either established or not. While it is true that affective or attitudinal attributes may change and develop later these may be sufficient only for non-science-based entrepreneurship.

2.9 Summary

This chapter has reviewed a number of literatures which are connected through a rationale linking RS&T, entrepreneurship and human capital within national innovation systems and other contexts. Where these literatures overlap, a novel concept of scientific entrepreneurship emerges about which little has been explicitly written. Thus there is a gap in the academic literature to be researched, and the next chapter (three) sets out to show that there is also a strategic policy gap.

The review of competency literature in section 2.5 also lays the groundwork for a framework which can be used to research and understand scientific entrepreneurship (see section 4.7.2) and this framework is developed more fully into a full methodology as described in the rest of chapter four.

CHAPTER THREE: THE NEW ZEALAND PUBLIC POLICY CONTEXT

3.1 Introduction

This chapter aims to provide an understanding of key elements of the national context within which RS&T-based entrepreneurship and innovation take place in New Zealand. It also seeks to show that, while the importance of RS&T in innovation is well recognised in policy and practice, there have been inconsistencies in the approaches taken to underlying human capital.

The chapter is structured along similar lines to chapter two, although the component sections overlap in different ways. Firstly, some relevant features of the country's economy are outlined in section 3.2, followed by more in-depth descriptions of aspects of the public system within which most research activity takes place (section 3.3). Section 3.4 contains a summary of findings that arise from key document analysis as part of the overall research methodology. The conclusion in section 3.5, when linked with the literature review, provides additional policy-based justification for the research question and methodology described in chapter four.

While much of the chapter is based on historical description, it also reflects a policy context existing during one period of time. It is thus a partial "snapshot" of a context which has been constantly changing in the past and will continue to change in the future. As well as description there is a degree of commentary in the text and in the footnotes.

3.2 The economy

3.2.1 Small, focused on primary production and exports

New Zealand has a population of 4.1 million people and an annual Gross Domestic Product (GDP) of \$US 80 billion in 2006. The country is comparable in area (270,500 sq km) and/or shape to Great Britain, Japan or Colorado in the United States (Statistics New Zealand, 2006). 45% of this land area was in productive use in 2002 (Ministry of Agriculture and Forestry, 2003b).

Exports of goods and services contribute 30% of GDP. A feature of the New Zealand economy is that its wealth-creating export sector is based largely on primary production of goods (pastoral and arable farming, horticulture, forestry and fishing). The “primary sector” directly contributes 8% to GDP, more than double the OECD norm (Statistics New Zealand, 2006). Agriculture in particular has been important since the introduction of refrigerated shipping in 1882 enabled food products to be sent to the British market. Because of its central economic role, for over 100 years the agricultural sector benefited from a range of Government policies including the provision of extension and research services. Many of these services were removed during a period of reform beginning in 1984 (R. Johnson, 2001: 121-2).

Although agriculture has been historically dominant, there has also been considerable diversification of products and markets since 1960 when agricultural exports comprised 92.5 per cent of all exports. In 1999-00 the proportion had fallen to 39.8 per cent as a result of considerable expansion of manufacturing, fishing and the forest products industry (ibid: 134). Taken together however, agriculture, horticulture and forestry still accounted for over 65 per cent of export receipts in 2002

(Ministry of Agriculture and Forestry, 2003b). Smith (2006: 37) dispels the notion that countries such as New Zealand cannot become wealthy from a low-technology economic base, since comparative countries such as those in Scandinavia have become rich by leveraging natural resources and persistently upgrading low tech and resource-based industries.

New Zealand's small economy is heavily dependent on overseas trade. The United Kingdom remains an important market, but it now shares that position with Australia, Japan, the US and Korea (ibid). Economic growth from exports remains a desirable goal, but since much of the country's income comes from primary produce, rapid demand and price increases are unlikely (Birks, 2001a: 110).

New Zealand producers have little control over overseas prices and have to accept what the market brings. This is called price-taking (R. Johnson, 2001: 132)

It is in order to reverse this situation that there have been calls for New Zealand to diversify its production and markets, to *add value* through further processing of produce before export, and to be more innovative (Birks, 2001a: 110).

The manufacturing sector is made up of a few relatively large firms, together employing almost half the manufacturing workforce, and many very small firms (Birks, 2001b: 151-2). Larger manufacturing enterprises are more likely to be exporting (ibid: 161). There is a variety of small, light manufacturing industries and New Zealand also produces coal, oil and natural gas and various metallic and non-metallic minerals (Statistics New Zealand, 2006).

The structure of the economy has been changing. Other sectors have on average grown faster than farming (R. Johnson, 2001; Statistics New Zealand, 2006) with a

growth in the services sector in particular (Birks, 2001a: 107). In March 2000 the services sector comprised 76% of the employed labor force. This is in line with the experiences of other developed countries where long-term change has typically seen a decline in the importance of the agricultural sector followed by a period of industrial growth followed by an increase in the size of the service sector (Birks, 2001c: 175). More growth in the services sector might be expected in the future (ibid: 180). However as of 2007, the majority of businesses in this sector were involved in what is known as the economic core - e.g. corner dairies, lawn-mowing business etc – which is characterised by low rates of innovation (Carden & Murray, 2007: 219).

3.2.2 *Addressing economic performance problems*

New Zealand has:

Recently enjoyed a resurgence in economic growth after a long period of decline. Given that the two main drivers of economic growth are labour utilisation, where New Zealand is high compared with the OECD standards, and labour productivity, where New Zealand is much lower than many OECD countries, increases in New Zealand's living standards will need to come from increased labour productivity (Workplace Productivity Working Group, 2004: 7)

Though productivity in the key primary sector has risen significantly, the OECD (2003) reports that manufacturing productivity has been disappointing.

A major effort to identify and address the New Zealand economy's perceived, deep-seated structural problems was the so-called "Porter Project" in 1991. The report of this project (Crocombe, Enright, Porter, & Caughey, 1991: Ch 2) contrasts traditional concepts of the *comparative advantage* of nations with determinants of national *competitive advantage*. In this view competitive advantage is based on *factor*

conditions or inputs of labour, land, capital etc; *demand conditions* in the internal economy; *related and supporting industries* especially *clusters* of related and supporting industries; and *firm strategy, structure and rivalry*. Government policy and chance also have an impact on the total system. The stages of development of national competitiveness are firstly factor driven, then investment driven, then innovation-driven. The final stage, which is driven by accumulated wealth, is a period of decline as:

Rivalry ebbs. Administrators replace entrepreneurs and company builders as senior managers. Firms take fewer risks and innovate less. Employees begin to lose the motivation to succeed. Government policies often focus on redistribution of wealth rather than its creation. The emphasis becomes gaining a share of the existing pie rather than making the pie larger. Rewards are often unrelated to performance. As a result, the nation's firms begin to lose competitive advantage to foreign firms (Crocombe, Enright, Porter, & Caughey, 1991: 36-7)

The report of the Porter Project finds that:

The primary source of competitive advantage for the majority of New Zealand's export industries that make up the vast bulk of our exports is our favourable natural-factor conditions complemented by efficient production. These industries compete mostly on the basis of low-cost primary production that relies on basic-factor advantages....very few New Zealand industries have developed multiple sources of competitive advantage (and)....these are very small (ibid: 95-6)

The report urges New Zealand to move beyond cost-based strategies (ibid: 158) and implies that despite being factor driven, New Zealand already shows some of the signs of being in a terminal, wealth-driven stage. This view is contradicted by a later study which finds that the New Zealand economy has ample creative destruction and that New Zealand's rich tend to be self-made rather than inheriting wealth; the business sector is reasonably accessible to entrepreneurs and quick to take up

electronic commerce; and regulation is not a heavy burden (McMillan, 2004). There is also evidence of considerable job creation and economic contribution by Small and Medium Enterprises - defined in New Zealand as those that employ fewer than 20 people (Ministry of Economic Development, 2007b: 5).

Some of the Porter Project's work is updated by Ballingnall and Briggs (2002b) who are particularly interested in identifying exporting sectors in which:

1. New Zealand export growth is higher than world export growth;
2. World growth is above average world export growth; and
3. New Zealand has a comparative advantage (a sector that has a comparative advantage is likely to be of a reasonable size)

Ballingnall and Briggs find that (unsurprisingly) New Zealand tends to export more in those sectors in which it has a comparative advantage - the top fifty commodities are mostly made up of primary products (ibid: 5-7). They also note a large proportion of traditional export groups (dairy, meat, wood and pulp etc) are in markets which are slow growing (ibid: 19) although a later MAF report describes a dramatic improvement in New Zealand's Terms of Trade due in large part to primary product exports (MAF, 2004: 4). The Dairy Industry in particular experienced high growth and profitability in the early part of the 21st Century (Australian Bureau of Agricultural and Resource Economics & MAF, 2006; Fonterra, 2007).

In many cases where New Zealand export growth has been stronger than world export growth – including a number of manufactured and high technology products -

this has been from a very low base and thus these sectors do not account for a large proportion of New Zealand's overall exports (ibid: 13).

There are however some star performers which also have comparative advantage (they are large and growing faster than average in fast-growing markets). Examples are predominantly other foods, wine and forest and metal products (ibid: 15). The authors conclude that:

Pinning growth hopes on tiny, high-growth sectors is probably futile. There are no "silver bullets". New Zealand's comparative advantage remains largely with agricultural, horticultural and forestry-based products. This study confirmed our earlier research that suggested that New Zealand's slow export growth (and therefore economic growth) has been due to it having a composition of exports that is skewed towards slow growing world sectors.

In order to improve New Zealand's economic growth, our study suggests that more emphasis should be placed on improving efficiency and encouraging innovation in the industries in which we already have a comparative advantage, rather than searching for solutions in industries in which New Zealand will not be competitive. The search for high value-added and technologically advanced processes is a valid policy direction, but it must be applied to the appropriate sectors (Ballingnall & Briggs, 2002b: 21)

A considerable weight of policy advice and opinion seems to be this way, i.e. supporting innovation and productivity growth in existing sectors and firms rather than creating new ones (Institution of Professional Engineers, 2004; Workplace Productivity Working Group, 2004). The latter group cites OECD findings showing that productivity increases are seen to occur through three different channels in an economy:

Typically the expansion of more productive firms and the contraction of unproductive firms account for small increases in overall productivity. The entry of new, productive firms and the exit of unsuccessful firms accounts for around one-third of overall productivity. The third channel, productivity gains in existing firms, accounts for the most productivity growth in the economy (ibid: 7)

The Workplace Productivity Working Group report therefore focuses on contextual, organisation-level factors in existing firms: building leadership and management capability; creating productive workplace cultures; encouraging innovation and the use of technology; organising work; networking and collaborating; measuring what matters. There is also a chapter on investing in people and skills, including management and leadership but with a considerable orientation towards vocational training and foundation skills development.

There has been limited success in creating new, high growth export sectors that can contribute significantly to increases in overall national economic growth. Tourism and Export Education are two exceptions but they are industries vulnerable to changes in consumer tastes and where sustainable competitive advantage is difficult to achieve (see section 2.2.2). Recent attempts to grow sectors based on Biotechnology, Information and Communications Technology (ICT) and the Creative Industries may be more promising (NZ Government, 2002). Out of these initiatives the Government has introduced a Growth and Innovation Framework (GIF)⁴¹ which has evolved into an Economic Transformation Agenda, led by the Ministry of Economic Development (Ministry of Economic Development, 2007a).

The Ministry of Agriculture and Forestry lays out a whole raft of prescriptions for the New Zealand economy, beginning with the need to promote the World Trade

⁴¹ <http://www.gif.med.govt.nz/>

Organisation and rules-based system of international trade and for firms to migrate into new, niche markets overseas. There is also a need to improve the domestic business environment, to maintain macroeconomic stability and institutional integrity, and to address skill levels, infrastructure, regulatory impediments, thin and distorted capital markets, and business short-termism (Ministry of Agriculture and Forestry, 2003a: 1).

3.2.3 *The role of RS&T*

In line with current thinking as contained in the literature and espoused by the OECD (see section 2.2) there is considerable emphasis in government documentation placed upon RS&T as a factor in improving innovation, economic performance and growth although there is a recurring debate as to what extent this requires the identification, appraisal, adaptation and “diffusion” of new technologies from the international pool rather than its local creation.

Over the years, agricultural sectors have benefited greatly from science-based improvements (Dick, Toynbee, & Vignaux, 1967; Scobie & Eveleens, 1987) but these sectors are generally of low research intensity and have relatively low levels of private sector investment in research. This may be because:

The homogeneous nature of the agribusiness and forestry sectors means that R&D focuses on a small number of major products and processes and R&D costs can therefore be spread over large production volumes. This leads to low R&D intensity, however it is typically associated with high R&D productivity because innovations are adopted widely and have large aggregate effects⁴². Conversely, more niche-oriented business competing in lower volume, more differentiated markets often have high R&D intensity and may earn

⁴² i.e. “carrier” technologies in Schumpeterian terms, “yeast” in Harberger’s terms (see section 2.2.2)

high premiums over smaller production volumes (Ministry of Agriculture and Forestry, 2003a: 6)

In general, New Zealand's national expenditure on R&D as a proportion of GDP is well below the OECD average. This low figure is almost entirely due to relatively low expenditure by the business sector but if there is correction for characteristics of the New Zealand economy: distance from world markets; population size; firm size; and industrial structure, New Zealand is not an outlier with respect to total R&D expenditures and the private R&D share (Crawford, Fabling, Grimes, & Bonner, 2004).

Nevertheless efforts have been made to increase private sector expenditure (MoRST, 2003b) and many public policy measures have been introduced to promote “demand-led” uptake of RS&T by business. These measures have struggled to succeed in existing industries because of the afore-mentioned low research intensity and investment or small size of most firms in New Zealand. Attempts have been made to compensate by combining the resources of a range of industry participants to gain “critical mass”, for example in clusters and consortia (ibid)⁴³.

Overall, a major barrier to the transformation of existing industries or the growth of new ones remains the inadequate “absorptive capacity” within the economy – i.e. ability to take up and apply new RS&T. Firms in New Zealand generally take an informal and incremental approach to innovation (Carlaw, Devine, Pirich, & Tullett, 2003) and rather than referring to R&D or ground-breaking innovations, most cite customer feedback, employee (especially sales staff) feedback and changing customer needs and values as important inputs (Knuckey et al., 2002). New Zealand's level of patenting is comparatively low (Carden & Murray, 2007: 215-7).

⁴³ Also NZTE <http://www.nzte.govt.nz/section/11736.aspx>

However *leading* firms are undertaking the “lion’s share” of both innovation-supporting activities and investment in research and development. Leaders are far more likely to be fully up-to-date with the latest technological developments and the vast majority have at least some employees engaged in R&D on a regular basis (Knuckey et al., 2002). Despite this, on the supply side if University post-graduate effort is included, 75% of research is undertaken in Universities and CRIs (Ministry of Research Science and Technology, 2006: 17, 27) so RS&T in New Zealand is predominantly located in the public sector. A major challenge is for research outputs to be taken up in relevant, useable forms by a broadly unreceptive business sector.

Various measures have been employed to address this challenge – most obviously institutional reform to establish sector-based research institutes which are expected to incorporate the business-oriented skills required to manage the science-based innovation process (see section 3.3 below). Major changes have also continually been made to provide incentives for innovative behaviour, such as in the way in which funding (investment) is distributed to research programmes and encouragement is given to technology transfer. The Government has also increased the availability of Venture Capital through the creation of two funds totalling \$200 million (New Zealand Venture Investment Fund Ltd., 2007).

3.3 Reforms in RS&T

3.3.1 General public sector reforms

For a number of economic, historical and political reasons described by Scott (1996) the New Zealand economy and public sector underwent major structural reforms in the 1980s and 1990s. The theories underpinning the public sector reforms are

described in section 3.3.3 below but the basic features of structural changes in public sector entities were: the separation of policy and operational functions; separation between funding, purchasing and provision of services; competition between service providers and some reallocation of responsibilities between government departments (ibid: 14). In the new system, the responsible Minister, acting within the collective responsibility of the Cabinet to which s/he belongs, becomes responsible for specifying performance requirements of the departmental chief executive responsible for service delivery. Decision-making authority on how to meet those performance requirements is passed to that Chief Executive (ibid 31-2)

The focus for the management system has become outputs (goods and services produced by departments) or outcomes (benefits sought by the Government) rather than inputs - as in the previous system. Desired outputs and outcomes are specified in advance through performance agreements between the Chief Executive and the Minister (ibid: 33).

3.3.2 Science sector reforms

Amid the general public sector reforms and reflecting the features described above, the science sector underwent significant structural change in the late 1980s – early 1990s. The former Department of Scientific Research (DSIR) the advisory divisions of the Ministry of Agriculture and Fisheries and some other smaller groups were disestablished and their assets combined and redistributed to ten (later nine) Crown (State) Research Institutes (CRIs) which were created in 1992 with their own Act of Parliament. The CRIs are a distinctive feature of New Zealand's National Innovation System, and at the time of their foundation were dominant providers of research.

Universities, which play a greater role in other countries, have over the years been increasingly drawn into an integrated New Zealand system but the following narrative leans towards a description of the CRIs rather than reforms in the tertiary education sector. There is however some discussion of changes in the funding of University research in section 3.4 and some of the international literature on Universities is reported on in section 2.3.5.

A number of other non-government research organisations were also included in the reformed system and some government departments continued to play a role in purchasing, regulating or in some cases carrying out some scientific research (Ministry of Research Science and Technology, 2006: 11-13; G. C. Scott, 1996: 15-17).

The CRI Act contains no reference to any responsibility for maintaining human capital but one of the principles of operation is that a CRI should be a good employer (CRI Act "Crown Research Institutes Act", 1992: Clauses 5[1e]; 5[4]; 39-41).

The CRIs have two shareholding Ministers of the Crown, one the Minister of Crown Research Institutes representing the Government's *ownership* interest and one the Minister of Finance representing the *purchaser* interest. CRIs are expected to run according to standard business principles, to make a return on capital and to pay dividends to their owners (MoRST & Crown Company Monitoring Unit, 2002: 10-15).

Prior to the formation of the CRIs, separate policy and research funding agencies were also established to assume two of the roles formerly undertaken by the DSIR in particular (the Ministry of RS&T: MoRST; and the Foundation for RS&T: FRST). Like the CRIs, FRST was constituted under its own (1990) Act of Parliament. Research funding was aggregated into one major scheme known as the Public Good Science

Fund (PGSF) which was later restructured into more targeted funds known as Research for Industry (RFI) and the New Economy Research Fund (NERF). Funding came to be allocated to research providers through a *contestable* tendering process.

3.3.3 *Theoretical basis for public sector reforms*

One of the motivations for the public sector reforms in New Zealand was that:

The practice of making strategic decisions at the central political level for major government-owned commercial activities after drawing on advice from the organisations themselves, was seen as a deeply flawed institutional structure for assuring the ultimate owners of these businesses – the taxpayers – that resources were efficiently used (G. C. Scott, 1996: 12)

In other words, prior to the reforms there were allegedly problems of *provider capture* in major areas of public service. The various new frameworks that were proposed were seen as a way of correcting this capture through increased transparency, changing organisational structures, and contestability in the provision of services (ibid: 13). All of these factors could be seen in the reform of the science system.

The principles underlying the general reform of the New Zealand public sector were based on Public Choice Theory, Agency Theory and Transaction Cost Economics (Boston, Martin, Pallot, & Walsh, 1996; G. C. Scott, 1996: 10 - 13). The central tenet of the public choice approach is that human behaviour is essentially based on self-interest. Individuals, are rational utility maximisers and concepts like public spirit, public service and the public interest have little place. This of course is at least superficially inconsistent with the traditional view of the norms of scientific activity described in table 2.3.

In agency theory, *principals* employ *agents* to perform tasks because the principals lack the required competencies themselves, or because the nature of the task demands a team effort (Boston, Martin, Pallot, & Walsh, 1996: 17-21). Agency theory fits well with the linear model of RS&T described in section 2.3.3.

Agency theory, like public choice theory and neo-classical economic theory:

Assumes that individuals are rational, self-interested, utility maximisers. Hence, the interests of agents and principals are bound to conflict. Moreover, the management of many principal-agent relationships is complicated by incomplete information, asymmetrical information, and various uncertainties: agents generally have access to information that principals do not (and vice versa) and have an incentive to exploit this information to their advantage....(A) good deal of agency theory, therefore, is concerned with determining - given various assumptions about the information available to the respective parties and the nature of the task to be undertaken - the optimal form of contracting, including the best way of motivating agents (ibid: 19)

Measures undertaken by principals to ensure that agency activity is properly aligned include the creation of incentives, rewards and sanctions but these create *agency costs* which are proportional to the extent of divergence between the interests of the two parties. Other problems with the principal-agent relationship might include *adverse selection* (picking the wrong opportunity) and *moral hazard* (goal-displacing behaviour towards what is measured) which derive from the unobservability of the agent's behaviour once a contract has been negotiated (ibid: 20).

Transaction cost economics (TCE) is closely related to agency theory, but the two approaches differ somewhat in their focus (ibid: 21-25). While agency theory focuses

on the selection and motivation of agents, TCE is concerned with optimal governance structures for various types of transactions.

Rational agents will select governance structures that minimise their aggregate production and transaction costs. As the complexity and uncertainty of a situation increases, the greater the limits imposed on individuals by their bounded rationality (see section 2.3.2) and the more likely it is that the transactions into which they enter will fail. One way of minimising such failures is to avoid, if possible, governance structures that entail high transaction costs and large cognitive demands (ibid).

Some transactions are more suited to market-type arrangements (provision based on tendering for external contracts) and some are more suited to *in-house provision* using standard practices of control such as hierarchies, rules and relationship management. External contracting is best when there is a large number of competing suppliers, behavioural uncertainty is low and the quality and quantity of goods and services can be easily measured. Rubbish collection, cleaning, laundering, and catering are good examples of where these conditions are generally satisfied. In-house provision is more appropriate when the opposite conditions apply: frequent transaction costs, high uncertainty and high asset specificity (Boston, Martin, Pallot, & Walsh, 1996: 23). In-house or direct provision reduces the need to specify in advance all the possible, complex and unknown contingencies that may emerge during the term of a contract, and allows faster and more flexible and effective responses to changing circumstances.

It would seem that the New Zealand science system was reformed very much in line with agency theory and the market-based arrangements envisaged by TCE, even though according to the precepts of TCE such arrangements are not suited to the delivery of scientific research which is highly specialised, complex and unknowable in

advance. However it might be that the science funding system has been gravitating back towards a more in-house approach, for example through the increased provision of stable institutional funding (FRST, 2005; Hodgson, 2004).

3.4 Overview of RS&T reforms based on documentary analysis

3.4.1 Introduction

This section summarises findings from review and analysis of a large number of documents relating to aspects of the history of development of the restructured New Zealand science system and its approach to the formation and management of human capital over approximately two decades. Also reviewed are policy documents from the wider innovation and education systems which indicate emerging perspectives on competency development and entrepreneurship. The section has been distilled from a comprehensive and tightly referenced narrative in order to make it more readable and keep within thesis space limits.

3.4.2. Human capital in RS&T policy

Pre-RS&T reforms

Science policy discussions about human capital (although generally in terms of knowledge, skills and human resources etc) preceded the reforms of the science system. Indeed the 1980s, and to some extent the 1970s, seem to have been a ferment of working parties, papers and conferences on science and technology, most of which included considerations of human capital (Bollard, 1986; Franko, 1989; Ministerial Working Party, 1986; National Research Advisory Council, 1984, 1985a,

1985b; Science and Technology Advisory Committee, 1988a, 1988b, 1988c, 1989a, 1989b).

There was an ongoing concern about science education and careers, and stress on greater involvement of industry with science organisations, traditional technology transfer and mobility of staff (National Research Advisory Council, 1985a: 4). The so-called Beattie Report of 1986 calls for updating of curricula for science, technology and mathematics based on fairly traditional views of knowledge which do not go far beyond the rhetoric of responsiveness to industry to a deeper determination of the nature of required knowledge or how it might be developed (Ministerial Working Party, 1986: ix). There were also attempts at scientific “workforce planning”, for example one based on a survey methodology and the results cast mainly in terms of forecasts of topical areas likely to grow in importance (computing, remote sensing etc) and conventional management skills such as planning, economics and financial analysis etc (Science and Technology Advisory Committee, 1989b: 4).

The integration of business and science skills was seen to be poor and in need of improvement. A 1989 report recommends major improvements in the skills and capabilities essential for science managers in the areas of personal and interpersonal skills in business management and notes the lack of integration of S&T with commerce and business management education (Franko, 1989: 3-4). This seems to suggest that there should have been more business skills brought into science, but the Science and Technology Advisory Committee also comments in 1988 on the low level of technical qualifications on boards and in management (Palmer, 1994: 24).

Along with considerations of human capital for RS&T there was much discussion of the need for technology transfer. A 1975 NRAC/Planning Advisory Group Report to

the Ministers of Finance and Science notes an urgent need to consider means of transferring science and technology into industry to improve productivity (Palmer, 1994: 8). The 1985 Science and Technology for Development Conference pointed out the need to improve technology transfer and NRAC's 1985 Science and Technology plan further highlights some major opportunities and priorities for research and development, including transfer of technology, education and training (National Research Advisory Council, 1985b: 15).

Post-reforms

The centrality of human capital in science and technology policy survived the initial round of reforms, but in nominal terms. For example, the Ministerial Science Task Group's (1991) discussion document has a rationale for Crown ownership of Crown Research Institutes that includes the maintenance of scientific human capital. However, there was considerable argument as to where this responsibility lay between the purchaser of research outputs (FRST) and the providers of science and direct employers of the science workforce (particularly CRIs).

The pendulum swung back and forward between these two positions, but in the main, and consistent with the theoretical underpinnings of the reforms, responsibilities for human capital development were effectively passed out of the policy and purchasing realms to research providers. As late as 1998, FRST's annual report identified that it had a role to:

Provide to the Minister the development of expertise to support long-term needs for public good science and technology, *complementing human resources developed indirectly through other public good science and technology programmes*. (Foundation for Research Science and Technology, 1998: 36; italics added)

The level of investment in the development of expertise referred to was around two percent of the Foundation's total budget and this statement shows that at the time FRST saw human capital development mainly as a *co-produced good* from investments in research outputs. Throughout the 1990s human capital became seen as an input rather than an output or outcome, and in the face of more pressing concerns policy was directed into a quest for better quantitative data so as to measure system performance.

MoRST's briefing notes to the incoming Minister in 1990 focus almost entirely on structural issues, including overarching policy, funding structure, priorities, international relations, science promotion and education. There is half a page on human resources in science in which an intention to build better databases is signalled (Ministry of Research Science and Technology, 1990: 49). This focus is repeated in the 1993 briefing notes (Ministry of Research Science and Technology, 1993).

A ministry background paper on science workforce supply and demand notes some difficulty retaining highly skilled, experienced and innovative research scientists in certain areas or replacing them with recruits of a similar culture or experience (Fletcher, 1991: 1). The paper hints at concerns about a *brain drain* of expertise and focuses on salary levels, stocks and flows, loss of specific areas of expertise (disciplines) demographics (age structure and gender) and international comparisons. There is no discussion of innovative capabilities in human capital terms. The report is essentially updated in the same form, with the spectre of the brain drain raised more specifically in later reports (MoRST, 1998a; Robertson & Cope, 1993; Rys, Edwards, & Fletcher, 1992: 19; P. Walker & Edwards, 1997). The Ministry's Research and Experimental Development Statistics (Ministry of Research Science and Technology, 1997) are primarily focused on funding (38 out of 50

pages) with one page on quantitative measures of personnel (totals, number of women in science; occupational classes and employment by sectors).

There were several attempts in the first half of the 1990s to prioritise Government expenditure on RS&T and some of these included references to the need to maintain scientific human capital (Minister of Research Science and Technology, 1991; 1994; 1995; Ministry of Research Science and Technology, 1992; New Zealand Government, 1994; Science and Technology Expert Panel, 1992; Science Funding Review Panel, 1991; Science Priorities Review Panel (SPiR), 1995a; , 1995b; Strategic Consultative Group on Research (SCGR), 1994)⁴⁴.

Much of the thinking about scientific human capital was characterised in science-centred terms of topical and disciplinary areas of expertise, very closely aligned to disciplines. Palmer (1994: 59) quotes the Minister of RS&T who noted that:

It was particularly necessary to secure key competencies, or skill bases, and important scientific databases, collections and curations that were insufficiently identified at the time of the 1992 science priority review - including taxonomy, ruminant physiology and indigenous forest management

After 1995, with the key reform processes having ended, policy emphasis shifted further towards a topical approach with reviews of Marine Science, Fisheries, Biosecurity, Climate, Sustainability, Mathematics, Calicivirus and International Science.

⁴⁴ I was an official servicing the STEP, SCGR and SPiR panels

Concerns continued to be expressed about the ability of the education system to produce the kinds of attributes required. A 1991 Task Group report circles around the language of competency in finding that:

The shortcomings of the education system in encouraging the development of personal attributes such as team building and interpersonal skills, verbal and general communication skills, problem solving, lateral and creative thinking, practical competency and even self-discipline, were criticised by many respondents...we need broad people, rather than narrow and specific people...the curriculum has become a bit too far focused on the specifics (Ministerial Task Group, 1991: 24)

A 1991 report commissioned by MoRST finds that public science providers were a poorly rated source of technology (R. Johnston, 1991: 3) and there are other indications that CRIs compete with the private sector to commercialise IP in order to enhance their own viability (Maplesden, 2004: 13; Ministry of Agriculture and Forestry, 2003a: 7).

The Technology for Business Growth (TBG) scheme was introduced in 1993 with an aim to invest public funds in research and technological development projects conducted jointly between business and research institutions (Palmer 1994: 37). FRST came to see the TBG (later to be renamed Technology New Zealand or TechNZ) as:

A very effective means of catalysing cultural change and upgrading technology management capabilities in firms....focuses on technologically less able firms (FRST, 1996: 4)

The findings of an evaluation of Technology New Zealand in 2001 are favourable although a relatively limited number of firms were found to benefiting in ways that were inconsistent with the scheme's original aims:

TechNZ funding is focused on a relatively small number of technologically capable companies that are generally reasonably advanced in relation to conducting R&D and applying technology for their business growth (Infometrics Ltd & Decision Research, 2001: 3)

Reinforcing this finding, in 2005 FRST saw that it was adding value to the RS&T system by strengthening linkages between science and business, and facilitating richer networks between researchers, managers, investors and entrepreneurs (S. Thompson, 2006).

Additional funds were also allocated to individuals to boost opportunities for post-doctoral study and to improve linkages between science school teachers and research providers (Palmer, 1994: 4). FRST asserted the importance of encouraging mobility of staff and the funding of cooperative research and the secondments/placement of technologists in companies as well as in-house research and development, and the removal of barriers to mobility such as lack of continuity of employment terms and conditions. Schemes were established to support postgraduate research undertaken in New Zealand companies aimed, inter alia, to build scientific and technical skills and competencies in industry, to provide early career support and to attract talented scientists back to New Zealand from overseas (FRST, 1996: 4; 12; , 1998, 1999, 2000).

The RS&T 2010 strategy highlights the importance of positive values and attitudes towards science at a societal level, careers for scientists and linkages within the

wider system (Ministry of Research Science and Technology, 1995). It proposes the building of skills bases through fellowships, and mentoring and the use of quantitative measures of the skill base as represented by the incidence of traditional qualifications. The strategy takes a wider view of the science system, for example encompassing linkages with the education sector, but without saying how these linkages would work. Nevertheless out of this strategy there arose the potential for more integrated policy through the identification of a “science funding envelope” including all government science-related investment and spending across all portfolios.

By 1997 human capital appears to have once more fallen off the official agenda. The Minister’s press release to go with the budget statement of that year includes no reference to any form of human capital apart from an increase in funding for Maori Fellowships (Williamson, 1997). The Minister’s notice to the Foundation emphasises systemic matters but includes no instruction about human capital in any form (Minister of Research Science and Technology, 1997).

However a MoRST report of the same year (B. Walker, 1997) does note concern about the erosion of the science base and proposes a swing to consideration of a science-based (rather than output based) assessment of the knowledge base. This is proposed as orthogonal to the output-based approach, with gaps quantitatively assessed in terms of shortfalls in the desired numbers of people.

A more extensive exercise in 1997 providing assessment of the knowledge base is based on the extent of coverage of fields of knowledge and subfields based on the Australian Standard Field of Research Classification. It also includes applied areas such as hybridising ryegrass, assessing fish stocks, machine vision, anti-cancer drugs and notes the need for more interdisciplinary teams and research into why the

uptake and management of technology by manufacturing industries was so poor (McGregor, 1997: 3-5). The overall approach taken is to determine gaps in the patchwork of desired human capital, which gaps are the most important, and how they should be filled – a mix of workforce planning, technology forecasting or, ultimately, *future watching* which reached its apogee in 2005 with a future watch exercise in biotechnology. This focused on the technologies themselves and took a fairly limited view of human capital in one sector (Ministry of Research Science and Technology, 2005b).

Attention in the late 1990s also swung back to boosting and measuring community interest in and understanding of science and technology (CM Research, 1998; P. Walker & Liu, 1998; , 1998a; Web Research, 1998b) and engaging under-represented groups such as Maori and Women (Barwick, N.A.; PHP Consulting Ltd, 2000).

In 1998 a broader view of human capital began to emerge in MoRST's thinking. Its 1998 annual report comments on the foresight project, which addressed the question of what sort of society was wanted in the future and what sort of skills and capabilities were consequently required to be created in the present (Ministry of Research Science and Technology, 1998c).

MoRST (1998b) began to define competency as skills, knowledge, and technology plus information systems and feedbacks, relationships and linkages (i.e. system-level *capabilities* in the terms used in this study) but not “drilling down” any further to define what those skills and knowledge were. The inconsistency of approach is demonstrated once more in MoRST's annual report two years later, which seems to downplay the importance of the knowledge base and capability and shifts instead to improving connections (Ministry of Research Science and Technology, 2000).

Early in the new century the prevalent model of technology transfer began to come under scrutiny, albeit inconsistently. McKinlay Douglas Ltd (2002) suggest that CRIs might need to have in place means for transferring capability. In contrast, the 2002 briefing note to the Minister expresses concern about the fragility of capability in CRIs, the risks arising from the contestability of funding and the need to motivate existing talent (Ministry of Research Science and Technology, 2002b).

But then the 2003 budget statement signals a shift away from traditional technology transfer onto ensuring:

A flow of people with appropriate knowledge, skills and ideas into New Zealand's research and innovation system (Ministry of Research Science and Technology, 2003a)

This notion is retained in the 2004 and 2005 budget statements alongside increased funding to CRIS to allow them to manage their capability demands and test out new ideas (MoRST, 2004, 2005a). However an evaluation of the Research for Industry fund is very much based on the traditional technology transfer model and contains virtually no reference to human capital (New Zealand Institute of Economic Research, 2003).

FRST Annual Reports from 2001 – 2004 begin to make specific reference to human capital (Foundation for Research Science and Technology, 2001; 2002; 2003d; 2004a) and also indicate a shift away from transferring technology only to existing sectors. The New Economy Research Fund (NERF) was established to:

Provide to the Minister basic research outputs focused on developing capability and knowledge in new areas or applications where industries are yet to emerge, in order to

underpin new high-technology business opportunities. The focus of the research will be on targeted basic research and human capital development that underpins new enterprises and new sectors (Foundation for Research Science and Technology, 2002b: 28-9)

A review of the New Economy Research fund adopts a technology transfer view of a migration of technologies from one team to another along a technology continuum, resulting in some spinouts from funding (Gamota, Messeri, & Lal, 2005).

In 2001 MoRST's Purchase Agreement with the Minister includes a statement about encouraging entrepreneurs in high growth, high value export areas (Ministry of Research Science and Technology, 2001a: 11) and the Ministry's Statements of Intent for the following two years note a requirement for more innovative and entrepreneurial people and, implying a causal relationship, refer to low numbers of researchers and technologists (Ministry of Research Science and Technology, 2001b: 27; 2002a: 25).

In 2003 FRST commissioned a review of the literature on human capital for RS&T (Menzies, 2003) and from that work derived a human capital development strategy which identifies key issues including poor flow of tacit knowledge and a need for stronger entrepreneurialism in RS&T. The Foundation's Performance and Achievement Reports of the same period echo this renewed interest in human capital, but the focus of these returns to traditional concerns of recruitment, development and retention problems and responses to these (FRST 2001: i). Other related issues are the low amount of codified Intellectual Property from Research for Industry funding and the variable quality of user links.

Measures of scientific productivity and impact continued to be based on bibliometric data (Foundation for RS&T, 2003a: 42). The quantum of relationships with users of research was used as evidence of the growth of desired capability as were numbers of improved products and services, third party revenue, items of IP and collaborative relationships (Foundation for Research Science and Technology, 2003b: 113). However, by 2004 the Foundation was measuring a development of skills: enhanced human capital outcome (Foundation for Research Science and Technology, 2004b: 24-5) based on the subjective views of survey respondents. Attention also switched towards identification of core capabilities for RS&T (Hodgson, 2004).

In 2005 the pendulum swung again. The Foundation's Statement of Intent for 2005/08 outlines four key initiatives, of which one refers to improving skills and supporting infrastructure but only in respect of the Foundation's own staff (Foundation for Research Science and Technology, 2005). Once again the policy focus was on the *context* for human capital rather than its component attributes. Responsibility for the latter was once more to be devolved to research providers.

Notwithstanding the inconsistent treatment described in the foregoing sections, in the early 2000s, signs were emerging in RS&T policy and funding practice of an increased acceptance of human capital's central role, and of a rationale for public investment in its development (Williams, 2005). Mobility of researchers had also received considerable policy attention from MoRST (Maplesden, 2004; 2006) and in the education sector:

Central to this process of national economic transformation is the development of a highly-skilled and adaptable people who move easily between the worlds of education, research, government and private enterprise....in particular, there is likely to be increasing co-location of educational, research and wealth-creating organisations.

The New Zealand tertiary education system as a whole does not have the capability to deliver the lift in human capital development and research that is necessary if New Zealand is to prosper. The theme of “connectedness” is an important one. We will not achieve our national development goals without strong and creative linkages and networks, both within the tertiary system and between it and other sectors of society and economy (Minister of Education, 2002)

However, pertinent to the current research is that the prevailing mental model of the relationship between science and entrepreneurship clearly continues to be based on a separation between two sets of competencies:

Entrepreneurship comprises a spectrum of skills including the ability to take risks, to raise capital and the capacity to commercialise a product or service. ***This is seen as the role of a specialised few who inherently thrive on risk and uncertainty, and not a role that can be easily learnt - or expected of people in RS&T careers.*** Rather, the RS&T system needs a culture that enables entrepreneurs to engage, function effectively and access the knowledge and ideas they need (MoRST, 2007: 12; emphasis added)

3.4.3 Human capital in research organisations

As discussed in the previous section, operational responsibilities for developing human capital for RS&T have, either explicitly or implicitly, been devolved to research organisations. CRIs and Universities have carried out this role in a variety of ways and measured and reported performance in a similarly diverse fashion - such that it is very difficult to aggregate data on human capital at a system-wide level. Nevertheless there are some common threads and emerging trends.

An analysis of the annual reports for the nine CRIs (2002 and 2005) and eight Universities (2001 and 2004) shows that financial reporting is very much to the fore.

But the reports also contain a range of qualitative and quantitative commentary on other performance matters, including many related directly or indirectly to human capital development (see table 3.1). Considerable attention is paid to human resources management, particularly by CRIs (AgResearch, 2002, 2005; Auckland University of Technology, 2002, 2005a; Crop and Food Research Ltd, 2002, 2005; ESR, 2002, 2005; Forest Research Ltd, 2002; GNS, 2002, 2005; HortResearch, 2002, 2005; Industrial Research Ltd, 2002, 2005; Lincoln University, 2002, 2005; Manaaki Whenua: Landcare Research, 2002, 2005; Massey University, 2002, 2005; NIWA, 2002, 2005; Scion, 2005; University of Auckland, 2002, 2005; University of Canterbury, 2002, 2005a; University of Otago, 2002, 2005a; University of Waikato, 2002, 2005; Victoria University of Wellington, 2002, 2005)⁴⁵.

Both CRIs and Universities report demographic data such as number of researchers, research output data, achievements (prizes, appointments etc) and contribution to future human capital development. Unsurprisingly, Universities' reporting on the latter is particularly comprehensive and their key targets are often set in terms of numbers of students they aim to attract and to graduate (e.g. Massey University, undated:b: 71; University of Auckland, undated:a: 4).

Even where there is some similarity in reporting across all 17 institutions, for example of numbers of publications, there is enough difference in the categories and criteria used to make aggregation problematic. A total of 226 different measures are identified as relating to aspects of human capital or its context, each having been explicitly reported on by at least one organisation or easily inferred from other information in their annual reports across two separate years.

⁴⁵ ESR specialises in Environmental Health and Forensic Science; GNS = Geological and Nuclear Sciences; NIWA = National Institute of Water and Atmospheric Research; Forest Research; Forest Research Ltd changed its name to Scion in 2005

These measures can be grouped into 15 different categories as shown in table 3.1.

Note that this table only identifies the number of indicators in each class, not how often each was used:

Table 3.1 Human capital indicators used in University and CRI reports

	Class of Indicator*	No. of Indicators in Class**	
		2001-2	2004-5
1.	Research Outputs	33	43
2.	Contributions to future human capital development	18	31
3.	Commercial, Research or other Collaborations	17	26
4.	Demographics (e.g. nos. of PhDs)	17	21
5.	Achievements/awards/honours	12	17
6.	Incentives/Rewards	10	13
7.	Good Employer	9	14
8.	Staff Development	8	10
9.	Productivity (financial performance/researcher ratios)	8	8
10.	Staff Turnover	6	11
11.	Sources of human capital (NZ, overseas)	6	7
12.	International Linkages	5	14
13.	Platforms/Capabilities	5	5
14.	Maori Development (overlaps with demographics)	4	3
15.	Community Linkages	1	3
	TOTAL	160	226

* Not including 25 financial reporting/productivity indicators identified, other than the eight performance/researcher type ratios (row 9 in the table)

**The increase across the two years' reports was due as much to changes in the indicators used to measure the same parameter as it was to new things being measured

Universities also produce public documents known as Charters, Profiles (post-2002) Strategic Plans and Teaching and Learning Plans. These collectively set out the broad vision and mission for each University and how it will go about achieving those in the medium to long term (Auckland University of Technology, 2005b, undated; Lincoln University, 2003, 2004; Massey University undated a;b;c; University of

Auckland, N.A.-c, undated a;b;c; University of Canterbury, 2003, 2005b; University of Otago, 2003, 2004; 2005b; 2006; University of Waikato, 2004; Victoria University of Wellington, N.A.-d, 2004, undated a;b;c;d).

CRIs produce Statements of Intent and other planning documents but these are less easily accessible due to constraints of commercial sensitivity.

From 2003 Universities' performance in research began to be rated according to the quality and quantity of individual academic staff members' research outputs and the aggregated institutional scores were translated into funding from a Performance Based Research Fund (PBRF).

Table 3.1 shows an emphasis on quantitative measures of human capital outputs and processes. Quality is measured only indirectly although research portfolio assessment as part of the PBRF, introduced in 2003, is an exception and there is an emerging tendency towards the use of the language of competencies. For example:

We are fortunate to have a high calibre and passionate workforce with *experience, skills and curiosity*. The value of these scientific entrepreneurs cannot be overstated and HortResearch has made strenuous efforts to balance the *drive for immediate commercial goals* with encouragement of *scientific foresight and courage* (HortResearch, 2005: 12, emphasis added)

The reference here to scientific entrepreneurs is the only one that was found across all the documents reviewed.

Universities seem more inclined than CRIs to have a competency orientation, albeit in their teaching as opposed to their research workforce. In this they reflect overall

trends in the education sector (see section 3.4.4) perhaps suggesting that competencies are seen in an educational light rather than a “vocational” one (see section 2.5.1). But this University orientation is uneven and often more implicit than explicit. For example, Massey University’s profile contains a strategic review which is bereft of any commentary on the content or nature of human capital – apart from one comment with respect to information literacy and communications technology competencies being viewed as critical to a knowledge economy (Massey University, undated:b: 15). Yet the same University’s strategic plan refers to:

An ethos of problem solving – Massey staff are characterised by a “can-do” attitude in developing innovative, value-added teaching and research solutions, often in collaborative partnerships.... University education must emphasise analytical problem-solving skills, creativity and logic (Massey University, undated:c: 2, 5)

Three Universities do specifically articulate the attributes that they seek to develop within their graduates. There is an interesting shift in Victoria University’s strategic plan from a focus in 2001 on participation rates, technology transfer, research outputs to a conclusion that:

Its graduates should be distinguished by a number of *key attributes*:....Leadership; Creative and Critical Thinking; Communication (Victoria University of Wellington, 2004: 9, 11; emphasis added)⁴⁶

Otago University has similarly listed “The Attributes of an Otago Graduate” and has begun tackling the issue of measuring the extent to which desired attributes are developed in graduates.

⁴⁶ I was employed by a subsidiary of Victoria University at this time

Perhaps the most comprehensive statement of desired competency, albeit again not couched in that term but including contextual and personal factors, is that of Auckland University:

The University has established graduate profiles for each level of graduate from its programmes: undergraduate degrees, postgraduate coursework degrees, postgraduate research degrees and doctoral degrees. All graduates should leave the University having acquired:

- Knowledge and understanding of the theory, history, methods, intellectual content and practice of an academic discipline, interdisciplinary study or profession;
- Generic skills such as an ability to think and reason inductively and deductively, to collect data, to observe, analyse and synthesise, to think through moral and ethical issues, to construct a logical argument with appropriate evidence, and to communicate clearly;
- Personal skills, values and commitments such as a love and enjoyment of ideas, discovery and learning, an ability to work independently and in collaboration with others, self-discipline and the ability to plan and achieve personal and professional goals, the willingness to accept civic responsibilities, tolerance and respect for the values of others, awareness of diversity and personal and professional integrity

Along with the graduate attributes expected of degree holders, transferable skills, workplace experience, IT literacy and career planning skills are now also seen as essential for a successful transition to the workforce....(University of Auckland, undated:c: 16)

The point here is not so much what is in the statements of attributes, but that there may be detected a trend towards Universities (and indeed some CRIs) taking more of

a *competency perspective* in describing and measuring the delivery desired teaching and learning outcomes⁴⁷. Also, there is a more general trend towards the creation of and reporting on teams, capabilities and research centres. These are applied, generally cross-disciplinary and topic-based, focused on research areas of high strategic importance (AgResearch, 2005: 5; ESR, 2005; 1; HortResearch, 2005; 6; Manaaki Whenua: Landcare Research, 2005; 47). For example Crop and Food CRI has identified five “centres of innovation”:

- Sustainable land and water use
- High performance plants
- Personalised foods
- High value marine products
- Biomolecules and biomaterials

(Crop and Food Research Ltd, 2005)

All of the CRIs and to a lesser extent the Universities aim at commercialising the outputs of research through technology transfer, in some cases through the use of spinouts (Industrial Research Ltd, 2005: 22). Crop and Food is researching how to measure and manage intellectual capital (Crop and Food Research Ltd, 2005: 35) and Landcare reports on the difference between tacit and tangible knowledge:

⁴⁷ However, the attributes identified in addition to traditional cognitive knowledge still do not include some which are above the heritable trait level and repeatedly seen as part of the make-up of an entrepreneur (see section 2.6) for example managed risk-taking, opportunity recognition and perseverance, although the latter may be implied. Self-efficacy is also not included, although it is arguable the extent to which this is an educable attribute

Tacit knowledge (that which resides within the heads of their scientists) is considerably more challenging to recognise, generate, share and manage (Manaaki Whenua: Landcare Research, 2005: 40)

This is indicative of increasing recognition of the need to integrate knowledge management with human resource management. The view of the attributes that are to be managed is still very much knowledge-based, yet no value is ascribed to intellectual property in CRI balance sheets (Manaaki Whenua: Landcare Research, 2005: 67; Scion, 2005: 57).

3.4.4 Developing competencies

Across the public education and training sector, there has been a pattern of reform since in the 1980s a series of reports identified:

A need to reform education and training in New Zealand to improve competitiveness in global markets, to create a modern education system that would encourage lifelong learning, and to increase skill levels in the labour force (New Zealand Qualifications Authority, 2005: 3)

Within these reforms, there are clear but inconsistent signs of emergence of the language of competency, all the way from early childhood to strategies for tertiary education and training. The frameworks used at each level are designed to be linked and feed into each other (Ministry of Education, 2005b: 11; , 2006b: 33).

The Curriculum for Early Childhood Education, *Te Whariki*, is founded in part on an aspiration for children to grow up as competent and confident learners and communicators (Ministry of Education, 1996: 9) with strands of wellbeing, belonging, contribution and exploration. The strands each have goals and learning outcomes

attached (ibid: 15-16) although these are mixed in style (some goals relate to the teaching environment and some seem more like competency statements in themselves).

In the schools sector, the National Qualifications Framework (NQF) has been developed as a key initiative to respond to New Zealand's need to develop its human resources (New Zealand Qualifications Authority, 2005: 3). The basic component of the NQF is the unit of learning defined in terms of learning outcomes, focussing on skills as well as knowledge and *inter alia* the integration of academic skills with applied skills, and to bring together theory and practice (ibid: 5, 6). There is also emphasis on application of learning within one or more contexts (ibid: 8,12)⁴⁸.

In schools:

Key Competencies are the capabilities people need in order to live, learn, work and contribute as active members of their communities. Competencies are more complex than skills. Capable people draw on and combine all the resources available to them: knowledge, skills, attitudes and values. The New Zealand curriculum identifies five key competencies:

- Managing self
- Relating to others
- Participating and contributing
- Thinking
- Using language, symbols and texts (Ministry of Education, 2006b: 11)

⁴⁸ www.nzqa.govt.nz/framework/about.html

At the tertiary level, the Ministry of Education has produced a discussion document which offers:

A New Zealand framework for key competencies for the tertiary education sector. Key competencies are the knowledge, skills, attitudes and values needed by everyone across a variety of life contexts....a person is more likely to achieve excellence in their chosen field when some kind of deeper connection takes place between their inner being and their outward skills and abilities (Ministry of Education, 2005b: 4, 8)

The fostering of higher levels of competence (sic) is seen as necessary to support economic growth:

In particular, the cross-cutting thinking group of key competencies, in combination with specialist and technical knowledge, forms an important element of economic transformation toward new markets and higher value-added products. Individuals with high levels of proficiency in this key competency group are more likely to exploit opportunities (ibid: 13)

Emphasising the outcome focus of competency development (as opposed to a focus on teaching inputs) both the new school curriculum and the tertiary education discussion document eschew prescription of programmes or qualifications, but assert that competencies should be taught and assessed in meaningful contexts with proficiency inferred from performance in those contexts (ibid: 14). The use of the term “inferred” rather than “measured” is interesting as it is the same one used by Gonczi (2002; see section 2.5) and implies the use of professional judgement in recognising the existence of competencies.

Overall, the tertiary discussion document aims to provide a common understanding of the nature of competencies and a shared language for talking about them, but at the time of writing no subsequent document is to be found, perhaps indicating the difficulty of reaching consensus on conclusions. This has not stopped the trend towards a competency-based approach in the tertiary sector, as indicated in a statement of priorities which includes the four groups of key competencies listed above, and the contents of some University documents as reported in Section 3.4.3. There also appears to be an expectation of an emerging understanding and consensus on the use of competencies (Minister of Education, 2005: 12).

More generally, the Ministry of Education claims that competencies for work are the same as competencies for life (Ministry of Education, 2005b: 13) and has drafted a second discussion document on *Descriptive Standards Describing the Literacy, Language and Numeracy Competencies that Adults Need to Meet the Demands of their Everyday Lives* (Ministry of Education, 2005a). This document has a flavour that is very similar to the discussion paper on competencies in tertiary education discussed above and presumably arises, at least in part, out of New Zealand's involvement in the OECD's DeSeCo project (see section 2.4.7). However, as with the tertiary education document, there is no follow-up document and the consultation process appears to have stalled at this point.

3.4.5 Public policy and entrepreneurship

At the highest level, New Zealand government policies for innovation recognise the importance of entrepreneurs in transforming the economy and generating increased rates of productivity and growth, and that workplaces must have access to the highest levels of talent and leading edge research science and technology

knowledge (MED, 2007a; Ministry of Economic Development, 2006). It will be recalled from section 3.2.2 that the Ministry of Economic Development is charged with leading the so-called economic transformation agenda.

In the RS&T system, there are a number of references to the importance of entrepreneurship contained in policy documents produced by MoRST and FRST in the late 1990s – early 2000s. But in 2007, the key reference to be found by a keyword search on MoRST's website was a report prepared by IPENZ, the Institution of Professional Engineers (2004). This IPENZ report is also cross-referenced by the Workplace Productivity Report (Workplace Productivity Working Group, 2004: 60) and its views on entrepreneurship still seemed to influence policy circles three years after its publication.

The IPENZ report concludes (p. 10) that:

New Zealand currently has a policy environment which is not that conducive to fostering research, development, innovation and entrepreneurship (RDI&E)

But most of the report is about the RD&I system with little reference to entrepreneurship in its own right. Four types of innovation are identified, the first of which is presumably where there is most scope for scientific entrepreneurship:

- at the fringes, looking for major steps toward new products and services not yet envisaged in the market;
- at the margins, spinning-off from existing intellectual property (sometimes called technology platforms) to extend or retain existing markets;

- in process; cost reduction in making and supplying existing products and services thus retaining their profitability;
- to retain market access: overcoming legislative barriers at home or at borders, or barriers imposed by consumers, that drive companies toward better environmental and social practice or to improving product quality (The Institution of Professional Engineers, 2004: 4)

Echoing Ballingnall and Briggs (2002b; see section 3.2.2) a critical question posed is whether new enterprises are of the right kind. Once again existing enterprises find more favour as drivers of economic growth:

It must also be remembered that, in other countries, new enterprises comprise only a small fraction of new economic activity - typically more than 90% of new intellectual property is taken up by existing enterprises⁴⁹. We would, therefore, expect that large-scale economic development would involve growing existing businesses to a much greater extent than starting up new ones (ibid: 7, also 12)

While it is acknowledged that there will always be innovations at the fringe, innovation at the margins - building on technology platforms, listening to the market and creating variants - is seen as the more important means of steadily growing an existing industry or company (ibid: 9).

The report bemoans the separation of decisions on the use of New Zealand's public research investment funds from market intelligence and low absorptive capacity (research receptiveness) of New Zealand industry. It refers to the importance of scientific entrepreneurship without calling it as such:

⁴⁹ Unfortunately no direct reference is given for this statement

We need business-savvy people in the R&D sector, and R&D-savvy people in the private sector. Additionally, when a technology is transferred, the technical knowledge to support and further develop it must continue to be available (ibid: 10)

It is argued that the emphasis on track record in funding decisions creates an environment where the retention rather than the transfer of researchers to industry is fostered:

We must develop a new breed of people who start in the research environment then transfer to industry with their IP, and progress in that industry to senior management (ibid)

It may be that policies related to the attributes of entrepreneurship are more advanced in the education sector than in the broader innovation and RS&T sectors. The Tertiary Education Strategy makes mention of the need to develop:

Leaders with entrepreneurial and business management skills to underpin innovation and productivity (Ministry of Education, 2007b: 8)

There is also recognition of the role that education plays in developing these skills for the modern economy, through professional and postgraduate education and through high quality education across disciplines such as the arts, humanities, social sciences and sciences (ibid: 23). In 2002 an independent stock take of the New Zealand School Curriculum noted that:

Many countries have identified creativity and entrepreneurship to be essential for occupational flexibility, lifelong learning and economic competitiveness (Le Métais, 2002: 12)

Various references to entrepreneurship can be found in reports on the schools sector, although these might be seen as peripheral. For example a statutory report to Parliament has in its foreword the statement that:

....good education requires a culture of *continuous inquiry, innovation and improvement, risk taking and entrepreneurship* mixed with strong school and community relationships
(Minister of Education, 2006: 4; emphasis added)

But this is the only reference to entrepreneurship in 100 pages, and seems to refer to the delivery of education rather than its outcome. The same phrase is repeated in the foreword only of another report but with a different meaning:

For New Zealand, the development of a prosperous and confident knowledge society means the development of new skills and knowledge. It will require a culture of *continuous enquiry, innovation and improvement, risk taking, and entrepreneurship*. This can only come from the education system (Ministry of Education, 2006a: 3; emphasis added)

However, the new school curriculum's vision for what is wanted for young people includes a desire that they be enterprising and entrepreneurial (Ministry of Education, 2007a: 8) and in an operational sense two pilot schools, one primary and one secondary, have been established with a focus on the development of the attributes of entrepreneurship⁵⁰.

⁵⁰ <http://www.discovery1.school.nz/Discovery%201/Welcome.html>; <http://www.unlimited.school.nz/>

3.4.6 *Other initiatives*

In addition to government policies for RS&T and the management practices of research organisations, there are a number of other governmental and non-governmental initiatives aimed at fostering entrepreneurial behaviour.

New Zealand Trade and Enterprise (NZTE) operates the Escalator Service which provides specialist skills and assistance to businesses and entrepreneurs who need to raise funds (up to \$5 million) to expand, diversify or commercialise a new concept; and Investment Ready Training which is aimed at helping business people learn about the type of finance they require to expand, diversify or commercialise a new concept and how they can access equity funding from investors (New Zealand Trade and Enterprise, 2007a; , 2007b).

NZTE also sponsors the World Class New Zealand Awards which recognise New Zealanders who are making an outstanding contribution to New Zealand's economic development (NZTE, 2006) and an Incubator Awards scheme recognises success in five categories including entrepreneur of the year (Incubators New Zealand, 2006).

Some non-governmental initiatives are specifically RS&T-based. For example the New Zealand Biotechnology sector runs its own award scheme for Distinguished and Emerging Biotechnologists (NZBio, 2006). The SPARK scheme based at the University of Auckland is modelled very closely on initiatives run at the Massachusetts Institute of Technology and the University of Cambridge⁵¹.

⁵¹ The MIT \$50K began in 1990 "to encourage students and researchers in the MIT community to act on their talent, ideas and energy to produce tomorrow's leading firms. It is entirely student-managed and "has produced hundreds of successful ventures that have created value and employment" <http://www.mit100k.org/>

The Cambridge University Entrepreneurs business planning and creation competitions have since 1999 had over 450 entries and awarded over £280,000 in grants to 31 business ideas. These companies have raised more than £15m further funding and are currently valued at more than £30m. <http://www.cue.org.uk/>.

SPARK also aims to build networks and the University of Auckland and the ICEHOUSE have also organised a non-credit course targeted at those who want to find out about entrepreneurship and determine if it is for them, and to prepare them to enter the SPARK competition (Spark, 2006). A similar programme (Entré) has also been operated by the University of Canterbury (Canterprise, 2005).

Notwithstanding the focus on existing firms, the importance of building up “stocks” of entrepreneurial human capital has also been recognised in the creation of an entrepreneur category of immigrant, aimed at attracting migrants “who can demonstrate they have been actively participating in business and contributing to New Zealand's economic environment”⁵².

⁵² New Zealand Immigration Service Website: <http://www.immigration.govt.nz/branch/BMBHome/entrepreneur/>

3.5 Conclusions

This chapter shows how, during the lead-up to reforms of the New Zealand science system in the 1990s, human capital requirements were accorded a high priority in debate but tended to be overlooked in reality as the focus later shifted to the tasks associated with reorganising structures and funding systems. The principles underlying the reforms tended to work from the “outside in” i.e. from a consideration first of all of what structures were required and then how the workforce could be managed within these. Some of these principles were in conflict with commonly accepted norms of science (see table 2.3).

Once reorganisation had been completed in the middle of the 1990s, more explicit considerations of human capital issues emerged once again, but in ad-hoc and inconsistent ways as policy makers groped to find an organising framework. From time to time attention was given to determining the desired present or future pattern of expenditure on science knowledge or skills. This was generally done on topical or disciplinary bases and there were few direct attempts to characterise other desirable attributes of quality of human capital, although the need to do so was hinted at from time to time.

Part of the problem was a lack of clarity as to where lay the ultimate responsibility for system-wide human capital. There was a pendulum swing between the view that this was entirely vested in research providers and one that it was a central agency responsibility.

Strategic intentions to build human capital (or capability) for innovation were often signalled, and some specifically targeted instruments introduced, but thinking seems

to have been mostly based on an unstated assumption that traditional methods of developing human capital, often in greater quantity, were what were required. Instruments tended to focus more or less exclusively on developing the *context* within which human capital was applied, for example through improving the overall scientific culture in society, building linkages, creating fellowships in industry and making scientific careers more attractive. Attention was also given to increasing access for under-represented groups. Measurement was focused on these contextual factors and on the demographics of the scientific and technological workforce, including its qualifications.

The importance of RS&T in contributing to innovation, productivity and economic growth was widely recognised, but there was also debate about whether emphasis should be placed more on improving performance in existing industries and organisations than on creating new ones. The ways in which the RS&T system has been structured reflects the former strategy, even though among existing businesses there is a lack of investment in and capacity to “absorb” the outputs of scientific research.

A conventional, linear approach to technology transfer has predominated, although there have been occasional challenges to convention. There have been expressed desires for the attributes of scientists and entrepreneurs to be combined, but in reality the competencies of science and business continue to be regarded as belonging to separate realms. Although there has been some policy interest in fostering the mobility of research personnel, few incentives for this have been put in place for research organisations. They are still incentivised to keep scientific personnel rather than facilitating their exit as scientific entrepreneurs and despite recent signs of change, traditional knowledge-based approaches and measures have prevailed overall.

With a few exceptions, policy-making regarding human capital for RS&T has lacked alignment with the education sector. This is somewhat ironical, given that much of the critical language coming out of the RS&T sector has implied the need for a competency approach without actually identifying it as such, and educators have been leading the way in competency-based approaches to teaching, learning, application and assessment in relevant contexts. These approaches are still in their formative stages and face considerable challenges, but they are integrated from early childhood to the tertiary sector. As a consequence the RS&T workforce that will emerge over the next two decades is likely to require different management.

The lack of policy alignment has been even more apparent in the case of entrepreneurship. Despite considerable rhetoric about its importance in innovation, there has been little evidence of explicit policy to develop it. Once again, some moves have been made in education but initiatives in the non-governmental sector are further advanced in terms of practical achievements.

3.5.1 Research implications

As has been shown in chapter two there are sound, logical and historical reasons for the kinds of public policies and strategies that have been used to promote innovation, higher productivity and economic growth, and so there is merit in persisting with these. However, there are alternative and complementary approaches available. For example efforts could be made to create absorptive capacity from a low base – i.e. a *science-push* approach to establishing small, high technology firms through the movement of people with high-quality competencies of scientific entrepreneurship.

Furthermore, since overall levels of investment in RS&T are seen to be insufficient, and prospects are not promising for current sources to greatly increase their contributions in real terms, it is worth exploring other avenues, including international sources, for attracting capital into the commercialisation of New Zealand's science-based products and services. The potential for scientific entrepreneurs to open up such avenues of investment is of more than passing relevance.

For these things to happen there will need to be a better understanding of what the desired competencies are, how they are formed and how they can be measured or otherwise recognised. In the current policy environment there are steps being taken towards gaining such understanding, but they are tentative, fragmented and uneven. The current research stands to some extent outside the conventional wisdom in order to propose the development of a more positive and integrated approach.

Overall, it can be concluded that there are gaps in policy with respect to possibilities for scientific entrepreneurship in New Zealand, and it is within this gap that the current research question is located. The next chapter describes the derivation of the precise question and the research methodology for addressing it.

CHAPTER FOUR: METHODOLOGY

4.1 Introduction

Section 2.8 identifies gaps in the academic literature with regard to the phenomenon of scientific entrepreneurship and section 3.5 describes potential gaps in New Zealand's policies for RS&T, entrepreneurship and innovation. These gaps may be seen to overlay each other, denoting a high level of academic and policy relevance for research undertaken at their intersection.

This chapter links to the previous two in its derivation of a model based on an expansion of Boyatzis' (1982) competency model as in figures 2.3 and 2.6 which show the strata and conceptual location of the competencies of scientific entrepreneurship. The competency model is then connected to a wider framework to help derive the specific research question and guide the design and implementation of a methodology within an extremely complex and "noisy" system.

The overall research design is based on particular ontological and epistemological assumptions and their associated strategy of retroductive enquiry. Discussion of general issues such as the role of the researcher, trustworthiness and generalisability of research and risk management is followed by specific description of the selected method and the grounded theory on which it is based. The final section of the chapter relates the actual research experience, including the tools used, out of which are generated the research findings and conclusions contained in chapter five.

4.2 Components of a research design

A research design describes a flexible set of guidelines that connect theoretical paradigms first to strategies of inquiry and second to methods for collecting empirical material. A research design situates researchers in the empirical world and connects them to specific sites, persons, groups, institutions, and bodies of relevant interpretive material, including documents and archives. A research design also specifies how the investigator will address the two critical issues of presentation and legitimation (Denzin & Lincoln, 2000: 22)

Common elements of research design can be drawn from a reading of Blaikie (2000) Denzin & Lincoln (2000) and Cresswell (2003). These writers approach the task in a variety of ways and they use different terms and definitions, but they share a view that research design is underpinned by a set of philosophical assumptions about how things are (ontology) and claims about epistemology (the nature of knowledge and how it comes to be known). Depending on the assumptions used, the researcher's own experience and values may also be seen to be influential, and the perspective taken on these questions needs to be explicitly stated. Then a methodology is required, outlining *a plan for developing an extended argument that addresses the research question(s)*⁵³ consistent with the assumptions and researcher perspective that have been adopted.

Methodology includes strategic and tactical elements. In this chapter, *research strategy* describes the general approach taken, while at the more tactical level, the *method* section (4.11) describes detailed procedures and techniques for carrying out the research, gathering and analysing data and making legitimate claims about *findings*.

⁵³ From Victoria University of Wellington, School of Government PhD Proposal Template

4.3 Ontological issues

In the positivist worldview, there is:

A reality out there to be studied, captured, and understood (Denzin & Lincoln, 2000: 9)

That reality exists independently of human knowledge of it. "Positive facts" concerning observable phenomena and their relations are all that can be known. Facts are often uncovered by breaking what is being studied into parts and studying a piece at a time (reductionism). According to positivists, inquiry into causes, origins and purposes should be abandoned (Boyd, Gaspar, & Trout, 1991: 779-80).

However, the positivist view is no longer fully accepted even in the purest of the physical sciences where it is conceded that decisions made by the observer have an effect on what is being studied (Capra, 1992: 143-50; 171). Gherardi and Turner (2002) also argue that the natural sciences are not so "objective".

What is more, natural scientists:

Either work within naturally occurring closed systems or deliberately create such systems, i.e. laboratory conditions, where they seek to control those external factors that may contaminate the workings of the system (D. Scott & Morrison, 2005: 30);

whereas educational and social sciences:

Operate in non-deterministic or open systems. What this means is that though objects cause changes in other objects, future causal relations themselves may not replicate

these original actions because the constituent nature of the object has changed, and as a result new causal configurations are now in place (ibid: 25)

Ziman (1984: 39) argues that ontologically speaking, the positivist stance is too rigid, because it fails to take account of tacit knowledge of the circumstances, objects, events, and operations surrounding and permeating all conscious human activity (including scientific work) which is impossible to catalogue and communicate in finite terms.

Doubts about positivist ontology have led to the post-positivist contention that reality can never be fully apprehended, only approximated (Denzin & Lincoln, 2000: 9)⁵⁴.

Further removed from positivism, indeed standing in complete opposition to it is the interpretivist/postmodern view that there is no objective truth at all. Instead, reality is subjectively created, and varies depending on the viewpoint of those who experience it. Reductionism cannot work because reality is complex and has to be studied as a whole to be understood.

There has been considerable debate over the most appropriate ontological approaches for social research such as that being considered here (Fukuyama, 2004). Positivist ontology has held sway for a considerable time, but in recent decades alternative views have established equally legitimate status, particularly in respect of social sciences (Yvonna S. Lincoln & Guba, 2000; Schön, 1983: 48). The position adopted in this research is that, given its uncertain utility even in the natural and physical sciences, positivist ontology is inappropriate for research into social phenomena such as scientific entrepreneurship, which is socially constructed and as will be seen can be defined only in very “fuzzy” terms. In such cases causation is not

⁵⁴ Citing Guba, E. (1990: 17-30) *The Paradigm Dialog*. Newbury Park, CA; Sage

linear but multi-directional, and positivist methodologies are particularly inappropriate when, as in the natural sciences, they attempt to establish general laws of cause and effect for social phenomena (Howarth, 1998: 281).

On the other hand a post-modern viewpoint can lead to “methodological paralysis” (Blaikie, 2000: 149)⁵⁵. At its extreme, it could be taken to mean that there is no general phenomenon of scientific entrepreneurship, so to even try to determine what it is would be futile. This is not a particularly helpful position, although it cannot be entirely ignored, given that the difficulties of defining what a scientific entrepreneur is or does have already been canvassed in sections 2.7 and 2.8. Furthermore, the process and content of a study of scientific entrepreneurship is likely to traverse ground between those holding more or less positivist, post-positivist and interpretivist worldviews.

A useful way forward is provided by the ontology of *critical realism*, in which the ultimate objects of scientific enquiry are considered to exist and act independently of scientists and their activity (as in the positivist and post-positivist ontology) but a distinction is made between three domains: the empirical, consisting of events that can be observed; the actual, consisting of events whether or not they are observed; and the real, consisting of the structures and mechanisms that produce these events (Blaikie, 2000: 108)⁵⁶.

Different assumptions might be adopted in each of the three domains. In the *structuralist* version, the empirical domain can be regarded as being an “external” reality such as a Marxian version of an underlying class structure, while in the

⁵⁵ Citing Mills, C. (1959). *The Sociological Imagination*; New York, Oxford University Press

⁵⁶ Blaikie actually uses the term “Scientific Realism” but this is not consistent with other writers reviewed. Scientific Realism is rather “the thesis that the most critically empirically tested and currently nonfalsified theory, i.e. a scientific law, in science is the most adequate available description of reality” (Hickey, T.J.: 2005; Bk 1 p.3)

constructivist version, reality is socially constructed by the actors in the system (ibid: 111, 119).

Scientific realism is associated with a *retroductive* research strategy which develops and tests models to build understanding of phenomena at different levels, but does not necessarily claim to uncover absolute truths.

Both critical realism and retroduction are discussed in greater detail below, in Sections 4.5 and 4.6

4.4 Epistemological issues

Often associated with the positivist ontology is empiricism, or the view that observers are able to accurately determine what is true, and thus gain knowledge, through experience and by using their senses. Post-positivism does not regard the senses as being so reliable (Blaikie, 2000: 102; D. Scott & Morrison, 2005: 81).

In an interpretivist view of the world:

There are no objective observations, only observations socially situated in the worlds of- and between-the observer and the observed. Subjects, or individuals, are seldom able to give full explanations of their actions or intentions; all they can offer are accounts, or stories, about what they did and why (Denzin & Lincoln, 2000: 19)

A major problem with empiricism is that of the impossibility of accessing data through the senses without some prior theory to make sense of it (see the discussion of mental models and paradigms in section 2.3.2). Empirical investigations:

Are necessarily theory laden. For researchers, the question is not whether to use theory or not, but whether to explicitly recognise the connections to theory (Sæther, 1998: 246)

Hickey (2005) cites Norman Hanson, an influential writer on retrodution (see section 4.6) illustrating how perception is theory-laden through the example of second-century and seventeenth-century astronomers who both look at the dawn but see different things, due to the different mental models they have of the workings of the universe.

In general critical realism cautions against a complacent link being made between reality and our knowledge of it (Downward & Mearman, 2007: 89). Its epistemology is based on the building of models of mechanisms such that, if they were to exist and act in the postulated way, they would account for the phenomena being examined (Blaikie, 2000: 108). This is a form of *inference to the best explanation* (Lipton, 2004, see also section 4.5). Description is required before explanation can be attempted (Blaikie, 2000: 82).

4.5 Critical Realism

It is generally acknowledged that the primary founder of critical realism is Roy Bhaskar. However, even a book in a series partly edited by Bhaskar himself states - albeit in a discreet footnote - that while (Bhaskar's) work is an extremely important contribution to philosophy, it has become more inaccessible since the 1970s (Fleetwood & Ackroyd, 2004: 19). The following review of critical realism is therefore derived from many of the writers who followed Bhaskar, while paying him due credit.

Although it is argued by some that critical realism attempts to reconcile positivist and post-positivist and empiricist and interpretivist views of the world and seeks to

distance itself from relativism (D. Scott & Morrison, 2005: 46-7) critical realists do tend to be scathing in their criticism of positivism:

It will be apparent that critical realism opposes relativist, idealist and strong social constructivist tendencies in social science. But on all of the matters I have discussed, critical realism also opposes positivism: its empiricist epistemology based on apparently theory-neutral observation; its confusion of matters of ontology with epistemology, as in equating the world with what can be observed; its flat, unstratified ontology which cannot comprehend emergence; its assumption of universal closed systems and its Humean view of causation as constant conjunctions, which leads it to encourage researchers to view the search for empirical regularities as the goal of science; its contemplative, unpractical view of the relationship between knowledge and its objects; its unqualified naturalism and its incomprehension of interpretive understanding; its indifference to the nature of science as a social activity; and its subjectivist conception of values which leads it to confuse objectivity in the sense of value-neutrality with objectivity in the sense of truth-seeking (Fleetwood & Ackroyd, 2004: 15)

The confusion (conflation) of epistemology and ontology mentioned above is described by Bhaskar as the *ontic fallacy* within positivism and empiricism (D. Scott & Morrison, 2005: 46).

Against critical realism though, Steele (2005: 146) claims that it is in error in insisting that closed-system models have no place in social science and in rejecting the scientific relevance of event regularities and statistical inference. The use of metaphor and intuition is not exclusive to critical realism (ibid: 151) and critical realism also acknowledges an empirical realm of experiences. Where it is different is in the development of a deep, stratified ontology (D. Scott & Morrison, 2005: 175) with further layers of reality consisting of events and their underlying causal factors known as powers, mechanisms or tendencies (Lawson, 2004: 235). Just as causality

within *natural* science rests in structured *generative mechanisms*, similarly deep social structures underpin all *social* activity (Steele, 2005: in abstract; 135).

Powers and mechanisms can retain their potentiality for influencing the world without them actually doing so. A power designates what something *can* do. Actual events or states of affairs may be co-determined by numerous, often countervailing, mechanisms (Lawson, 2004: 235) and they may or may not be observed (Outhwaite, 1987: 45). Mechanisms are relatively enduring, whereas:

Our capacity and our procedures for knowing them changes and is determined by social and political arrangements, in the present and stretching back in time (D. Scott & Morrison, 2005: 46)

Another key feature of critical realism is that the *nature of things* emerges out of the things themselves, not from the way that researchers conceptualise them (Fleetwood & Ackroyd, 2004: 10; Outhwaite, 1987: 37-8). Likewise social structures:

Are emergent phenomena in the sense that there is some lower level out of which something has arisen which, although dependent on that lower level, is not predictable from it....social rules, relations, processes, systems and so on are ontologically distinct from (or irreducible to) behaviour (Lawson, 2004: 236-7)

Furthermore, the collection of sense data about the world is never adequately constitutive of that world, and this means that the observer or researcher has to intervene in the world in order to understand it. The emergent quality of social phenomena means that notions of reality are determined by both current and evolving ways of understanding (D. Scott & Morrison, 2005: 194-5).

Overall, it is claimed that critical realism is able to explain emergent structures, whereas:

Empiricist and radical relativist descriptions of reality always lag behind the way society is presently constituted, which is understood as an on-going process (D. Scott & Morrison, 2005: 47)

Three basic steps involved in a critical realist approach are: the postulation of a possible mechanism; the attempt to collect evidence for or against its existence; and the elimination of possible alternatives. The resulting explanation can be considered a good one if: the postulated mechanism is capable of explaining the phenomena; there is good reason to believe in its existence; no equally good alternatives can be thought of (Outhwaite, 1987: 57).

Notwithstanding some criticisms, critical realist ontology has much to recommend it. In summary, its main claims are that there is:

A world which exists largely independently of the researcher's knowledge of it. This independence implies not simple, direct access to the world but a more difficult relationship. Our knowledge of the world is always in terms of available descriptions or discourses, and we cannot step outside these to see how our knowledge claims compare to the things to which they refer. It is the experience of the fallibility of our knowledge, of mistaking things and being taken by surprise, that gives us the realist conviction that *the world is not merely the product of thought, whether privately or socially constructed* (italics added). But it is also this experience which suggests that although it is always mediated by and conceptualised within available discourses, we can still get a kind of feedback from the world. In the realm of practice, not just anything goes: wishful thinking rarely works. At least part of the world is accessible to us, though, as we have noted, always in a mediated way (Fleetwood & Ackroyd, 2004: 6)

Fleetwood and Ackroyd go on to note (ibid: 11) the implications that social research should place much more emphasis on conceptualisation and description than positivism assumes, and that the search for regularities through quantitative analysis becomes relatively downgraded (though not redundant). They argue that critical realism implies the need to distinguish between generalisation, which is about finding out how extensive certain phenomena are, and may give little explanation of what produces them; and explanations of what produce particular stages and changes, without necessarily indicating much about their distribution, frequency or regularity.

Retroduction is the research strategy which is virtually inseparable from critical realism (Downward & Mearman, 2007: 78). One of the advantages of critical realism and its associated strategy is that it breaks down interdisciplinary boundaries and allows for multi-disciplinary research design (Downward & Mearman, 2007: 86, 97; Mansilla, 2006; Sæther, 1998: 248). The next section turns to a fuller discussion of retroduction.

4.6 Further justification for use of a retroductive strategy

4.6.1 *Induction and deduction*

Retroduction is an alternative to pure *induction*, which detects patterns and derives theory from data, and *deduction*, based on the logic of critical rationalism developed by Karl Popper in the 1930s (Blaikie, 2000: 102). Deduction works from hypotheses which are either proven or disproven, and theories confirmed or falsified.

Steele (2005) refers to the orthodox deductive-nomological (ODN) tradition; i.e., to mathematical deduction and statistical induction. As this statement implies, statistical

analysis is the most common form of inductive social research but this has been criticised by critical realists as:

A variant of positivism where statistical explanations are developed for social phenomena in the form of universal laws or generalisations (D. Scott & Morrison, 2005: 175)

A further epistemological problem with induction is the circularity of presuming that patterns are likely to be repeated based solely upon the knowledge that patterns have been repeated in the past; i.e. induction is invoked in support of induction (Steele, 2005: 141). Most famously, if all swans that have been studied hitherto are white, then all swans must be white (Ziman, 1984: 40).

Despite these criticisms, many social research designs build in an inductive element to allow for responsiveness to the setting within which the research is to be carried out. This *reflexive* element is largely neglected in deductive strategies (D. Scott & Morrison, 2005: 57).

The deductive process is also criticised for a number of faulty assumptions which underpin it, for example that discrete and measurable variables can always be identified:

So, for example, each individual can be racially classified, and that classification is not determined in any way by context, self-reporting or history; or at least, that measure of race and consequent gradations in the classificatory system are agreed and generally accepted in society (ibid)

This is clearly not so, particularly in social settings. It will be recalled from section 2.7 for example that there is no such thing as an “average” entrepreneur.

In practice, although they have different ontological assumptions and are often seen as mutually exclusive, inductive and deductive strategies may be combined in sequence (Blaikie, 2000: 102). Combining methods in the process can also be justified ontologically (Downward & Mearman, 2007: 80).

4.6.2 *Abduction*

Abduction and retroduction are two strategies that have been developed as a consequence of the failure of inductive and deductive research strategies to provide convincing explanations of how social scientists develop knowledge of society (D. Scott & Morrison, 2005: 58). Abduction is sometimes seen as an *alternative* to retroduction (D. Scott & Morrison, 2005: 2) and sometimes as the same thing e.g. Sæther (1998: 246). But both are a form of inference to the best explanation in which an explanation (or hypothesis) is suggested from among all available explanations to account for an observed fact or set of facts. For example, Jones was in the building during each of the murders. Perhaps he is the killer (B. Thompson, 2007). However, something cannot be inferred simply because it is a possible explanation. It must somehow be the best of competing explanations (Lipton, 2004: 56). Because such explanations may turn on mere coincidences (or even conjecture) they are regarded as the weakest type of argumentation (B. Thompson, 2007).

Abduction is generally an interpretivist research strategy based on gaining an insider's perspective (outsider views are held to give a partial view of reality). In education research, the abductive process comprises the way researchers:

Go beyond the accounts given by social actors about their plans, intentions and actions in the real world. This process is multi-layered, with the first stage being the collection of

data that reports how individuals understand reality, using methods such as semi-structured and auto-biographical interviews. At the second stage the researcher moves from reporting lay accounts to constructing social scientific theories about human relations (D. Scott & Morrison, 2005: 1)

But Scott and Morrison (ibid) also point out that there is no such thing as “pure” abduction since the researcher cannot help but have an influence in the process (ibid).

4.6.3 *Retroduction*

Retroduction has deep historical roots going back to Aristotle, but among the most noted modern contributors to this tradition (even founders) are C.S Peirce and Russell Hanson (Hickey, 2005; Sæther, 1998: 246). Evoking its ontological base in critical realism:

Retroduction can be contrasted to other research strategies such as deduction or induction, as not simply developing specific claims from general premises nor general claims from specific premises respectively, but “the mode of inference in which events are explained by postulating (and identifying) mechanisms which are capable of producing them (Downward & Mearman, 2007: 78)⁵⁷

Retroduction is suited to finding theoretical patterns, or deep structures, that if valid will help in conceptualising the empirical and deductive patterns that are observed in a single case (Sæther, 1998: 246; see figure 4.1). For Peirce, retroduction is the only kind of inference that actually can create new knowledge (Forstater, 1999: 9).

⁵⁷ Citing Sayer, A. (1992: 107). *Method in Social Science: A Realist Approach*. London, Routledge

Figure 4.1 Deduction, induction and retroduction (Sæther, 1998: 246)⁵⁸

Matthew Forstater (1999) adds another dimension by describing the work of the early 20th Century economist and sociologist Adolph Lowe, and pointing out that Lowe's instrumental approach, which brings to the fore the role of discovery and creativity which are central to Austrian conceptions of entrepreneurial activity, *matches in action* the retroductive process. According to Forstater, Lowe's instrumentalism has affinity with the ideas of C.S. Pierce and Russell Hanson, as well the mathematician George Polya's work on heuristics and Michael Polanyi's explorations of tacit knowledge (Forstater, 1999: 6).

Peirce refers to retroduction as reasoning from consequent to antecedent, or inferring a cause from its effect. Lowe's instrumentalism similarly works backward, but from a desired future to the present, rather than from an observed present to the past. Beginning with a vision of desired outcomes, focus is then brought to bear on the discovery of the technical and social paths by which those outcomes might be achieved, including the requisite behavioural and motivational patterns and

⁵⁸ Based on Alvesson & Sköldböck (1994). *Talking og Reflektion*; Studentlitteratur, Lund

environmental contexts. Carden & Murray (2007) similarly attribute to Fritz Roethlisberger the observation that:

Most people think of the future as the end and the present as the means, whereas, in fact the present is the end and the future the means. What this means is that the future forms and alters what people do now. In that respect, the future is the *means* to alter behaviour today (ibid: 277)

Forstater compares the process for a business man who forms an expectation with that of a scientist who formulates a working hypothesis, and differs from Ziman (1984: 44) by asserting that they are both carrying out the same process. Both are reflecting:

An attempt at cognition and orientation in an imperfectly known world, both embody imperfect knowledge to be tested and improved by later experience (Forstater, 1999: 15)

Because of its ontic depth that is, “moving beyond the immediately postulated level of events and/or texts” retrodution is advocated in preference to the “faulty” logic of inference described by deductivism (Downward & Mearman, 2007: 88). However, retrodution is by no means universally accepted and is “not proven” according to Steele (2005: 151). Steele also criticises critical realism, although he does allow to some extent its usefulness and like Forstater (1999) in its focus on underlying mechanisms sees affinities with the Austrian school of economics (Steele 2005: 135-152).

4.7 The research framework

4.7.1 *Analytic frames and models*

The critical realism - retroduction strategy, with its reliance on analogy and metaphor and dynamic interaction between deduction and induction, is manifested in practical terms in the ideas of *analytic frames* (Ragin, 1994: 55; Sæther, 1998: 247) and *models* (Blaikie, 2000: 165). According to Ragin social research, in simplest terms, involves a dialogue between *ideas* and *evidence*. Ideas help social researchers make sense of evidence, and researchers use evidence to extend, revise and test ideas (Ragin, 1994: 55). *Analytic frames* are what most social scientists make use of when they have a specific research question in mind. Analytic frames:

Articulate ideas, and through this both classify and characterise phenomena. After collecting theory-laden data, the researcher has to make sense of them in one way or another and relate them to ideas and frameworks that so far have guided his or her research. Analytic frames and images interact to produce a progressively refined picture, which becomes the representation and the explanation (Sæther, 1998: 247)

This combination and interaction is a retroductive process (ibid).

In Blaikie's terms, it is essential to have an initial conceptual *model* to work with in an area that is enormously complex and fluid. Diagrammatic models help draw out patterns from large amounts of data, provide clues and suggestions about what to look for (Blaikie, 2000: 136) and allow for interplay between research activity and theory building. However, the model will not be allowed to become a mental

straitjacket (Bryman, 2004: 271). It is possible to distinguish between arriving with closed minds and arriving with an idea of what to look for:

Preconceived ideas are pernicious in any scientific work but foreshadowed problems are the main endowment of a scientific thinker, and these problems are first revealed to the observer by his theoretical studies (Stake, 2000: 449)⁵⁹

This view echoes the difference between observations that are *concept-dependent* and those that are *concept-determined* (D. Scott & Morrison, 2005: 82). The former is desirable but the latter would imply that the researcher lacks the necessary degree of detachment:

Models can play a sensitising role (emphasis added) a point of reference and a guide rather than predetermining the phenomenon under investigation.... the connection of concepts and data means that a concept provides a set of general signposts for the researcher in his or her contact with a field of study. While the concept may become increasingly refined, it does not become reified such that it loses contact with the real world.... a sensitising concept retains close contact with the complexity of social reality, rather than trying to bolt it on to fixed, preformulated templates (Blaikie, 2000: 253)⁶⁰

Maykut and Morehouse (1994: 37) also note the importance of maintaining a tolerance for ambiguity (avoiding premature closure on the subject under investigation) and the researcher coming to understand the phenomena as patterns emerge. Miles and Huberman (1994: 16) address the question of *tight* versus *loose*. If the conceptual framework is too loose, everything looks important at the outset. If it is too tight, there is insufficient flexibility to take account of what is actually found.

⁵⁹Citing Malinowski, B. (1984: 9). *Argonauts of the Western Pacific*. Prospect Heights, IL: Waveland

⁶⁰ Citing Bryman, A. (1988). *Quality and Quantity in Social Research*. (p. 68). London: Allen & Unwin

4.7.2 *A competency model*

As has been noted in section 2.7, many researchers have explored the various dimensions of entrepreneurship, including the deep reaches of personality theory, without succeeding in fully defining entrepreneurship or entrepreneurs. Partly, as shown in table 2.2, this is because research has tended to focus on one part or another of a very broad and complex system, but it is also unlikely that the phenomenon will ever be fully defined. Indeed this is ontologically and epistemologically an impossible goal and it is more realistic for research - particularly that which seeks to inform policy development - to aim at improving *understanding* of entrepreneurship.

The picture is made even more complex by the introduction of the extra dimension of *scientific* entrepreneurship, but the research and policy gaps discussed in earlier chapters justify such a move. Given the complex layering and highly variable understanding of key concepts within scientific entrepreneurship, critical realism provides an appropriate ontological and strategic framework to be used to address the topic. In particular, the use of a model helps locate the research within the wider system, and enables focus on a core research question.

Following on from chapter two, the model to be used needs first of all to incorporate consideration of both the *individual* and his or her component *attributes* with a *system-wide* perspective, including the *processes* of interaction between the individual and systemic levels. The literature on competencies is particularly cognisant of these requirements and, although Boyatzis (1982) focuses on managerial competencies and not entrepreneurship, and despite warnings about

weaknesses in methodology and its generalisability (ibid: 232) the model proposed by Boyatzis (Figure 2.3) provides a basis from which to proceed.

Boyatzis' competency model includes visible behaviours (which might be used as "hooks" to identify potential subjects and thus to enter the research process) but it also recognises the deeper layers that contribute to behaviour, along with organisational and environmental context and the interdependency of all these levels. It is this layered structure that makes critical realism of particular relevance to a discussion of competence (sic) theories (Lawson, 2004: 235).

One of the weaknesses of Boyatzis' model (and Baum et al's, see figure 2.5) is that it lacks a lifecycle dimension. A *longitudinal* dimension is thus added in figure 4.2, relating to lifecycle or career (i.e. time). The *horizontal* dimension is represented by the overlapping of the competencies of science and entrepreneurship shown in the Venn diagram in Figure 2.6.

Converting Boyatzis' model from its "ring" format for the purpose, a three-dimensional framework for organising research is constructed as shown in Figure 4.2 below. The vertical dimension is captured as in the original competency model.

Figure 4.2 An extended competency model for research

A model is the basis for the development and testing of theory which may be generalisable rather than the enumeration of frequencies – that is analytic rather than statistical generalisation (Yin, 1994: 10).

An entirely new understanding is seldom reached but refinement of understanding is more achievable (Stake, 1995: 7). It is not possible to establish whether models are true or false, valid or invalid. The only judgement that can be made about models is whether they are useful or productive (Blaikie, 2000: 171). When researchers use the retroductive strategy:

There is no way that the validity of any “empirical” data can be established; all measurement has to be directed and interpreted using the constructed hypothetical model. In the end, the degree to which any model is a valid representation of reality will be a matter of judgment. This is an inherent problem for the retroductive research strategy, regardless of issues associated with triangulation (ibid: 266)

Metaphorically, knowledge about scientific entrepreneurship might be gained in the way that knowledge is gained about the earth’s crust. Geologists are able to observe some elements of crustal structure directly, e.g. uplifted layers and core samples, while other aspects are detected indirectly by intercepting and measuring signals such as shockwaves. Similarly, knowledge about processes within the crust (e.g. movements, flows) is gained by direct or indirect measurement. Observations make sense only in the context of a mental model, which is constantly open to challenge and revision. What is directly observed clarifies what is detected indirectly, and vice versa. Models gain credibility as more observations fit and fewer don’t. Ultimately, earth scientists build understanding to the point where they are able to recognise particular features and processes within the earth’s crust, and whether or not they are present within a given location.

4.7.3 *The research framework*

In the case of scientific entrepreneurship also, it is asserted there are visible (behavioural) and invisible “structures” and mechanisms to be more fully understood. Understanding is developed through iterative comparison of the *unit of analysis* which is the focus of the study (scientific entrepreneurs) with the competency model.

However, as has already been shown in sections 2.7 and 2.8, because of their uncertain natures, questions such as *what is a scientific entrepreneur?* or *what is*

scientific entrepreneurship? are not likely to lead anywhere useful on their own – particularly in guiding potential policy or management interventions.

Instead, a wider research framework is developed to include a process that *can* be influenced, implied by the geological metaphor described above and captured in the question:

How is scientific entrepreneurship recognised?

This is a universal question and through retroductive study, the usefulness of the competency model is tested and so grows understanding of the underlying phenomenon. The New Zealand context is added to give the question a strategic focus and particular cogency with regard to implications for public policy in a specific national setting.

At any level, the process of recognition can be seen to encompass a number of phases:

1. Knowing what something is, and what distinguishes it from other things (having a mental model of what it is);
2. Receiving direct or indirect signals that if detected will indicate the presence of the phenomenon in question (if these signals are not detected, the process of recognition will stop);
3. Becoming aware of presence or absence – “making it out” or detecting signals which may be measured; and

4. Acknowledgement of presence – a response.

4.7.4 *The link between the literature review, methodology and research questions*

There is a negative and a positive explanation for the choice of the research question. The negative reason is that, as is demonstrated by the review of the literature on entrepreneurship (section 2.7) there is no consensus as to what entrepreneurship is or what entrepreneurs “are”. In part this is because research has tended towards reductionism (see table 2.2) and to some degree positivist approaches. Therefore, even though the topic of scientific entrepreneurship has been shown in the thesis to be of academic and strategic interest, there seems little prospect of fruitful research using conventional approaches.

Fortunately, an alternative methodology for building understanding is available, as described above. The focus on “recognition” provides the basis for a question that can meaningfully be researched, and is effectively a way of encapsulating the critical realist/retroductive strategy. The component steps of “recognition” operationalise and provide the basis for the research instrument.

Thus the research question does not arise purely from the literature reviews in chapter two (and three) – it equally arises from this methodology chapter. Indeed, the design and application of the methodology to addressing the topic of scientific entrepreneurship (in its own right and as a representative public policy question) and findings as to the efficacy of that methodology, *might be seen as in themselves contributions to new knowledge*. The wording of the question reflects this dual focus.

All of the elements of recognition, and their relationship to the competency model, are considered in the framework as shown in Figure 4.3.

Figure 4.3 The high level research framework: recognition and model building

This high-level schema is used to frame detailed questions and to generate and make sense of data from interviews with scientific entrepreneurs as they describe ways in which scientific entrepreneurs are recognised - or not - within the New Zealand innovation system. By working iteratively and interactively between new knowledge gained by observation and interpretive methods, and synthesising this with existing knowledge, the model develops a firmer shape.

There is a parallel line of enquiry in this research. As well as the methodology being used to answer the research question, *at another level the research is also being used to test the efficacy of the methodology*. In other words there is an underlying question as to how valid is critical realism and the retroductive strategy for addressing this sort of policy problem (the relevant conclusions are in section 6.4).

4.8 Qualitative or quantitative research

Approaches to research vary across a spectrum where at one extreme is the use of qualitative methods in a study of few cases and many features, and at the other the use of quantitative methods in surveys with many units, but only a few features. In

the middle is the comparative study of diversity across a moderate range of 5 to 50 cases (Sæther, 1998: 247).

It is common for qualitative and quantitative approaches to be accorded the status of research strategies (Ragin, 1994: 33) and each to be lined up with a particular ontology (e.g. Denzin & Lincoln, 2000: 9; Maykut & Morehouse, 1994: 2) but there is no particular reason why this should be the case (Miles & Huberman, 1994: 41; Yin, 1994: 15). A major difference between the two approaches:

Is not the counting or lack of counting of the occurrences of a particular word or behaviour, but rather the meaning given to the words, behaviours or documents as interpreted through quantitative analysis or statistical analysis as opposed to patterns of meaning which emerge from the data and are often presented in the participants' own words" (Maykut & Morehouse, 1994: 17)

Qualitative research is appropriate to searching for pattern to help understand a particular phenomenon as it is based on postulates that: (1) reality is multiple and constructed; (2) events are simultaneously and mutually shaped; and the (3) goal is discovery – rather than proof (ibid).

Scientific entrepreneurship is an elusive phenomenon – there is some essence that escapes quantitative measurement and may be discoverable only through understanding the words of the people who come into contact with it.

In chapters two and three, there are indications that quantitative measures of human capital are not capturing an increasingly crucial aspect of quality. Furthermore, recognition of scientific entrepreneurs is likely to be based on a socially constructed process which cannot be easily measured. These factors, along with the theoretical,

exploratory nature of the research in question, mean that a predominantly qualitative approach is merited (Cresswell, 2003: 22). It would be inconsistent to rely on quantitative methods, although they may play a part - evoking the concept of “bricoleur”, albeit this is intended for qualitative research only (Denzin & Lincoln, 2000: 5).

Llewellyn and Wilson (2003: 345) argue there is much scope for interdisciplinary research and an increased awareness of the possibilities raised by different yet complementary specialisms (such as psychology, economics, sociology and business theory) can only enrich this process. An open-minded approach must be maintained, with potentially fruitful cross-validation of results by the integration of approaches and perspectives. A broader, multi-disciplinary methodology is more consistent with a critical realist approach and is more likely to result in enhanced understanding. A mixed-methods approach also provides a measure of triangulation as the research question is addressed from a number of perspectives: that of the researcher, the subjects and the system as a whole (Downward & Mearman, 2007).

4.9 Human-as-instrument

4.9.1 Overview

The human-as-instrument is a concept developed by Lincoln and Guba (1985: 193-4) and explained further by Maykut & Morehouse (1994) to illustrate the unique position taken by qualitative researchers. A person, that is a human-as-instrument, is the only instrument which is flexible enough to capture the complexity, subtlety, and constantly changing situation which is the human experience. It is the person with all of her or his skills, experience, background, and knowledge as well as biases which is the primary, if not the exclusive, source of all data collection and analysis. A

human instrument is responsive, adaptable and holistic. A human investigator has knowledge-based experience, possesses an immediacy of the situation, and has the opportunity for clarification and summary on the spot. Finally, a human investigator can explore the atypical or idiosyncratic responses in ways that are not possible for any instrument which is constructed in advance of the beginning of the study.

The approach used in this research is *perspectival* rather than objective or subjective (ibid: 20). Nevertheless it is also important to include an element of *reflexivity* - reflections on personal experience of the fieldwork (Yvonna S. Lincoln & Guba, 2002: 207):

Reflexivity is a key notion for most post-positivist researchers. This is because they do not believe that a clear separation exists between the observer and what they are observing, and therefore the values and frameworks through which they operate are implicated in the research account they produce. Reflexivity, therefore, may be defined as “the process by which the researcher comes to understand how they are positioned in relation to the knowledge they are producing” (D. Scott & Morrison, 2005: 201)

The social scientist must begin with data which are already partially interpreted in the language of everyday life (Outhwaite, 1975: 16):

But there is a distinction between *interpretation* which tends to be from a particular theoretical perspective (as in “the Marxist interpretation of history”) and “understanding” which suggests a more all-round approach (ibid)

Outhwaite describes (though he is unable to adequately translate) the concept of *verstehen* which is deeper than mere understanding and derives originally from Max Weber. People can only really be understood by putting oneself in their shoes. The use of *verstehen* does not rule out causal explanation (*erklären*) but a *verstehende*

approach operates by situating phenomena in a larger whole which gives them their meaning (ibid: 33).

Markers of a good qualitative researcher-as-instrument are thus:

- some familiarity with the phenomenon and the setting under study;
- strong conceptual interests;
- a multi-disciplinary approach, as opposed to a narrow grounding or focus in a single discipline; and
- good "investigative" skills, including doggedness, the ability to draw people out, and the ability to ward off premature closure (Miles & Huberman, 1994: 38).

In this research, previous knowledge and experience, along with a literature review, is being applied to identify a particular problem, a set of research questions and conceptual models of scientifically entrepreneurial competencies. The role being occupied by the researcher is that of empathetic observer (Blaikie, 2000: 39) since there is a need to be able to understand the viewpoints of scientific entrepreneurs and other informants while also aiming to achieve some degree of reflexivity. It is by grasping subjective meanings used by social actors that their actions can be understood – this in Blaikie's view is what constitutes *verstehen* (ibid: 52-3).

The aim is not to act as a "voice" or an advocate for participants in the research. They may not personally need advocacy in any case, as most of the subjects are

selected since they have come to notice due to some degree of success as scientific entrepreneurs. Despite that it is presumed that they have stories to tell of struggles they have had, and as a class of people they may gain future benefit from any improved recognition of their particular qualities within the overall innovation system. It is from the point of view of systemic performance that the research is being undertaken, and the system includes scientific entrepreneurs and their activities.

Nevertheless in reporting on findings, some interpretation of social entrepreneurs' *reality* is required. There is a need to construct an account of what they say, and that is not likely to be a totally neutral process:

Researchers have to invest something of themselves into their account. Social, geographical and historical locations, as well as the interests of the researcher, have a bearing on the nature of the account produced. Hence, detached objectivity is seen to be impossible, as the author's voice will always be present (Blaikie, 2000: 53)

What is important therefore is to be aware of one's own personal history and values and their impact on the research.

4.9.2 Personal standpoint

As someone with an affinity with the humanities who nevertheless pursued a science path, graduated BSc and taught sciences at secondary school level, I have long wondered about the possible existence of a *scientific personality*, independent of knowledge, that orientates some people towards scientific competencies and virtually disqualifies from the natural and physical sciences those with different sorts of inclinations. If it exists, this scientific personality may contribute to the existence of the "two cultures" famously identified by C.P. Snow (1960) and possibly also the gap

that has emerged between the scientific and non-scientific communities in general. Interestingly, Snow wrote not only of the gap between science and the humanities, but also of that between pure and applied scientists (Snow, 1960; , 1963). As has been discussed in chapter two, much science policy has focused on finding ways to form links between people on either side of this supposed gap. However, at face value it appears that some people bridge the gaps *within themselves*. Informal observations and intuition suggest that such people, even when they are high achievers in conventional terms, have other attributes that are not developed or recognised conventionally. The research has been designed to investigate these attributes in more depth.

Further education and experience in training and development, business, science policy and knowledge transfer (including some involvement in generating documents which have been appraised in chapter three) has led me to a belief that policy for RS&T-based innovation, while correctly focusing on systemic issues, may have also developed a “blind spot” with regard to the role of human capital. Although this starting position has influenced the searches reported on in chapters two and three, the research question has not been selected only in terms of what is important to me in value terms (Fleetwood & Ackroyd, 2004: 10) but in terms of what is more objectively important, as shown by the rationale that has been built through this document. Given that, I also believe that I am familiar enough with the system to carry out the research while at the same time being sufficiently detached and objective to be able to reach independent conclusions.

4.10 Managing the research

4.10.1 Ethics

It is expected that those who agree to be recruited into the full research process are sympathetic to its overall aims and thus willing participants. Trust is further enhanced because there is unlikely to be any negative power differential for the interviewee, nor any personal risk arising from their participation. Given that the participants are unlikely to be marginalised and the topic not likely to be highly personal or threatening, the ethical requirements for the research are not particularly onerous. An exception is where family members or mentors are used as informants to triangulate the views of participating scientific entrepreneurs. There are some standard ethical measures to be put in place and Human Ethics Committee approval for the research method has been granted. In particular, there are:

- appropriate procedures to ensure that the terms of participation are made clear, including who is involved in designing and steering the research, the purpose of the research, benefits that will accrue, the time and effort involved in participating, the kind of data collection, provisions to ensure privacy, confidentiality and anonymity and participants' rights to validate the accuracy of records;
- informed consent to participate on these terms; and
- clarity about ownership of data and conclusions, and the use of results (adapted from Miles & Huberman, 1994: 48).

4.10.2 Data capture

In determining the criteria which will govern the admissibility of the data into the research design, it is necessary to consider: what data are needed?; where are the data located?; how will the data be secured?; and how will the data be interpreted? (Debakey, 1976).

In this research, there are two forms of data. Firstly, documents relating to organisational reporting on human capital and policies on RS&T, competency development and entrepreneurship are collected and analysed with findings already reported in section 3.4.

Secondly, a semi-structured interview format (appendix 8.3) is developed to elicit data from respondents about their experiences of:

- Their own life histories;
- Scientific entrepreneurship; and
- The “recognition” process.

The concept of recognition is seen to apply to an individual (recognising self) as well as to others. Hence the interviewees include individual scientific entrepreneurs (as defined for the purpose of the research) as well as others who have worked with scientific entrepreneurs or in other ways have been involved in policies or practices that impact on actual or potential scientific entrepreneurship. In addition, the analysis of policy-related documents in chapter three focuses on more disembodied

(systemic) recognition. Thus there is a considerable degree of triangulation on the recognition question.

4.10.3 Trustworthiness of findings

The ultimate test of trustworthiness is whether we believe the findings strongly enough to act on them (Maykut & Morehouse, 1994: 147) and the key issue becomes whether the relevant community of scientists evaluates reported findings as sufficiently trustworthy for their own work (ibid: 147). Presumably this view could be taken to apply to non-scientists (including policy makers) as well and to this end, the current research project and its emerging findings are presented to policy and industry audiences at various stages of the process as a form of “reality check”.

Several features are included in the research process to build trustworthiness:

- Multiple methods of data collection;
- Building an audit trail;
- Member checks - research participants are asked whether their experience has been accurately described (Gherardi & Turner, 2002: 90; Maykut & Morehouse, 1994: 147).

Another feature proposed by Maykut and Morehouse, i.e. working with a team, is not possible in a PhD project. Other approaches to ensuring trustworthiness include looking purposively for contrasting cases and triangulation, or cross-checking the evidence by collecting different kinds of data about the same phenomenon to make validation possible (D. Scott & Morrison, 2005: 252). Blaikie (2000) is sceptical about

triangulation but Downward and Mearman (2007) go so far as to argue that combining methods is *central* to retroductive activity and a retroductive methodology *requires* the triangulation of research in order to reveal *different* features of the same layered reality without the presumption of being too exhaustive. In their view, Mixed Methods Triangulation (MMT) is an *operational statement* of retroduction (ibid: 78, 81, 90, 93 all emphases in original).

Research also needs to be reliable, in that the process of study is consistent, reasonably stable over time and across researchers and methods; internally valid (the findings are consistent with the data); and externally valid (the findings are transferable - Miles & Huberman, 1994: 278-80).

4.10.4 Risk management

Apart from the possibilities of flawed design or implementation, in this project there are risks that are common to any qualitative research, and these either do not come to pass or are satisfactorily managed.

For example, an obvious structural risk is that the methodology does not allow for the identification of hitherto unsuccessful yet emerging scientific entrepreneurs who have by definition not (yet) been recognised (Roberts, 1991: 50). If it were possible to identify them, the reasons for their lack of recognition could be studied, and provide richer conclusions. However, the literature on entrepreneurship shows that serial experiences of failure are common before an individual succeeds and so even successful participants are likely to shed light on flaws in the recognition process. In addition, by using a snowball method of sampling some informants are identified who are not yet popularly identified as scientific entrepreneurs.

Another risk is that posed by aiming to study personal attributes separately from social capital and other contextual factors when these are intimately connected, and despite a reductionist approach being eschewed. This risk is managed through the use of the integrated competency model, acknowledging the connections and overlaps that exist, and focusing mainly on intra-personal attributes that enable scientific entrepreneurs to engage with social capital. There are also risks in that the use of an *a priori* definition to select a sample and model to construct an interview instrument will result in circular, “self-fulfilling” findings. These risks and their management are described in more detail in sections 4.10.4 and 6.5.

Finally, there is a possibility that the researcher’s employment in a University-based company results in a perception of conflict of interest, particularly among managers of research institutes. For example questions related to human resource management processes may impinge upon matters of competitive advantage and commercial sensitivity. In the event some reservations are encountered but not pervasive, and even where they occur it is still be possible to gain useful data from publicly available sources and there are sufficient numbers of other respondents.

4.11 Method

4.11.1 Grounded Theory

Theory: A set of well-developed concepts related through statements of relationship, which together constitute an integrated framework that can be used to explain or predict phenomena (Strauss & Corbin, 1998: 15)

The approach used to develop theory from this research is derived from the work of Glaser and Strauss (1967) which is later enlarged upon by Strauss and Corbin

(1998). In the preface of the former publication, the authors write about their wish to close the embarrassing gap between theory and empirical research. They argue for grounding theory in social research itself – for generating it from the data. Hence they invent the term *grounded theory* and a means for discovering it known as a *method of constant comparative analysis*. What this means is that out of data derived from comparing different instances of a particular phenomenon, themes emerge which can be categorised and further compared on a continuous basis, then related in a way such that the resulting pattern provides a theoretical explanation or prediction of the phenomenon being investigated.

Grounded theory is consistent with critical realism (Lee, 2002: 790) and abduction or retrodution (Downward & Mearman, 2007: 96). Indeed Lee (2002) rejects retrodution as a strategy and poses grounded theory as an *alternative* which is truer to critical realism.

Thematic categories derived from constant comparative analysis need to be:

Readily (not forcibly) applicable to and indicated by the data under study (Glaser & Strauss, 1967: 3)

However, Glaser and Strauss allow that it might be possible for the researcher to:

Begin with a partial framework of "local" concepts, designating a few principal or gross features of the structure and processes in the situation that he will study (ibid: 45)

Comparative analysis puts a high emphasis on *theory as a process*; that is, theory as an ever-developing entity, not as a perfected product (ibid: 32). The researcher constantly works with the data and theory as it emerges, making refinements and

charting a course but never achieving a full explanation. Strauss and Corbin (1998: 266-7) discuss scientific canons in qualitative research and make the point that:

In grounded theory we are talking about explanatory power rather than that of generalisability. Indeed, multiple theories are usually needed (Glaser & Strauss, 1967: 35)

Although they don't use the term *model* as employed in the current research, Glaser and Strauss are clearly thinking in such terms when they explain that:

The elements of theory that are generated by comparative analysis are first, conceptual categories and their conceptual properties; and second, hypotheses or generalised relations among the categories and their properties....a category stands by itself as a conceptual aspect or element of the theory. A property, in turn, is a conceptual aspect or element of a category (ibid: 36)

Strauss and Corbin add the element of *dimensions* of a property and describe conceptual ordering, or the organising (and sometimes rating) of data according to a selective and specified set of properties and their dimensions, as a precursor to theorising (Strauss & Corbin, 1998: 15, 20).

Theoretical sampling is an alternative to random sampling for the purposes of statistical analysis. It is:

The process of data collection for generating theory whereby the analyst jointly collects, codes, and analyses his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges. This process of data collection is controlled by the emerging theory (ibid: 45)

Strauss and Corbin also refer to *open sampling* wherein approaches are made to a broad category of individuals without knowing which characteristics will emerge, moving on to *relational* and *variational* sampling where the researcher looks for examples that demonstrate range or variation of a concept that has emerged and the relationships among those concepts (ibid: 206).

Given the emergent and iterative nature of grounded theory, the process of sampling, collection of data, coding (the creation of categories and assigning data to them) and analysis goes on simultaneously – unlike research which seeks to verify existing theory, where all these phases are separated (ibid: 71). However, while this could be a strength, it is also a weakness:

The constant comparative method is not designed (as methods of quantitative analysis are) to guarantee that two analysts working independently with the same data will achieve the same results; it is designed to allow, with discipline, for some of the vagueness and flexibility that aid the creative generation of theory (ibid: 103)

Strauss and Corbin (1998: 7) list two important things to remember in assuring the objectivity of comparative analysis:

The first, is for the analyst to always compare what they think they see to what they see at the property or dimensional level because this enables use of experience without putting the experience itself into the data. The second is that it is not the researcher's perception nor perspective that matters but rather how research participants see events or happenings. What helps is that the researcher has a comparative base against which she can measure the range of meanings given by others and a beginning list of properties and dimensions that she can use to gain greater understanding of their explanations (Strauss & Corbin, 1998: 47)

The process of coding begins first with *open coding*:

The analytic process through which concepts are identified and their properties and dimensions are rediscovered in data (Strauss & Corbin, 1998: 101)

Open coding often proceeds line by line of text at first, because it enables the analyst to generate categories quickly and to develop those categories through further sampling along dimensions of a category's general properties. The names of the codes are taken from the words of the respondents themselves, and thus called *in vivo* codes (ibid: 105, although attributed to Glaser and Strauss 1967). *Axial coding* is the process of relating categories to their subcategories, so named because coding occurs around the axis of a category, linking categories at the level of properties and dimensions. In axial coding, categories are related to their subcategories to form more precise and complete explanations about phenomena (ibid: 123-4). A category is *saturated* when no new information emerges during coding, that is, no new properties, dimensions, conditions, actions/interactions, or consequences are seen in the data (ibid: 136).

Selective coding is the process of integrating and refining categories (ibid: 143) and when major categories are finally integrated to form a larger theoretical scheme, the research findings take the form of *theory*.

4.11.2 Sampling

For the purposes of selecting a sample and based on findings of the literature review reported in chapter two, a definition of scientific entrepreneurs is formulated as follows:

***Individuals who have taken substantial and personal financial risk to commercialise
a product or service based on scientific research, whether successfully or not***

It is acknowledged that this is a behavioural definition which does not include reference to underlying attributes or context and it is prescriptive to a degree which has already been dismissed earlier (in section 2.8) as unrealistic. But it does allow for the recruitment of individuals from a New Zealand-wide, scientifically entrepreneurial milieu who have demonstrated behaviour that to some extent matches the definition. They are then interviewed to discover their perspectives on how their own scientific entrepreneurship has been recognised, by themselves, by others, and by the system.

Respondents are located using a range of opportunistic methods from use of personal knowledge and asking around, to looking in current business literature, tracking through websites of science-based companies and some *snowballing* (one respondent recommending another). There is a deliberate decision taken not to concentrate on high-profile and over-exposed candidates (“usual suspects”) although some of these are eventually included.

Potential respondents are initially approached by letter, sometimes sent by post and sometimes by email attachment (see appendix eight for a sample letter, including consent forms). There are indications that some of those approached are nervous about disclosure of sensitive information. It becomes clear that it is important to stress the research’s focus on the *process* of entrepreneurship and the entrepreneur themselves, rather than the business or the technology being commercialised, as a way of addressing these concerns. Where this message about the research focus can not be got across, a refusal is likely to ensue and in the end, twelve people turn down the invitation to participate.

4.11.3 Three sets of respondents

As well as “primary” respondents who closely match the above definition of scientific entrepreneurship, interviews are held where possible with informants who have known the primary respondents at other times of their lives, for example those who have had responsibility for their scientific or entrepreneurial education and training, or their management. In addition, a range of government policy personnel is also interviewed to give three principal categories of respondent: primary, secondary and tertiary. As shown in table 4.1, primary respondents are later “graded” according to their degree of match to the definition of a scientific entrepreneur and it emerges that ten respondents closely match all the elements.

Table 4.1 Subcategories of primary respondents

Extent of Scientific Entrepreneurship	Definition	No. in Category
Full	Meets all criteria	10
Partial	Meets all criteria except “substantial” personal financial risk	2
Intrapreneur	Meets all criteria except financial risk is organisational, not personal	6
Scientist	May take non-financial risks but assists the commercialisation process with research only	3
Broker/manager	May take risks of any kind but primarily facilitates the entrepreneurship of others	4
Total		25

Primary respondents come from a range of organisational and scientific backgrounds: thirteen from biotechnology, ten from the physical sciences and two from ICT. Five (20%) are women. Disappointingly most of the 12 potential

respondents who turn down the invitation to participate in the research are, on the face of it, full scientific entrepreneurs.

The 13 *secondary respondents* come from a range of different types of research organisations⁶¹.

The eight *tertiary respondents* are individuals working in government policy or operational agencies with some degree of responsibility for developing policies or implementing programmes to foster the commercialisation of scientific research. Several of these respondents also come from prior backgrounds in scientific research and/or its commercialisation.

Table 4.2 Numbers of respondents in each of the three major “sets” of respondent

Set	Number of Respondents
Primary	25 (including 10 “full”)
Secondary	13
Tertiary	8
Total	46

4.11.4 Interview process

The interview instruments are sets of semi-structured questionnaires derived directly from the research framework and piloted with three acquaintances known to have some of the characteristics of scientific entrepreneurs (see appendix 8.3 for interview templates). The first full interview also has some of the characteristics of a pilot, as it

⁶¹ Note that the original research design conceives secondary respondents as family members or previous managers or teachers who can provide some “triangulation” on primary respondent’s own views of themselves. Primary respondents are asked to nominate such candidates but they prove reluctant to do so and the request tends to create awkwardness at the end of the interview. In the few cases where nominations are made, the success rate in recruiting them as secondary respondents is very low. As a result of these experiences secondary respondents are recruited independently of primary respondents, although some connections between individuals still emerge (see table 5.5)

is fully transcribed and analysed before slight modifications to the questions are made and the next tranche of interviews organised. Consistent with the precepts of grounded theory, other phases of the research (coding, analysis and further literature review) proceed in parallel with interviewing. At the end of each interview an undertaking is made to give the respondent feedback on progress of the research and to “keep in touch”. This commitment is met by circulation of a memorandum on which a handful of respondents make brief comments.

Interviews are recorded on an Olympus digital recorder using Digital Speech Standard (DSS) software and downloaded into a secure directory in high quality WMA format for playback and transcription. In the early stages written notes are also taken, but as the research progresses and confidence in the hardware and software grows, note taking stops so as to enable a focus on the interview itself. As time goes on, the interview template becomes so internalised that it is barely noticeable, like a well-worn stone. Interviews take on more of the character of a conversation which flows naturally over the template. The lack of discordant sharp edges in the format reinforces the relevance and robustness of the template, which in the end is used mainly for a check at the end of the interview for questions missed. There could be a downside in this fluidity in that interview transcripts are not structured in a common pattern, but the coding process is not affected by this. Indeed the lack of structure helps address the risk of circularity of coding (see sections 4.11.1 and 4.11.8).

4.11.5 Transcribing

There is a valid argument that qualitative researchers should do their own transcription of interviews so that they “run their fingers” through the data and get to know it intimately. With this in mind, the first interview, which occupies just over an hour, is personally transcribed taking an additional nine hours. Six more interviews

are then conducted, with the average length settling at around 45 minutes, and transcribed into Rich Text Format at approximately the same 9:1 ratio of transcription to interview time. At this point it is calculated that personal transcription alone could occupy up to 15 weeks time and so a decision is made to purchase professional transcription services and switch to other, higher value tasks such as coding. The required degree of intimacy with the data is still achieved since all transcripts are checked against the recording, corrected as necessary then exhaustively coded.

The professional transcriber is experienced in processing research interviews and very efficient (three times as fast). She has her own code of professional conduct to ensure that confidentiality is assured. A change is made to the consent forms sent to later respondents in order to allow for the outsourcing of transcription.

Once prepared, transcripts are sent to the respondent for them to check if they wish to do so. Most do, and their amendments are included in the final record used for coding. Only three respondents out of 46 do not take the opportunity to explicitly approve the final transcript of their interview.

4.11.6 NVivo

Thirty-four hours of interviews provide 400 Megabytes of digital recordings and around 300,000 words to analyse. Once confirmed, interview transcripts are transferred electronically to a Project Database in NVivo 2.0 Software, which is specifically designed to facilitate qualitative text analysis. While not explicitly linked to grounded theory or the work of Corbin, Glaser and Strauss (see section 4.11.1) the conceptual origins of the NVivo design are plain to see, even to the extent of its name which must surely be derived from Glaser and Strauss's (1967) *in vivo* term.

NVivo also has a range of functions which equate to those used in the process of comparative analysis.

Transcripts are stored as *documents*, each titled with the name of the associated respondent. The list of document titles is sorted alphabetically by the respondents' given names and numbered sequentially based on its positioning in the list – to enable quotations to be easily linked and anonymously labelled. Thus the document numbers are more randomly allocated than they would have been for example by category of respondent or place in the sequence of interviews.

The next step is to identify the “chunks” or units of meaning in the data, a process referred to as *unitising* the data (Maykut & Morehouse, 1994: 128). These “meaningful chunks” of transcribed text are able to be highlighted using NVivo’s *coding* tool which electronically tags and allocates the text to a *node* or category. All text allocated to the node from multiple documents is then able to be retrieved and read as one aggregated document. Each node is carefully defined (given properties) and the dimensions of each property are able to be revealed through the creation of subcategories. Initially, the nodes that are created are “free” (open coding) but then they are axially coded based on the relationships between the various nodes.

4.11.7 Data Analysis

Coding is analysis. To review a set of field notes, transcribed or synthesised, and to dissect them meaningfully, while keeping the relations between the parts intact, is the stuff of analysis. This part of analysis involves how you differentiate and combine the data you have retrieved and the reflections you make about this information (Miles & Huberman, 1994: 56).

As previously discussed, there is some contention as to the level of a *a priori* structure that might be given to a coding system without compromising development of grounded theory. According to Miles and Huberman (1994) some researchers create a provisional start list of codes prior to the fieldwork, derived from the conceptual framework, list of research questions, hypotheses, problem areas, and/or key variables that they bring to the study. They also point out that:

A second main coding alternative, partway between the *a priori* and inductive approaches, is that of creating a general accounting scheme for codes that is not content specific, but points to the general domains in which codes can be developed inductively (ibid: 61)

Many researchers use a simple two-level scheme: a more general “etic” level, like those suggested above; and a more specific “emic” level, close to participants’ categories but nested in the etic codes. In NVivo, the “etic” and the “emic” levels are reflected in “parent” and “child” nodes arranged in hierarchical “trees”.

Another key question is to determine how “fine” or at what level of detail the coding should be. Miles and Huberman advise that the important thing is for the researcher to be reasonably clear about what constitutes a unit of analysis (ibid: 64-5). Whatever approach is used, coding changes as it proceeds, but:

Codes should relate to one another in coherent, study-important ways; they should be part of a governing structure. Incrementally adding, removing, or reconfiguring codes produces a ragbag that usually induces a shapeless, purely opportunistic analysis (ibid: 62)

It is in coping with the emerging coding structure that the major advantages of using NVivo become apparent. As well as enabling the easy management of vast amounts of data it is possible to redefine nodes, to combine them if necessary and to

rearrange them in relation to each other. It is also easy - and methodologically permissible according to Maykut and Morehouse (1994: 138) - to assign the same information-rich chunk of text to different nodes. Ultimately, the use of software does not eliminate the relatively subjective nature of coding and reliability becomes an issue, even with a single researcher. Miles and Huberman advise a check of the first dozen pages of field notes, once right away and again (on an uncoded copy) a few days later, to determine the level of internal consistency:

reliability = no. of agreements/total number of agreements + disagreements (Miles & Huberman, 1994: 64)

4.11.8 *Creating codes*

Analysis is the interplay between researchers and data. It is both science and art (Strauss & Corbin, 1998: 13)

It is a moot point as to the degree to which coding is purely inductive or determined *a priori*. On the one hand, the interview instrument is derived from the wider research framework and the extended competency model. It can therefore be argued that the data generated are likely to fit within the categories implied by the model, leading to circular rather than grounded theory development. On the other hand, the initial categories or nodes are created purely out of the first few transcripts which as has been pointed out are relatively unstructured. Also some nodes do not fit because of their cross-cutting, thematic nature and others are created that are not initially envisaged in the competency model. These surprises give support to the groundedness of the research.

The first interview creates 24 initial nodes. This number increases to 44 after the second tranche but it also becomes apparent that some duplication is appearing and

some nodes are underutilised. This leads to a revision of definitions for each node, to tighten up “rules of inclusion” (Maykut & Morehouse, 1994: p 138). Early documents are recoded in the light of the expanded list of nodes, and as interviews proceed, confidence in the coding system grows.

At an early stage attempts are made to begin rationalising or shrinking the number of nodes in order to make them easier to manage. But later it becomes clear that the nodes are too broad to be meaningful and need subdivision. Through a number of iterations between the -etic and the -emic levels the imperative for finer analysis prevails and the final list of nodes reaches more than 500 reflecting finer and finer analysis and delineation of multiple dimensions of the properties of the higher level nodes. This creation of subcategories or subordinate nodes, described as *coding on* in NVivo, stops when no further subdivision is possible.

At the same time, the nodes begin to show a good fit with the original model, and so despite reservations about circularity it is decided to return to the research framework as an organising principle (see appendix three).

At the highest level, nodes are sorted into the contextual and attribute layers, the longitudinal (life history) dimension, cross-cutting themes and processes (of recognition). The findings presented in chapter five are also organised on this basis.

Some comments are extremely rich in meaning, and are multiply coded. On the other hand, there are a few occasions where *richness* extends to contradictory meanings within the same statement. These are multiply coded so that unfortunately the contradiction is not always captured in the analysis.

4.11.9 *Further analysis*

Boolean searches are used to find passages in documents or nodes with a particular combination of features, for example the intersection of primary respondents and *full* scientific entrepreneurs with the *child nodes* of the *own life histories* tree (see table 5.1). The resulting cross-tabulation is presented in a table with the respondent characteristics as columns and the nodes as rows.

NVivo automatically stores the results of each search as a new “matrix node” which can then be labelled and browsed at any time to access passages coded at the intersection of columns and rows. Representative quotations are also thus sorted and easily retrieved as required in order to illustrate findings.

An unexpected benefit of Boolean searching is also the “cleaning” of some data, for example where a few comments from secondary and tertiary respondents are erroneously coded to “own life histories” which by definition should have included only primary respondents. However, once analysis gets underway in earnest, the underlying data and coding is left intact so as to preserve a constant and robust base for analysis.

4.11.10 *Theory building*

Theory derived from data is more likely to resemble the “reality” than is theory derived by putting together a series of concepts based on experience or solely through speculation (how one thinks things ought to work). Grounded theories, because they are drawn from data, are likely to offer insight, enhance understanding, and provide a meaningful guide to action (Strauss & Corbin, 1998: 12)

Meaning emerges from the detection of patterns or the ways in which categories relate to each other (Strauss & Corbin, 1998: 135) or in this case from the respondents' own words, structured according to the underlying themes that are extracted by the coding process. Patterns are provided by the matrix intersection tables produced from NVivo searches. Each cell in each matrix is able to be browsed and the following narrative (chapter five) emerges almost of its own accord – the main intervention is of editing and the selection of the most illustrative quotations. Some of the respondents are more quotable than others, and therein lies a risk – that the sample of 46 may in reality be fewer. There is also the danger that always reading comments from top to bottom of the list of respondents is more likely to privilege those at the top, since if they are merely echoed further down the document the latter comments may be seen as duplications and not quoted. An attempt to mitigate this risk is made by also reading bottom to top on occasions but this is difficult given the way English prose is written. In the final analysis the order of reading is not critical since it is meaning that counts, not who expresses it.

4.12 Generation of research findings

Up until this point there has been established an academic rationale for the research (chapter two) and a strategic, public policy rationale (chapter three). The current chapter has drawn on key elements of the literature to generate a competency model within an overall framework for research that is compatible and coherent with the strategy described in sections 4.2 to 4.6. Out of this platform has been derived a pragmatic method which uses the precepts of grounded theory to feed forward into the generation and analysis of findings to be found in the next chapter (five). The concluding chapter (six) synthesises all the foregoing to identify the overall implications of the research for public policy and management in the sphere of scientific entrepreneurship.

CHAPTER FIVE: RESEARCH FINDINGS AND ANALYSIS

5.1 Introduction

Given the precepts of grounded theory (section 4.11.1) the voices of respondents are given the maximum possible space in this chapter, albeit for reasons of space a limited selection of particularly illustrative quotations has been used. This selectivity, and the general shaping of findings, reflects the iterative analysis that has been carried out, particularly where resonance is noted with the findings of the literature review, and anticipates the conclusions to be found in chapter six.

Furthermore, for reasons described in section 4.11.8, findings are able to be structured according to the research model shown in figure 4.2. To this extent they are presented in discrete “chunks” but while outright repetition has been removed, some overlapping has been retained to provide a degree of triangulation and to show which findings have emerged as having particular weight.

Also, due to space limitations and given that the reporting framework is similar throughout, description of process is more detailed in the earlier sections of the chapter and becomes attenuated later on. For the same reason a limited selection of particularly illustrative quotations from respondents has been used.

5.2 Life stories

5.2.1 *Narrative on own life histories (of primary respondents)*

At the first level of open coding under “own life histories”, 22 child nodes are created. As well as providing a mechanism for sorting aspects of the experiences of scientific entrepreneurs, these codes provide useful descriptive and classificatory information about the respondents (see appendix two).

Most primary respondents describe a management background, followed by recollections of childhood and youth, technical background, non-formal learning, jobs, family and interventions of others as shown in table 5.1 below. Commentary drawn from these nodes follows, and quotations are attributed to the relevant respondent by number (see table 5.2). The total content for all cells is fully searchable in the NVivo project data base, and provide an auditable trail of the content that underpins analysis and conclusions.

Table 5.1 lists nodes for the 25 primary respondents, including the subset of ten “full” scientific entrepreneurs, and so the columns show:

- The number of coding references (passages or comments) allocated to each node. This gives an idea of the volume of comment;
- The number of primary respondents making one or more comments allocated to each node; and

- The subset of full primary respondents making one or more comments allocated to each node.

Nodes are sorted in descending order of the “number of primary respondents” column (the middle one) and the following narrative is structured accordingly. The “full” subcategory is used in order to tease out whether there is any distinction between this group, comprising the kind of individuals initially targeted, and the group of primary respondents as a whole. Some rudimentary statistical analysis of these differences is available but its use is spurious in research of this kind. The tabulated information can only hint at the weight of content of transcribed comments and real meaning is to be found in the narrative.

Table 5.1 Nodes within “own life histories”

Nodes	No. of coding references i.e. comments (primary)	No. of respondents commenting (primary)	No. of respondents commenting (full)
Management Background	49	21	8
Childhood and youth	37	19	7
Technical Background	24	16	7
Non-formal learning	23	15	6
Jobs	37	14	6
Family	20	14	7
Interventions of others	36	14	6
Early Responsibility	14	12	6
Chance/Luck/Timing	17	11	5
Travel	20	10	3
Multiple worlds/balancing	25	9	2
Tertiary Education	19	9	5
Plans	20	9	5
Ideas	15	8	3
Hated control, wanted autonomy	6	6	4
Farming Background	7	6	4
Schooling	6	6	3
Experience of stress	6	5	3
General life experience	9	4	3
Gender	6	3	2
Decisions	5	3	1
Crisis	1	1	1

Table 5.2 Sets of respondents

	Respondent sets		
	Primary	Secondary	Tertiary
Individual respondents in set	1	8	5
(By Identification Number)	2	9	17
	3	11	19
	4	14	20
	6	15	26
	7	18	35
	10	23	36
	12	24	42
	13	38	
	16	41	
	21	43	
	22	45	
	25	46	
	27		
	28		
	29		
	30		
	31		
	32		
	33		
	34		
	37		
	39		
	40		
	44		
Total Number of Respondents	25	13	8
Key: "full" scientific entrepreneurs			

Management background

This node codes for experiences of management/ownership position(s) in commercial or not-for profit enterprises or laboratories and includes business qualifications and experience/learning from experience in business. Thus the node also helps capture aspects of mobility.

A majority of primary respondents have a business background, with most of these being involved in science or engineering-based businesses but a smattering of others such as musical bands. Generic project management experience is also mentioned by several respondents.

Childhood and Youth

Initial indications from the first few primary respondents were that there may have been some early predictors of entrepreneurial behaviour in their remarkable stories:

I remember when I was a kid on the school bus. I found that the guy who had the school bus run also owned a dairy. And so my early experience must have been when I was about nine or ten, was getting him to bring a range of sweets on board the bus which I then sold to the kids on the bus (laughter) it was a country school so we had an hour on the bus. I think the parents eventually revolted against that because the kids turned up with sweets each night (laughter). (Respondent 13f)⁶²

Some more startling stories cannot be reported because they would identify the respondents. On the other hand, nine primary respondents specifically disavowed any early indications of entrepreneurial attributes, and there was no seeming correlation of early experiences with any aspects of later entrepreneurship.

The inconclusive nature of data coded at this node is reinforced by that coded for “early responsibility”, where seven respondents say they had an unusual amount and five say they did not.

⁶² “Full” scientific entrepreneurs are designated with an “f” beside their respondent number

Technical Background

Sixteen primary respondents describe a “technical background” in science or engineering, although this aspect is coded only where it is raised by the respondents and therefore probably under-reported. There is also a degree of overlapping with generic “problem solving” and “diverse” backgrounds:

I have always been one to fix things. I've always been one to construct things. I built model planes and cars and boats since I can remember. (Respondent 3)

Early on in the interviewing process, the tension between width or “breadth of knowledge” and “depth of knowledge” emerged as a key aspect to explore. Twelve respondents report deep relevant scientific knowledge and two report bachelors-level knowledge. But this analysis needs to be placed alongside that which codes for instances of “non-formal learning”, “tertiary education” and “multiple worlds/balancing” (see below). The interaction between breadth and depth appears complex.

Non-formal learning

Non-formal learning is defined as *all kinds of formative experiences outside school and University which may have contributed to the evolution of competencies*. Simply having experience in business is an important way of learning for some respondents, and several have an extremely proactive learning style which involves finding out where leading edge expertise resides, and going to the source of that expertise.

This behaviour seems to be of critical importance as it suggests a high degree of self efficacy and self esteem, and internal locus of control (see section 2.7.3).

Multiple worlds/balancing

In the process of analysing interviews, some nodes are able to be *coded on*, i.e. subcategories are created. For example, as examples of operating in two different modes, and balancing involvement in both, are further able to be coded on as in table 5.3, creating richer meaning. Three respondents make comments that are coded in terms of multi-disciplinarity (working in more than one scientific discipline). One reports deliberately creating this approach as a strategy:

You must think laterally all the time and try to, almost on everything and you need to train yourself to think this way and out of it you suddenly see things differently. (Respondent 33)

One respondent reports having a “dual personality”; is explicitly aware of this and able to observe her own behaviour in a seemingly detached way:

So I decided to then do an NZCS which is where I could work 4 days a week and I could go to school 1 day a week. So I was sort of having that...again, my dual personality was kind of coming out....I was working in industry and I was going to school 1 day a week fulltime....so I was doing that. So I was sort of nurturing both sides of me. And I loved that, I loved doing that. (Respondent 1)

These notions of “stepping outside of oneself” or seeing things from two simultaneous points of view may be of critical importance in the identification of entrepreneurial opportunities (see section 6.2.3)

Table 5.3 Nodes within multiple worlds/balancing

Nodes	No. of coding references (primary)	No. of respondents (primary)	No. of respondents (full)
Facility with music	5	4	0
Life-work balance	6	4	1
Simultaneous education & work	4	3	0
Multi-disciplinary	6	3	1
Dual personality	2	1	0
Facility with languages	1	1	0
Managing across boundaries	1	1	0
Involvement in sport	1	1	0
Involvement in religion	1	1	0
Participation in Arts	2	1	0

Jobs

This node codes for past employment rather than running businesses and includes teaching. As with management background, the node captures the flavour of the mobility of respondents but in this case there are no other patterns that justify coding on, suggesting that job history is not particularly significant in terms of conclusions to be drawn.

Family

Fourteen respondents report significant *general* family influences (as opposed to the influence of a specific individual within the family) – ten from “family of origin” (mother, father, siblings etc) and six from “own family” (spouse, own children etc). There is multiple reporting of types of family influences by some respondents. Unsurprisingly, it would seem that families of origin are important early influencers, but not necessarily always in the direction of entrepreneurship:

.... my family overall exhibits quite a bit of entrepreneurial spirit. My father has never been shy of picking up an idea and trying to set up a business around it. It hasn't always worked, but he's not scared of taking risks. The same with my brother. (Respondent 10)

Current family is reported as being particularly important in determining career choices (e.g. whether to come back to New Zealand or not) or for one respondent only, the sustaining of entrepreneurial effort. Once again, few conclusions can be drawn from family history.

Interventions of others

Fourteen respondents make 43 comments that can be coded to this node as *remembered actions of specific individuals (including family members) in one's own life e.g. mentoring, financing, encouragement etc.*

Perhaps the most obvious feature is the relative importance of interventions of managers/mentors, and these are common enough to influence the conclusions in chapter six:

J headed the University's commercial office and I guess I must have initially met him socially or something, and engaged him more and more in just general conversations. And then eventually he made it clear that part of his brief was to try to identify researchers at the University here who potentially were doing research that may have commercial potential. That was his job. And so he would sit me down and try to tell me the commercial facts of life. (Respondent 27)

Parents are also reported as being important in a number of ways in addition to the general family influences already mentioned, but with no discernable pattern.

Chance

Fifteen respondents comment on how lucky they have been or how chance or circumstance – apart from their own abilities - has played a part in them “falling into” a good situation. The importance of luck cannot be discounted, but neither can the influence of modesty in some cases where respondents have plainly “made their own luck” through ingenuity and hard work (see the discussion on n-Ach in section 2.7.3)

Travel

Ten respondents make 20 comments about overseas travel, five specifically for study and two for long term employment, to seven different countries. Several others have travelled regularly from onshore employment within New Zealand and it could be concluded that primary respondents are all internationally connected to some degree.

Tertiary education

Most of those who mention University training say they have done well as opposed to three who make negative comments about not doing well (including one who *has* in fact patently done well, based on credentials attained and the comments of others). Respondent 2 reports *both* that University education is narrow and flexible. Two of those who did non-University training are women who initially worked in fields related to animal and human health. Training also emerges as a cross-cutting theme and is discussed in more detail in section 5.5.3.

Plans

Descriptions of experiences of early life plans for the (then) future show that as many respondents have been “goal directed” or “proactive” as were not, and instead took one step at a time or were reactive (although Respondent 2 describes himself using both approaches, a typical contradiction in this complex and highly successful character!). Similarly, there emerges no pattern in the way that decisions (at a point of time rather than longer term planning) are made – they are just as likely to be spontaneous as non-spontaneous. Thus in terms of the kinds of planning and “discovery” discussed in sections 2.2.3; 2.7.1; and 2.7.3 there are few conclusions that can be drawn. In the same way it is difficult to characterise decision making as heuristic or otherwise (see sections 2.2.3 and 6.4.3) and given the smallness of the sample in this research the above findings reported in the literature on this point hold sway in the conclusions drawn in section 6.4.3.

Ideas

Eight respondents make comments that relate to the origin or progress of their own scientific/technical ideas through their lifetimes. Not many of these core ideas have been diverted substantially – notwithstanding one being turned on its head from a cooling to a heating technology. The most striking comment is that of one respondent who had an idea as a student almost as an epiphany and has followed the same basic quest throughout his long and distinguished career.

Comments from this node on ideas are also coded where appropriate to "opportunity" or "nature of RS&T" or "science-business models" (see below) so that they can also be looked at in a wider consideration of "progression of ideas".

Hated control, wanted autonomy

Six respondents, four of them “full” scientific entrepreneurs, report a history of reacting against control, constraint or convention:

I find it actually quite difficult to, how would you say, accept hierarchal control systems when it comes to people particularly, because all I see there is that it constrains individual expression and creativity and I think in this environment anyway it's very very important. So I must admit I object to that at times (laughter) a lot of the time. (Respondent 33)

Other factors

Six of the respondents, four of them “full” scientific entrepreneurs, describe farming backgrounds. Six talk about experiences of their schooling, but these comments are more related to things that happened at school rather than the process or effects of schooling *per se*. Five respondents speak of their experiences of job-related stress, one to the point of it being the likely cause of ill-health.

Some comments about life history are not easily coded as anything but “general”, including reflections on how things might have been different. If they could have their time over again, two respondents would have done business training, one in preference to science.

Three respondents report experiences of life chances opportunities being affected by their gender, two women who fought against discrimination and one man who feels he was advantaged by being male. One respondent specifically reports a life crisis as a stimulus for engaging in entrepreneurship.

5.2.2 Narrative on others' life histories

General observations of other people's life histories could come from any set of respondent - primary, secondary or tertiary. Specific comments about entrepreneurial behaviours and experiences are allocated to the appropriate node in the attributes layers as reported below. There are also nodes for comments about specific other individuals including some other respondents in this research (fortuitously, because no respondent knew who else was being interviewed).

The rest of the data from interview transcripts is organised in a different format as in table 5.4, which shows high level nodes and the number of comments in each from each of the three main categories of respondents. These "parent" node are also coded on and tables containing "child" nodes are included in appendixes four to seven (see also tables 5.6 and 5.7 in this chapter).

Table 5.4 Nodes within others' life histories

Nodes	Number of respondents commenting			
	Primary	Secondary	Tertiary	Total
Generic	18	11	5	34
Nature versus Nurture	12	8	4	24
Key attributes are innate	4	4	2	10
Possible to "tip over"	3	5	2	10
Neither predominates	4	2	0	6
Nurture predominates	3	1	0	4
Generational	13	1	1	15
Difference between generations	9	1	0	10
No difference	1	0	1	2
Gender differences	1	0	0	1
Specific other non-respondent(s)	13	10	5	28
Specific other respondent	5	4	1	10

Nature versus nurture

Because questioning sought to elicit comment on personal histories and their effects on future competency development, discussions frequently turned to the question of whether people are born with certain attributes (nature) or develop them as a consequence of learning or contextual factors such as family environment (nurture).

Just over half of all respondents express a view as to whether nature or nurture predominates. A majority of those think that key attributes are innate, but there also emerges a commonly-held view that some people born with these attributes either might never express them nor become scientific entrepreneurs due to some circumstance. A number of respondents express views that neither nurture nor nature predominates, while a minority thinks that nurture is the predominant factor.

I think entrepreneurs are essentially born and I don't think you can train someone who is not an entrepreneur to be one but I think you can train somebody who has a tendency, to be better. (Respondent 24)

Generational differences

Early on in the interviewing process there emerged a possible difference in the propensity of younger generation scientists for entrepreneurship and this difference was subsequently probed for where possible. Ten respondents (nine of them primary) are of the view that younger scientists are more so inclined, and two respondents are of the view that they are not. If the generational difference exists, it does not necessarily reflect badly on the older one:

Some of the most entrepreneurial scientists I know are older, they're over 50. One of the staunchest traditionalists I know is 46 and I know one of these people who's in that grey area where I think he can be tipped over and he's 42. So, no I'm not noticing big

generalisations, you know the older guys are all still occupied in professorial positions in the Universities and the young guys are out in the commercial world, I don't think I'm noticing that. (Respondent 17)

It is interesting to reflect on this comment in light of the view of Kuhn (section 2.3.5) which would suggest that younger scientists would be more likely to break the mould.

5.2.3 *Comments on identified individuals*

Identified New Zealand entrepreneurs

Whether prompted or unprompted, a number of respondents identify particular individuals in New Zealand as scientific entrepreneurs and add comments to explain their choices. Most of the individuals commented on are not part of this study, but 12 are – even though as already stated in section 4.11.2 a deliberate decision had been taken to not target all the “usual suspects”. A notable feature of the overall list of 43 is that it includes only two women.

Comments on specific other respondents in this research

There are also specific comments on other respondents in this study, and this allows some comparison to be made with what those respondents say about their own personal attributes. It should be remembered that any references to other respondents are accidental – no participant is aware of whom the others in the study are, although there are some close relationships between respondents as shown in table 5.5 and some of these are a factor in the “snowballing” selection of the sample.

Table 5.5 Significant relationships between respondents

Respondent ID nos.	Respondent ID no.	Description of relationship
2	34	2 is commercialising IP arising from 34's research
6	21	6 was an early and crucial mentor of 21
15	12	15 was an early and crucial mentor of 12
25	33	Formerly close colleagues in the same institution
40	32	40 is commercialising IP arising from 32's research
39	44	39 is a former student and now colleague of 44
6, 21, 32	45	Formerly colleagues in the same institutions

Of most interest are comments about how respondents recognise in others the signs of scientific entrepreneurship. In each of these cases the “target” respondent also makes comments about their “own personal attributes” and so it is possible to make a comparison of different perspectives on the same person. These show the highly personal and idiosyncratic nature of “recognition”.

Comments on respondent 2

A. And what I see in (Respondent 2) is quite a remarkable phenomenon from my perspective because he's someone who's come through the science system, but he's now got a business head on him. And it's a business head based on experiences in much bigger economies. And yet he has this very strong scientific understanding as well. So he's what I would call a science entrepreneur in the way that I am not. I mean he really does understand the way in which businesses work and what are the essential factors that make the business successful and where to focus the energy, what are the important things from a business perspective rather than just from a science perspective. So I find that quite interesting. And I think it's partly to do with youth. I think it's partly to do with a sort of a fresh approach.

I would say (Respondent 2) was a born entrepreneur. (Respondent 34)

B. So I've had to learn human skills, how to manage programmers, how to manage the wider web of things that you have to deal with and I've found that really challenging and exciting. So it's stimulated me and I found I was quite good at it again and because I was good at it I enjoyed it and the rewards were a lot better. (Respondent 2)

Here there is consistency between the views of the observer and the observed. Indeed, respondent 2 came across at interview as an extremely engaging, multi-faceted and successful character. His complexity is further reflected above in the discussion of his own life history, which shows some contradictory elements.

Comments on respondent 12

Certain aspects of respondent 12's behaviour (finding gaps or new ground) are recognised by her mentor (respondent 15) as being unusual and (possibly prompted by the interview) consistent with scientific entrepreneurship. Respondent 12 also identifies this pattern of behaviour in herself and to this extent there is a consistency of view between the two respondents. But another key attribute identified by respondent 12, the ability to form and lead teams, is not mentioned by her mentor in the course of a very long interview.

Comments on respondent 21

Respondents 6 and 21, who obviously have an extremely high mutual regard for each other, recognise as one of respondent 21's key attributes the ability to persevere. But it is also obvious that respondent 21 has many other attributes, the sum of which are recognised almost intuitively by respondent 6, his initial boss in research.

A. Interviewer: Is there anything that tells you that some young scientist has got not only a good cognitive knowledge in the sciences but some extra dimension?

Well I can pick that up very quickly and have done particularly with (Respondent 21). I knew from day one that he was special. I made sure that his career was not hampered within

Interviewer: So what was special about him?

Oh it's 101 things. There isn't one, there isn't even 10 things. It's everything. Everything adds up in the same direction....You've got to be hammering on their door at 10 o'clock or whatever, 8 o'clock each morning until you get it done. And that's what I've done. I think that's one thing you need. You need persistence. And you need to just keep on pushing continuously. I know (Respondent 21) does that and may be that's what I recognised in him. I don't know. (Respondent 6f)

B. Respondent 21 was not originally a confident kind of a person. In fact he was a shy person in many respects....Personally he had been extremely well supported all the way through, first of all by his immediate bosses, then a wonderful period of research working with (Respondent 6f). Head office and the funding agencies had continued to support him but there had been a lot of nay sayers as well. He dealt with them in some cases by tackling them head on. He was an optimist, and in some cases it was a belief that things would come through⁶³

Comments on respondent 22:

Respondent 22 is a distinguished scientist and without doubt a "full" scientific entrepreneur but as the quote below illustrates, also extremely self-effacing. It might be speculated that this self-effacement is in fact a kind of masking of underlying attributes which would explain the early lack of recognition of entrepreneurial attributes.

⁶³ Note that the transcript of the interview with respondent 21 was a summary prepared by the researcher from a tape which was discontinuous due to the recorder being on an incorrect "voice activated" setting

A. We were all surprised when (Respondent 22) went into business, but when I think about it, he was a person who thought very widely and was interested in medical applications as well as ...

Interviewer: So you wouldn't have picked (Respondent 22) as a scientific entrepreneur at the time?

No at the time I wouldn't have. But of course he came back and I only knew him from talking to him when he was a student....And I met him again then, and so I didn't really know him well. Now that I know him better, I think I can see he is the sort of person that I would have picked. He's got the sort of...certainly what I seen in the people who have gone into business (Respondent 15)

B. Aah...I'm a pretty dull guy I think I was fairly independent. (Respondent 22f)

Comments on respondent 33

Respondent 25 describes his erstwhile colleague (33) as a serial entrepreneur, yet respondent 33 quite specifically eschews this title. The two do have a common view of respondent 33's versatility and tendency to try many different things but this could also be interpreted as a lack of perseverance, identified in the literature (section 2.7) as a critically important attribute of entrepreneurs.

5.3 Contextual layer

Table 5.6 Nodes in the contextual layers

Nodes	Number of respondents commenting			
	Primary	Secondary	Tertiary	Total
Science-Business Models	25	12	8	45
New Zealand: Broad	21	12	8	41
Organisational Aspects	20	13	7	40
Characteristics of RS&T	24	8	7	39
Characteristics of Business	20	9	6	35
Other Science and Innovation Systems	15	10	7	32
Differences: Science and Business/Entrepreneurship	11	6	6	23
Boundaries	10	6	1	17
Similarities: Science and Business/Entrepreneurship	10	2	2	14
Region	7	3	1	11
Industry/sector aspects	4	4	3	11

5.3.1 Science-business models

The node for science-business models codes comments on characteristics of actual (not putative) models for combining RS&T and business, including specific networking for this purpose. Of most interest is the degree of predominance of the traditional technology transfer model and its variations, and it appears that though it is seldom explicitly mentioned, this model remains very powerful in shaping respondents' perceptions – particularly among managers and policy personnel who express scepticism about the ability of scientists to engage with business:

I think you have to create a system approach that really provides pull for the ideas out of science and academia if you like, but whatever the science institution, into vehicles where you can let the entrepreneur grab it or you can let the experienced commercial manager grab it. And let the scientist have a role, an engagement because they're still going to add

value to the enterprise. But probably they also let go of a lot of the ownership of the entrepreneurial activity in the business growth activity, and go somewhat back to what they're good at which is going to be leading to another potential opportunity. (Respondent 26)

Scientific capabilities can also be added to business, so that the two mutually serve each other:

if you look right back to Herbert Boyer from Genentech, when that was the first biotech company that was ever formed, it wasn't until he became very good friends with a San Francisco investment banker to the point where he could explain and interpret his science to this person that there was enough trust in the financial person to say okay I don't get this science at all but I think I understand what he's saying and I think there's an opportunity here. (Respondent 17)

The notion of technology transfer need not be incompatible with that of individual mobility. Spinouts, where Intellectual Property (IP) is taken out of a research organisation into a "start up" company structure, are often mentioned as a way of commercialising research, and may or may not involve the movement of the researcher:

I think it's absolutely crucial and the more I've read on a lot of technology transfer and entrepreneurial activities etc, one the key things to success is that the person that has been involved with the inception and their original developments needs to move with it and be nurtured. (Respondent 33)

There are a few references to instances where scientists have proactively taken IP out of a research institution (or been pushed out) and themselves driven the growth of a company:

I did actually meet several academic staff who literally left the University to join the spin out company that they'd helped to create. They became part of it. And never came back. They stayed out and have gone on - one particular case has actually gone on - he's left his first company and started a second company with a new opportunity. He's still a major shareholder in the first. (Respondent 14)

There are almost equal numbers of references to “market pull” and “science push” as ways of determining what research should be commercialised, and many that describe a mix of these within the same commercialisation process. Four of the “full” entrepreneurs describe a process of “growing organically” into a new space in the market, in other words proceeding cautiously step-by-step, modifying plans depending on feedback and learning, and reinvesting to finance growth. This approach is summed up very well by respondent 31:

Interviewer: Do you have any ambitions to grow it? To go the next step?

We've grown slowly but that's been intentional. It's been intentional in the sense that we've grown solidly instead of quickly. And not really having - I didn't really have the feeling that we had all the pieces to the jigsaw, the right people, the right situation to be overly ambitious. Now we're starting to - I'm getting a feeling that we're having the right mix of skills, and the right mix of people to be - and the right team atmosphere. We're sort of getting there now. But we should be more ambitious in a few years. (Respondent 31f)

One common variation of the technology transfer model is the involvement of a “third party” or broker who facilitates the process of transfer:

We would rather support and encourage scientists to get on and do what they are extremely good at, which is science, and the brokers, the entrepreneurs, the go-betweens are the people who can pick up and see the possibilities for application of that research in a, for example a business setting. (Respondent 42)

Not that the brokering approach is always successful:

It is so myopic. You've spoken to a number of these commercialisation arms, most of them are massively myopic, they're control freaks, they are greedy, it just gets up my nose a bit. If this is where you've got to be willing to give something more, if you try and maximise it or control nothing, you've got a 100% of nothing - it's still nothing. That happens in too many cases. (Respondent 38)

And direct scientist-to-business contact is almost equally favoured:

The second formative thing was right through my career I had always gone out, because we made our money from doing things with customers and customer projects, going to see each of those different companies and being exposed as a scientist, and that's all I was doing I was being the scientist. I would go along with the manager and we would go and see this company and he'd say I want this done and we'd come back and package up a project and sell it off to the project and start the next one. So we had this industrial interface. (Respondent 29)

People often have business managers with them, they may not know the science, you get the scientists and the business manager travelling together. But for us I just go by myself and I think that's very efficient. But I see the CRIs they seem to employ business managers from a different space, different commercial space. They just don't relate. (Respondent 43)

There are thus a number of models for commercialising RS&T and for growing businesses, and technology transfer need not be achieved through a simple linear movement of the IP from the research institution to a commercial entity. Some firms have their own in-house R&D capability or "reach back" into providers by outsourcing their research requirements. Associated with this is a model of selling scientific services (effectively highly skilled labour) rather than IP. There are also signs of radical changes in approach, towards more of an open, network model with linkages

being made through movement of new human capital (students) between academia and industry, and international connections are important.

5.3.2 *New Zealand: broad*

A major challenge for this node is to *summarise* the issues that are raised and the general tenor of respondents' views. It is possible to "code on" but in this case a proliferation of nodes at a more detailed level would add considerably to the volume of reporting but little extra value.

Many negative comments refer to New Zealand's culture of knocking "tall poppies" who do things differently or stand out ahead of the crowd, and a prevalence of risk aversion and intolerance of failure, particularly when compared with other countries. There is also seen to be antipathy to business among the general population and, among those who are in business, a determination to "go it alone" rather than collaborate. But things may be changing:

There's certainly in the last five years there has been a - there is the sense of a culture shift here. Suddenly businesses - when I was at University in New Zealand business was a dirty word in science departments and when they started bringing in....running departments like proper business units, people complained to high heaven about it and resisted it fiercely. Whereas now I think people have accepted that, hey you can actually be successful by bringing on business partners. You can get funding from industry, it's okay, it's alright to be successful. It's okay to want to commercialise your IP. It's okay to do your research slightly differently because there's a bit of a commercial opportunity there rather than the pure way where there's no commercial opportunity. Or the idea that you can do both. That's starting to change. I don't think it's changed like it has in Australia and UK and I don't have a lot of experience with the States, but what I hear from the States is they're like 30 years, 40 years ahead of us in that regard. (Respondent 2)

This young chap Sam Morgan⁶⁴, the lack, the stunning silence from the tall poppy hackers. It was quite a revelation to me to see that happen and maybe we're stepping out of that. (Respondent 23)

New Zealand's distance from markets is an issue, as is its smallness creating lack of "critical mass" and perhaps a distorted view of just how good its science and business are:

What I see often there though is, in New Zealand, that the isolation is such that we've got a lot of "reinvented here", that's not particularly novel, except in their own mind, and the degree of obviousness is tragic all the prior art, the degree of prior art's tragic. All...they're focused world domination in a market segment that is so small that there'll never be a payback. You know I've seen a lot of misguided efforts, and a lot of them have been reinvented because of the New Zealand context and the need to do it in New Zealand. I've not come across lots that's really been globally relevant. (Respondent 13f)

However, smallness can also be an advantage, allowing entrepreneurs to be "big fish in a small pond" and to do things that wouldn't be possible elsewhere. One respondent who worked for a number of years in Germany has this to say:

I think the infrastructure here, the flexibility of our society for new ventures is actually very good. So it is easy to get something started here....I think that the infrastructure is good and I think the people around you tend to be supportive. So that would be certainly far easier here than in a country like Germany. There's no two ways about that. (Respondent 31f)

One respondent points to a prevailing attitude of complacency:

There is a satisfaction with the way of life in New Zealand which I think in some ways almost curbs entrepreneurship. You can actually have a lifestyle without having a net

⁶⁴ Sam Morgan is a young entrepreneur who set up New Zealand's equivalent of eBay and later sold his company for \$700 Million

income of above \$100,000 say or less than that. You can actually get there without a reasonably low to medium income by world standards. (Respondent 20)

Within the innovation system, barriers between research organisations and existing business are a major issue, unlike in the past:

I have gone into research organisations or talked to people who are totally taxpayer funded and they're extremely protective of what they're doing because they keep it in-house, in fact there's a lot of work that is re-done that is funded by the taxpayer over and over and over again simply because of the lack of sharing of knowledge institutionally. And that's a huge waste. I don't know how you get over it but it definitely occurs. (Respondent 4f)

We had a meeting with MoRST last night, and it's apparent that industry is very scared and untrusting of research institutes that are going to do commercialisation simply because there is that competitiveness. Because we keep the IP yet we're wanting to sell them a product and then they will think well how are we going to make money out of that. (Respondent 1)

These comments are consistent with behaviour of research organisations who are incentivised to control the total commercialisation process rather than encourage or push ideas and people out into the market place at an early stage (see section 3.4.20 and with perception of the funding environment which is also generally seen to be a constraint:

I think when we do recognise people we're almost constrained by the mechanisms to work within the rules as opposed to say, that person has a passion and a drive and an ability let's back that winner. We hide behind our bureaucracy. (Respondent 18)

In the science system at the moment, we are training people and hiring awfully clever people and then second-guessing them at every step of the way...it can't succeed. (Respondent 22f)

The funding system is not all bad though:

You just need to have a look at the whole history of the evolution of the Foundation system to see the huge changes that have gone on. And I think they're only now refining the model and getting better and better and better. (Respondent 29)

I have to acknowledge the fact that the main reason we set up [a spin-off company] was because the last time I came to apply for a NERF grant, the Foundation required that we showed a pathway to commercialisation. (Respondent 34)

Poor pay and limited careers for scientists in New Zealand are also a brake on scientific research, and by implication entrepreneurship;

Of course staying in New Zealand has meant that there has been quite a barrier to my maximum salary. (Respondent 6f)

You probably don't want to be talking about what I think is happening to science in New Zealand. But I think the good people have left the country. There's just nothing for scientists here. Scientists are poorly paid. (Respondent 7f)

5.3.3 *Organisational aspects*

Organisations lie at a level below the general environment, regions and industries or sectors, and there are many comments on the ways in which these organisations are managed, with roughly equal numbers of negative or positive impacts on scientific entrepreneurship. Positive management is often associated with the mentoring performance of an outstanding individual or a decision to provide institutional support at a critical time (consistent with the most influential people intervening in primary respondents' life stories, see section 5.2). Good management of innovative science

revolves around allowing the expression of creativity in research. Consistent with these views, a common refrain about negative management concerns constraints placed on creative thinking or risk-taking:

If you are entrepreneurial, you soon become “corporatised”, because there are a lot of rules, and we’re a government body, so you’ve got to do things doubly cautiously and minimise risk, whereas entrepreneurs are prone to take greater risks and take greater gains. (Respondent 8)

They’ve a passion to go with the development and growth of their ideal and they often don’t know the boundaries ahead of them, the barriers ahead of them. But they find inside institutions most of the rules and regulations are processes we’re just managed by aren’t sympathetic. Not necessarily antagonistic, but they’re not sympathetic to that different way of doing things. (Respondent 9)

But this may be simply a feature of large organisations:

You have to remember is that with 380 staff, we can’t just say, right, get an entrepreneur and rush off in that direction, it takes 3 to 4 years to make change, proper change to manage within the culture, evolve the culture and the people and the focus, so it’s not just one thing in a big organisation. It’s a lot easier if you’ve got an emerging high tech company and you get an entrepreneur coming in with a great idea, with a very good scientist behind them, and off they go, and the market is ready and they time it right, it’s hard, but it’s still ... but if you’ve got a large company, you evolve the culture and what you want the culture to deliver. (Respondent 11)

I see entrepreneurialism as not easily compatible with large corporates as well as it’s not compatible with science institutions. It’s not compatible with large corporates for many of the same reasons. There’s a degree of conformity that happens in those corporates. It means that people actually have to get out and start things up and make it happen themselves. (Respondent 26)

There is also criticism of the tendency to keep scientists away from the downstream commercialisation process:

I mean there are people here that have an invention that want to see it right the way through. And we don't want to - what happens a lot of the time and everywhere really is that you come up with the invention, you go through the process, you get your market, you understand what's happening and then bang you know business development takes it and runs away with it and that's it. You never see it again. And then you're expected to churn out another idea. And that's difficult. (Respondent 1)

The Universities may be different, and have particular strengths for non-incremental innovation:

Universities are chaotic. They're run as fiefdoms and people can develop their interests with a huge amount of freedom. So the ones that are entrepreneurially minded have a lot of freedom well, they can carve out an entrepreneurial niche for themselves and ready themselves to leave without an awful lot of interference from their senior management, it seems to me. That might be a slightly distorted perspective because I've not worked in the University system.....University staff have more freedom to do their own thing which can be entrepreneurial if they want it to be...So in a sense some University people find a transition relatively easy to take. (Respondent 36)

But managing entrepreneurial behaviour within Universities brings its own challenges:

I'd have an organisation of entrepreneurs or people who I say they're our stars who create their own centrifugal force. They're bastards to manage because they're always trying to find a way around the rules, regulations. So you've got to be understanding with them....And there's nothing rapid about how Universities make decisions by and large. So that immediately starts to feel like the walls are closing in on this guy. (Respondent 9)

There is a fair amount of criticism of the ways in which New Zealand research organisations are set up and it has to be said that the organisational environment within research organisations appears to be inimical to entrepreneurial behaviour. Although a difficult step to take, the best chance for staff to exercise scientific entrepreneurship might be to leave.

5.3.4 Teams

Interaction with teams, the level of capability between the individual and the organisation, is strongly identified as being essential for all forms of entrepreneurship. This includes both membership and leadership of teams, but there is a key difference as to whether a team should be “added to” an entrepreneur to make up for his/her deficiencies or whether an entrepreneur can conceive and build the team they need:

I think the danger is that people can be entrepreneurial but in a reasonably single, lone type way. Usually what you need to be successful is much more than any one individual and most entrepreneurs are very good at being entrepreneurs but not much good at some other things. And it's very hard to recognise when it's time for the other things to be part of your team. And I think the real value is to form a team around entrepreneurs and their passion and drive in the early stages of the development is absolutely essential often to get momentum going. When others don't want momentum, don't even see where momentum can take them. But almost certainly they won't have all the skills or all the patience to do some of the things around them to make something commercially successful. (Respondent 9)

This view is consistent with the mental model which underpins much policy, wherein science and technology are in separate competency domains. But there are alternatives, and for more than one respondent, building a team is at the core of scientific entrepreneurship:

In this day and age it's hard for anyone to be good at everything and the general formula is you build a team - that's why the successful entrepreneur is focussed on building the team, including the science. So a science entrepreneur is someone who recognises the good science and recognises the right people and stitches it all together. (Respondent 23)

When you take a team of scientists out of a CRI or a University and into a new company, not all of them have to be entrepreneurs but there has to be someone in there, a team leader, who can excite these people's commitment and be the champion and deal with these entrepreneurial issues and work out if necessary when to step aside when the firm's got to a certain size. (Respondent 36)

5.3.5 Characteristics of Research, Science and Technology

Scientific research is seen first of all as a creative and systematic, analytical process. Primary respondents in particular note that it tends to have a long timeframe and outcomes are often uncertain. But business may not be too different. Engineering also has recognised phases progressing from a conceptual idea to design, testing, manufacture, implementation and commissioning and commercialising of new scientific discoveries also has a sequence of recognised steps: discovery, proof of concept, prototype, various trial stages etc.

Six "full" primary respondents comment on the "seamlessness" of science, a perspective which may help both the creation and application of new ideas:

I do everything from blue skies research, fundamental knowledge generating ideas right through to very pragmatic stuff that we will use. And that's what I like about it. There's a whole raft of that and I don't put any boundaries in terms of where those will fit into our system, what students might take on. (Respondent 33)

A researcher is a person who is capable of putting two ideas from different areas, mixing them to produce a new idea that can be commercialised. How can I explain that? Inventions nowadays don't come because you know a field very well. Very good ideas come from the ability to see something here, transfer it to another field and then make it successful. What I have done is use the knowledge I had of research and applied this knowledge to a totally different field which is And then change this knowledge accordingly to the new field. (Respondent 16f)

This idea of “transferring” knowledge from one field to another in order to create an opportunity is mentioned by a few respondents and is similar to the notion of seeing things from two points of view as reported under the “multiple worlds/balancing” node above.

Scientific ideas most frequently emerge as a response to problems or, in a commercial enterprise, as a result of a strategic decision to allocate resources to a particular area of research. This process might be as much collective as it is individual, since ideas are also seen to be more likely to come out of a research base or “platform” and take a long time to gradually develop from many different approaches – sometimes sequential sometimes simultaneous - than to “pop out of nowhere” or arise serendipitously. This runs counter to the notion of an individual scientist making brilliant discoveries in a “Eureka” moment:

I attribute some of the directions we've gone to open discussions amongst a number of people. I don't think any one person has any startling idea. I think it's an amalgam of people's inputs through association. (Respondent 33)

Most ideas aren't original that pop up. They come from fusion, really good ideas, from fusion of different approaches. And what a dumb idea, this idea of focus. They probably had a great idea there but they were slapped down. That's why we had to cut focus for everybody, it's great, it increases our competitive position. (Respondent 37f)

Nevertheless intuition and insight have their places:

I guess you know you're passionate when a lot of your thought processes occur when you're not at work....most of the good ideas don't come while I'm in here and I've got people banging on my door, or I'm dealing with the administrators. They come when I'm out walking on the beach.
(Respondent 27)

When I think of an idea and it might be when I'm sleeping or at a party, or some time, that's a real idea. (Respondent 1)

And four respondents report a kind of "whole of picture insight", for example:

Interviewer: do you suddenly have "aha" moments where, suddenly the whole picture comes together, you see something in the laboratory ...

Well as a scientist you do.

Interviewer: You said that happens in the laboratory in an aha moment. Is that about the science, or is it about the whole opportunity? The scientific opportunity matched with the commercial opportunity?

That's the whole thing yeah.

Interviewer: Do you get those moments?

Yes! (Respondent 1)

5.3.6 *Characteristics of business*

Entrepreneurship is a subset of business in general and in order to tease out this distinction a node is created for general comments on how business "works" i.e.

process or contextual elements of business rather than the personal attributes of people within it or what they do. Then a separate node includes responses to the specific question “what is entrepreneurship”? (see section 5.4.1).

Many of the comments on business in general make comparisons with the world of science and these are more specifically coded as similarities and differences (e.g. more money, less security in business). But a key theme is that business is about meeting customer needs and creating value and that this is a major difference from science.

5.3.7 Other science and innovation systems

Other countries (the US, UK, China, Germany, Switzerland, Israel, South Africa) are seen as having cultures, systems including regional clusters and “critical mass” more conducive to entrepreneurship than is the case with New Zealand. There are many comments, often based on personal experience about the greater tolerance of risk and failure in the United States, and the opportunities and potential rewards are much greater overseas. A minority comment is that there is more venture capital and more government incentives available elsewhere. Although five respondents cite instances where other countries are *less* conducive to entrepreneurship and innovation than is New Zealand, in general the opposite conclusion can be drawn.

5.3.8 Differences and similarities between science and business/entrepreneurship

Half of all respondents report that there are differences between science and business or entrepreneurship, principally in the motivations that underpin each activity (see section 5.4.9 for more findings on motivation):

Well, some things (about scientific research and entrepreneurship) are the same. So when you are dealing with research you are also trying to break new ground. You are also requiring to have perseverance and length in order to get there, you've got to find your funds and all that sort of stuff, but the end point is different, so the end point is not a tradeable product or service, the end point is a piece of knowledge. So, and that's where I think there is a lot of difference. (Respondent 46)

When you get into the further development of a proof of concept into a potential product lead that it becomes quite, well a bit more monotonous and a bit more boring, which I don't think sits well with scientists who are discovery focused. (Respondent 10)

Possibly as a result of these different motivations, there is a different culture and different timeframes:

Short-term horizons: these are (where) the science - business/commercial clashes an awful lot - the timing, the language, the whole culture, yeah there's a whole list of ...which I keep meaning to write down every time I fall over something. But they are two culturally distinct. (Respondent 12f)

The gap between a good scientist and a good business person - it's a cultural gap. Sometimes they don't even realise that they're not really speaking the same language. They may share English but their hidden assumptions and what both sides expect naturally can be poles apart and it can be really frustrating for both of them unless they realise that there's some adaptations that need to be made on both sides. (Respondent 36)

Several respondents speak about the "perfectionism" of science compared to business:

Entrepreneurship is often taking a punt. You go ahead with maybe 40% of the knowledge whereas in scientific research of course the whole point in doing it is to gather as much knowledge as possible, to be comprehensive about things. (Respondent 15)⁶⁵

Four perceive science as more analytical and one respondent considers there is more objectivity in science. Other single comments are that there are bigger monetary rewards in business, science careers are more secure, business has more of a focus on customers, is more exciting (and stressful) and involves more people skills. There are clearly differences between the two realms.

On the other hand, half a dozen mostly primary respondents comment on the similarities between science and business or entrepreneurship, in particular within the processes used in each realm:

I don't put things in boxes. I do not see the difference between basic research and applied. They're a long stream. And at one end in people's minds they've got basic research. At the other end you've got this so-called applied. But again I don't see the difference. You need the same skills or similar skills. And the same with being a research scientist and managing a research team. You need the same skills as if you're in a commercial organisation. So I don't - the first thing I do is I don't put things in boxes. If you want to describe what life is like it is really like a porridge with all sorts of things in there. With lots of raisins or whatever, or nuts. So I don't distinguish between the basics side and the commercial side. That's important to note.

Interviewer: So you're saying that there's very little difference between the world of science and business, there's no barrier?

No.

⁶⁵ Respondent 6 demurs in feedback he gave on preliminary findings: "I doubt that any scientist (wants) expects his work to be 100% right before publishing..... Nice thought but not practical - usually the scientist believes he/she is right or at least has a worthwhile contribution to make. In the case of the entrepreneur manufacturing he/she had better be 100% right or the enterprise will fail". Notwithstanding this rebuttal, the consensus clearly supports the "perfectionist" archetype

Interviewer: The same processes?

The same processes. (Respondent 6f)

5.3.9 *Boundaries*

In keeping with the above discussion about similarities and differences, several respondents perceive a sharp boundary between science and business but almost as many do not. One respondent complains bitterly about what they see as the creation of unnecessary boundaries:

One thing that we've tended to do in New Zealand, in our funding environment, is compartmentalise our research and make it more and more prescriptive. For example, originally we had a programme that was a multi-million dollar programme, which covered everything from discovery to the product. We had the entire pipeline covered. Now that one grant has now been split into four separate grants, each with separate criteria. So what that tends to do, is it tends to compartmentalise people, and not give them the freedom to stretch from one area to another. And I think what we're losing is the flexibility, both in activity and mindset, of people, and to enable people to... If we want people to be entrepreneurs, we've got to give them freedom to cross boundaries, and often the way we fund people now is through the compartmentalisation process (which) inhibits that.

(Respondent 28)

5.3.10 *Regions and industrial sectors*

Regional context is important, as is the sector or industrial context:

Innovation is basically a local event. And by that I mean in my view what we need to try and do in our cities, local being city or region, is get as much of the virtuous circle of innovation and entrepreneurship in one place. Entrepreneurs are just one component of

innovation, but entrepreneurs need an innovative zone, an innovative community.

(Respondent 9)

This is effectively a statement in support of clusters (see section 2.2.3). Taken together with comments on organisations, it is clear that context is highly influential in determining whether or not scientific entrepreneurs can flourish.

5.3.11 Finance

Opinion is divided as to whether the availability of finance is a major constraint to scientific entrepreneurship and overall, it is difficult to draw firm conclusions about this factor. Although a slight majority is of the view that it is not a constraint, some report very negative experiences in trying to raise capital. A lot of capital is required and it is particularly difficult to find for individuals and risky projects or for “scaling up”. There is a high attrition rate in commercialisation projects. Finance tends to come with very high accountability requirements and a loss of control (although in one case it enabled the respondent to take up equity in a commercialisation vehicle). It may be that private funding for research is more difficult to find than for commercialisation *per se*.

5.4 Attribute layer

5.4.1 Introduction

There is potential for overlap or merging of some elements of the contextual and attribute “layers” of the competency model, for example “what is entrepreneurship” is at times seen to be conflated with “attributes of entrepreneurs”. If this were to occur to a significant degree, the effectiveness of the model would be diminished.

In the event however, it is possible to clearly differentiate the definitions of nodes in each of the layers, and to tease out respondents' comments accordingly (albeit in some cases they are multiply coded). To test the degree of overlap in the entrepreneurship example, a matrix search comparing the 38 coding references for "what is entrepreneurship" with the 210 for "attributes of entrepreneurs" shows that only 11 coding references overlap. In other words, just over a third of comments on "what is entrepreneurship" are also coded as attributes of entrepreneurs. Given that this case is the one in which overlap is most likely, the above comparison indicates a fair degree of differentiation between the layers.

Comments are elicited on the attributes of four main types of people: business people; entrepreneurs, a subset that is far larger in number than the "parent" category; scientists; and scientific entrepreneurs. Respondents also provide their views on similarities, differences and boundaries between scientists and business people/entrepreneurs and comments provided by them on their own personal attributes and present or recent roles are also coded. Table 5.7 includes high level nodes and coding on for each of these is shown in appendix five.

Table 5.7 Nodes in the attributes layers

Nodes	Number of respondents commenting			
	Primary	Secondary	Tertiary	Total
Business People	24	13	8	45
Entrepreneurs	24	13	8	45
Scientific Entrepreneurs	20	12	5	37
Scientists	18	12	6	36
Differences: Scientists & business people/entrepreneurs	17	9	5	31
Present/recent role	9	7	4	20
Similarities: Scientists & business people/entrepreneurs	9	8	1	18
Boundary	4	3	1	8

5.4.2 Business People

At the highest level, this node contains attributes of business people in general and entrepreneurs are included as a “child” node – albeit a very substantial one. Given the research focus, attributes specifically identified for *scientific* entrepreneurs are coded at a completely separate node.

Being a self-starter and goal oriented and having a good reputation are mentioned by a few respondents as being attributes of business people in general and these might therefore also be seen as part of the make up of entrepreneurs, since they are a particular type of business person albeit with a unique set of characteristics.

5.4.3 Entrepreneurs

The most often mentioned attribute of entrepreneurs is that of “risk taking” – mainly of a *personal* financial kind but not exclusively so. Some risk-taking might be unknowing, but a large proportion of comments, particularly from primary respondents, also point to risk being managed. Findings on the theme of risk are discussed more fully in section 5.5.1.

There is a whole cluster of attributes around “determination”⁶⁶, “tenacity”⁶⁷ and “overcoming or going around barriers”. Tenacity includes “hard work” and excessive drive or obsession (an initial node coding for “drive” is merged with this one). A slightly different but linked attribute mentioned by 20 respondents is “passion”⁶⁸, which is interpreted as a motivator or fueller of determined behaviour and so coded separately. Motivation is discussed separately in section 5.4.9.

That all came back out of this kernel of this entrepreneur being quite far sighted and pig headed, obstinate. I mean that's the other dimension is just the sheer willingness to just keep on trying to overcome obstacles as they come towards you. Dismissing a lot of things as obstacles and being very thick skinned about - I actually think that's one of the key things. (Respondent 35)

I would say that probably most entrepreneurs have some degree of obsessional thinking which makes them, makes their thinking very targeted and focused but they're also open to allowing a range of ideas to float around in the head as well. (Respondent 32)

⁶⁶ Firmness of purpose (Oxford English Dictionary)

⁶⁷ Doggedness; perseverance, persistence, holding firmly to something and hanging on through thick and thin (adapted from Oxford English Dictionary definition)

⁶⁸ A very strong emotion, intense enthusiasm (OED). As used here includes “spark” (but passion is not the same as ambition, which is much more focused on an achievement)

They've (entrepreneurs) got to have drive towards goals and things, so they've got to have a vision of what might be and a drive to get there and that leads to a degree of unreasonableness and persistence. (Respondent 26)

After the major attributes of risk taking and motivation comes another consisting of "realise the market opportunity" – defined as the ability to both see the opportunity and to make it happen. Similar numbers of comment are made about: "think(ing) outside the square", including creativity and new ways of doing things; "good people person"; and "ability to sell the vision". The theme of "opportunity" is discussed more fully in section 5.5.2 and in the conclusion (section 6.2.4, figure 6.2).

So to actually build a company you have to be very aware of the marketplace so you know an opportunity when it floats past you. It's sort of like my favourite quote is Louis Pasteur's chance favours the prepared mind. So you've got - technological entrepreneurs are brilliant because they've got this fantastic wealth of technological knowledge of facts behind them. You stick them out into the marketplace, they gather marketplace facts. So then when an opportunity goes bobbing along, they can actually recognise it where other people won't....it's that ability to recognise opportunity which is the key skill of the entrepreneur. (Respondent 29)

There is a noticeable difference between categories of respondent with respect to an attribute of an entrepreneur being a "good people person" where 17 primary and secondary respondents mention this attribute but only one tertiary respondent does so. A separate node of "has vision" codes ten comments but only one from a primary respondent. It may be that those who are active scientific entrepreneurs are insufficiently detached to be able to reflect on such aspects of what it is they are doing. An interesting question, discussed in section 6.4.3, is whether increased self awareness of these aspects would make any difference to scientifically entrepreneurial performance.

5.4.4 Scientists

Aside from “motivation” which is coded and analysed separately, the most common attribute of scientists is “curiosity”. This is followed by “poor appreciation of business” whether in the sense of understanding or valuing business - although there is a distinction here between the “pure” scientist and the applied or entrepreneurial scientist:

“True” scientists abhor the notion of commerciality. (Respondent 17)

Not to say they don't exist but the generality is that most creative science technology people are actually completely useless at running a business or at being entrepreneurs because they're not actually focussed on a broad enough set of detail and their goals tend to be too narrow, technology focussed goals. (Respondent 23)

Scientists are recognised as being impartial, methodical and analytical and having good intellects and deep technical knowledge and skill. In contrast to entrepreneurs they are often seen as introspective, perfectionist and very autonomous to the point of being somewhat isolated. There is very little reference to cross-disciplinarity:

The born scientist sails under the radar, they are happiest in the lab. (Respondent 38)

The combination of all these attributes means that, along with the perfectionism mentioned above, scientists are often risk averse and reluctant to “let go” of commercialisable ideas:

A lot of the companies I see out there or we work with or whatever you've got a bunch of scientists holding the cards up here and they never let the bloody thing go to grow. A lot of them get caught up with I want to own all the IP and I'll struggle along instead of getting

the right people to grow the opportunity. And that's something that's the same throughout the world. New Zealand is no different. (Respondent 29)

They won't let go. They're also distrusting of the commercial world in a lot of cases and there hasn't been that long relationship where the commercial faculty, business faculty have been able to change that attitude. (Respondent 41)

Now I suspect that a lot of scientists are a bit wary of doing that with the commerce sector because they think they're going to get their IP stolen. (Respondent 46)

But the above views of scientists don't always apply, as discussed in the next section (5.4.5).

5.4.5 Similarities: scientists and business people/entrepreneurs

This node includes comments on how individual scientists and entrepreneurs/business people are similar to each other (as opposed to broader similarities in the worlds of science and business which are coded for in the contextual layers).

A good scientist, I think, knows when it doesn't matter. A good scientist can cut through the crap, and actually figure out...you know, there's lots of answers, but what's the question? And actually knows really what the proposition is, from day one, that he can answer, and then sets about doing the critical experiments to prove that. A poor scientist mindlessly crunches through every last aspect, and then ultimately might make a decision. You know, they might be a good analytical thinker, a good scientist, but they're not going to be the ones that make a difference. There is probably a few percent in every bunch that have this intuition, which comes from experience or just perception, and maybe its ego or self belief in combination too, but it's intuition as to what will work and why it will work, and they'll run it down. So a scientific entrepreneur and a business

entrepreneur will be similar really - someone who will have a view or a perspective on something and sets about doing the critical work to prove it. (Respondent 13f)

Although they might be applied differently in each realm, some attributes enable people to work in both science and business. The ability to communicate in each is a key example:

Whether people believe it or not, if you're not a good communicator you're never going to be an effective scientist. And the people who ultimately make it in science and distinguish them from those who don't but show promise, is that they can write well and they can speak well and clearly about their work, and speak simply about their work. Because they need to speak clearly because science ideas are very complex, they need to be communicated effectively to your peers. You've got to also communicate in a very simple way to the people who are going to fund you because they don't want to hear your science spoken about in a way that you would communicate to the experts around the world. So you've got to be a salesman in a sense in a balance way, not in a crude way, but you've got to have a lot of the qualities that a business person has. (Respondent 34)

Alternatively, the same or similar attributes, such as creativity or perseverance, might be applied out of one realm into another in much the same way:

Of course the attributes of a good scientific researcher are a person who is patient, and perseverant, and very organised and very creative. And the two there that are in common with entrepreneurship is persistence or, perseverance and creativity. (Respondent 17)

I think a good scientist could be a good entrepreneur but - it's the same tools but a different mindset. (Respondent 43)

Another respondent also refers to differences in "mindset" but sees no reason why a scientist can not also be entrepreneurial:

Scientists are good at innovation, you know coming up with solutions to a tricky problem. Those are all skills that I find the science training just ports straight across without any trouble.....scientists I think are in some ways entrepreneurial in that they're looking for opportunities and they're looking for opportunities partly to get money through granting organisations, and also they're looking for opportunities to take their science elsewhere, so they're not down this track, we do this and then well that's all we're going to do. (Respondent 44)

Another attribute shared by scientists and entrepreneurs is networking ability. The difference is in the networks to which they connect. There are also a number of other differences, as discussed in the next section

5.4.6 Differences: scientists and business people/entrepreneurs

Many respondents are of the firm view that the attributes of scientists and entrepreneurs are totally different, but allow that there is some overlap. The most significant difference is that scientists are less likely to be “ready for market” or willing to let a product go:

Wrapped up in the science rather than market facing. (Respondent 10)

Once again, scientists are seen as being more driven by curiosity about the world but having a narrower focus than entrepreneurs:

An entrepreneur I think tends to have broad based skills rather than narrow based and a researcher is perhaps the flipside, the other way around. (Respondent 3)

An entrepreneur needs to be, if you like, very broadly looking and not see problems. So, if they come across a problem they'll either solve it or ignore it and then somebody needs

to pick up the pieces after them. But a science person, or a University-trained person, will tend to identify a project and risk and analyse it and all that sort of thing. (Respondent 8)

Scientists and business people/entrepreneurs are seen as having quite different modes of communicating:

You can put a scientist into a business meeting and it goes down. You don't talk the same language. (Respondent 2)

When you have a group of entrepreneurs and scientists in a room, watch how you will find two complete streams of conversation going on and it takes about 4 or 5 such interactions between these groups of people before they start coming up with a reasonably common language and that's when you start picking out, well hey look, of the group of 20 people in the room these 4 or 5 are showing strong.... you know, they might have the ability to work with entrepreneurs or have scientific entrepreneurship. (Respondent 45)

There may be different attitudes to problems:

There's an incredible level of discipline required I think to do research and an incredibly ordered and methodical approach. And that seems to me to be somewhat inconsistent with the highly creative paradigm - the paradigm that doesn't see the problems. It just sees that there must be an answer. (Respondent 40f)

This does not sit with the view of scientific problem solving held by respondents 15, 21, 31 and 37 – all prominent, successful scientists, who see science as being highly creative.

But in general it is clear there are areas of difference, similarity and overlap between scientists and entrepreneurs as in figure 2.6. The challenge, discussed in section 6.2, is to find a model that incorporates these similarities and differences and allows for connecting the two realms across any boundaries that may exist. One

respondent describes a model of an entrepreneur as a “broker” who can cross boundaries between science and business in order to help them come together:

I've spent a lot of time in with people who are like, operating across the boundary, and some, some were quite good at it, but they ended up becoming managers in operations that meant that they had to leave the science bench behind....Entrepreneurs are a different kettle of fish, they are people who operate in this case, if we're focusing around science and business, then they are people who operate between science and business, and they might not be the scientists themselves. They're most likely not the scientists themselves. (Respondent 42)

Three respondents are of the view that entrepreneurs work on or across boundaries easily because they are either not aware of them or see them as being of no significance at all. Scientific entrepreneurs are different again, as described in section 5.4.7.

5.4.7 Scientific entrepreneurs

In general, this node codes for attributes *in addition* to those of "ordinary" entrepreneurs so for example there is no coding on for risk taking. However, there are included some attributes demonstrated by scientific entrepreneurs which match those of entrepreneurs as a class, for example “confidence” and “highly committed” because the latter is of particular importance in some areas of scientific research:

You've also got to have the commitment to follow it through, and that's particularly true in biomedical research because the average time from a proof of concept to delivery is between 12 and 15 years. (Respondent 28)

Also, like other entrepreneurs, those of the scientific variety are seen by some respondents as being able to take an innovation or a company “only so far”:

Yep, yep. No, we've found plenty of those (scientific entrepreneurs). What we haven't found is anybody that's capable of taking it through. There comes a point in the business where the prototype's been produced, maybe sales have been made, the business is running but in order for the business to be efficient and to grow and to run successfully by that stage the entrepreneur is basically run out of entrepreneurial ability. (Respondent 24)

Scientific entrepreneurs are seen by respondents as rare individuals, but those that do exist are seen as having a cluster of similar attributes, headed by the "ability to see the big picture".

I think that scientific researchers can become pretty effective entrepreneurs. I think that comes by them being able to see the big picture. Being able to see more in depth and very narrow field but be able to see breadth as well, be able to see applications, be able to see situations in life, typically problems, that what they are doing or what they have seen or what they can do can actually present the solution to. If they can see the bigger picture and recognise that they may have a solution to a problem or a need, then the next step that they need is they need to be able to be game enough to leave their somewhat protected and well defined environment and branch out a little bit. (Respondent 3)

I suppose you go back to what an entrepreneur's about. I've always got a global vision of what I'm about, I've got a picture in my mind as to what my particular sphere is about. (Respondent 13f)

I think there are heroic scientists also who actually are more visionary, see things and go for them and are able to make, able to add to the normal scientific method, I don't think they abandon that at all, but I think they're able to add intuitive leaps to it and some of them are entrepreneurs - they're also prepared to take risks and then to go beyond science into commercial activity and are motivated by the outcome. (Respondent 26)

As an aside, respondent 26's comment above is a description of scientifically entrepreneurial behaviour even though in his earlier, explicit responses he is

extremely sceptical of the existence of scientific entrepreneurs or of the value of any policies to encourage them. In other words scientific entrepreneurship is being recognised by him at one level but not overtly or consciously. In this instance there may even be a degree of overt *resistance* to recognition.

Equal numbers of respondents note the need for a *broad* “big picture” as do the need for a *deep* one. One respondent refers to research (Roberts 1991) which shows that successful intrapreneurs and entrepreneurs need:

A deep conceptual understanding of the basic science or engineering behind the idea, the product or the service if it is a scientific based one. So we have little evidence of generalists producing real innovations. (Respondent 30)

The problem you're going to have also is to achieve a certain scientific standard you really are going to have to be at the top. You can't be an average scientist and a successful entrepreneur I suppose. So your science has to be good. (Respondent 31f)

This is not a view shared by all respondents, and lack of high level academic achievement is not necessarily a barrier to scientific entrepreneurship. But only one respondent suggests that scientific entrepreneurs can operate without at least a sound technical knowledge.

Breadth can come from life experience or the application of particular problem solving techniques:

It's a way of looking at problems from different angles, approaching from different points of attack. (Respondent 31f)

Within the workplace another respondent describes an approach that is not so much “having a sense of the big picture” but rather being a “jack of all trades”. Filling a variety of roles also requires a variety of skills, including an ability to communicate within both the science and business realms as discussed above. The ability to communicate is respondents’ most frequently mentioned personal attribute. Two respondents see themselves as *bridges* or *interpreters* – a concept not unlike that of “broker” mentioned earlier. But entrepreneurs can be more than brokers:

I think entrepreneurs have to be people driven by curiosity and inventiveness, I think they are people who think outside the square. I think often it can be due to life experiences or it could be due to extensive training in particular disciplines, which because these people think outside the square, *they can take advantage of the knowledge they have in one area and translate it in a very imaginative way into another area*. So it's all about opportunism and it's all about extending your mindset beyond your conventional boundaries
(Respondent 28; emphasis added)

The italicised remarks in the above paragraph repeat a recurring theme, as does the following quote about the importance of an orientation towards the *application* of science and technology:

You will find brilliant fundamental scientists who are also scientific entrepreneurs, so the two can overlap, but generally with scientific entrepreneurs in my experience, they're more likely to be guys who are, or girls who are, more at the applied end of the spectrum, possibly a bit more towards, yes, applied, so applied science and engineering They're someone who's going to be more connected to the market at the practical applications of the idea, they'll be scanning the environment for, “hey, if I take that I can use it there”, and then maybe have more of the skills in terms of pulling the interest in and getting a group together to drive the thing forward. (Respondent 25)

What we want, is someone who can develop a product with the commercial goal in the forefront of their mind and not the scientific goal. (Respondent 43)

Only two respondents state that in the context of scientific entrepreneurship they consciously “switch” the way they operate from one realm to the other, despite this type of strategy being probed for. Most respondents who comment on their own behaviour in this regard speak of the “seamlessness” of science and business, or of themselves “being the same person” in both realms. This reinforces the presence of core attributes that enable some individuals to be both scientists and entrepreneurs, as shown conceptually in figure 6.2.

5.4.8 Motivation

Motivation clearly emerges as a core attribute (internal) rather than a contextual (external) feature. Motivation is defined to include the drive, goal or vision for scientists or entrepreneurs (i.e. a noun) not the motivation of others (a verb) – which is coded in “skills”. Also not reported on are generic career-related comments, for example the desire to emulate others, reach the top management role in a laboratory or to gain tenure or teach in a University setting. Rather, the focus is on specific motivations that scientists have for being scientists, entrepreneurs for being entrepreneurs and so on.

Entrepreneurs are seen by most respondents as being motivated by a vision of what can be achieved or “the project” and its successful implementation, or the growth of a business and recognition for that - rather than primarily by earning money. Money is a motivator for some, but gaining it is a by-product or measure of success rather than the central purpose of entrepreneurial endeavour:

Often the money they make is a measure of how well they've done, not that they're driven by the money, they're usually driven by the desire to really do something special.
(Respondent 23)

Indeed, several comments are made to the effect that money brings a lifestyle and it is the achievement of a certain lifestyle that motivates many New Zealand entrepreneurs. Once that has been gained ("a reasonable income plus the boat, the holiday cabin") then there is often no longer any motivation on the part of an owner to further grow a business.

There are different types of entrepreneurs though and for non-technical entrepreneurs, non-scientific entrepreneurs, money can be the key driver. One respondent also notes that a well-known investor entrepreneur with whom he is acquainted is driven by "ego" or the need for fame. Some scientists may not be entirely different:

Yes I think so, the scientist is the famous, the scientist wants to be the Nobel Prize winner. He wants to be the hero, he wants to be recognised internationally and everything else. Or she. (Respondent 12f)

In which case, the place to be is a University rather than an Industrial Laboratory:

I remember when I was a scientist in an industrial research situation. My boss always told me this is no place for Nobel Prize winners. It was no place for high flying scientists, who wanted to be high flying scientists because institutions in that case it's different than Universities, industrial research institutions are driven by industrial agendas, not by science agendas and not by entrepreneurial agendas. They're driven by ownership of the business needs. (Respondent 26)

This statement reinforces the (proper) focus of sector-based research institutes on sector needs and their unsuitability for promoting entrepreneurship.

Like entrepreneurs, scientists are motivated by recognition of their successes, but more by peers for scientific excellence than by the broader community (that is not to say that business people do not seek peer approval – they do). Scientists and entrepreneurs are both problem solvers, but scientists are likely to be curious about and motivated by the science itself, “the love of science” or the “search for new knowledge” and seldom by money: (one respondent notes that this was perhaps just as well, given New Zealand salary levels). Money is more likely to be a means to an end (making it possible to do science). This is not to say that scientists are motivated *only* by science:

Probably all scientists want to feel they're making a contribution to society, I think that's true of all of them. Some of them want to do that in a bigger way and the money comes with it as an aside; so they're still getting their buzz out of making this fantastic contribution to society rather than a buzz out of the money. (Respondent 8)

But scientists' primary motivations certainly diminish the likelihood of any entrepreneurial behaviour:

Often has a goal in the University of publishing those results for peer recognition, but has that priority so high that there's no room really for becoming a commercial entrepreneur. And there's a lot of academic staff who are like that. So they may come up inventions that have value but their focus is on their academic research plan, not on going with a potential opportunity. It means a risk in terms of a redirection of their energies and time. (Respondent 14)

Scientists get reputations through publishing articles and get known in their scientific community so they tend to disclose their information very easily. (Respondent 41)

In one sense this comment contradicts others about scientists keeping IP to themselves but the difference reinforces the different imperatives that apply in commercialising science. Elements of scientific recognition are able to be redirected:

As the knowledge economy has taken off globally there's many more celebrations of spin out companies and the academics behind it so it's becoming something that most academics would like to have - driven by jealousy in matching their peer group as much as anything. I've noticed particularly is that Bristol and Edinburgh, you take the medics there who are very competitive between themselves so if Professor X down the corridor has got a spin out company then well Professor Y a few doors down says well my research is just as good I need to have one of those too. And they kind of rub against each other. Those motives might not sound particularly grand but my experience is that keeping up with the Joneses in academia, that competition between professors in the field and in a department is a major driving force. (Respondent 14)

Although I do have still some scientific friends and peers who are very much traditional and are not interested in that sort of thing, I have many more who have opened their eyes to the fact that well you know Governmental research grants aren't the only way to get money to fund research. So they're actually looking to the commercial world for alternative ways to fund their science and if you think about that in itself, is a bit more of an entrepreneurial bent. (Respondent 17)

Scientific entrepreneurs are probably more akin to entrepreneurs in their motivations but they still have something of the scientist about them. Indeed they commonly have elements of both sets of motivations, thereby showing that the two are not mutually exclusive. Respondent 3 would not be satisfied with marketing a product that is either not technically sophisticated or "makes no difference", and respondent 4 is very explicit about having dual motivations. Respondent 14 is seen by a former colleague as someone who is motivated to discover or invent technologies *and* take

them all the way to market. But the key differentiator for scientific entrepreneurs (from scientists) is the desire to personally *apply* knowledge in the marketplace:

The funny thing is I don't really want to be rich, I want to have something that grows and develops and I want to have something that can eventually be self sustaining. I do want to have that. I would like to be comfortable. I don't particularly want excessive money because I think that's probably has some very negative impacts too, but I do want it to be beneficial. For example, I wouldn't care if I invented goodness knows, a pen that could make me millions of dollars, because at the end of the day it wouldn't give me any satisfaction. But what I've been doing is basically, leads towards a medical device that will help people in hospital and to me it's in some ways a perfect combination of both of them. That's what I really like. So making money alone isn't good enough but then again probably helping society - nah, I would do it if it just helped society and didn't make any money. (Respondent 3)

Knowledge for knowledge sake isn't a driver - I like to have some sort of practical application. So I like to always have an endpoint in mind. So I'm not the sort of guy that will just sort of wade into a publication or wade into a book and just see what happens, I mean I'm sort of results or task or outcome - oriented. (Respondent 13f)

Money seems not to be a primary motivation for scientific entrepreneurs, but money sometimes follows success, for example when value is released from the sale of a company. For several primary respondents, the key to combining the motivation of scientist and entrepreneur is a focus on the broader public good, whether in the development of a particular product for market or more generally in terms of national welfare (fully half of all primary respondents and six of ten "full" scientific entrepreneurs are "doing it for New Zealand"):

There is this desire to genuinely get some public benefit out of a discovery that we make here in New Zealand. And we're also particularly focused on things which would give New Zealand a competitive advantage, because that means more for us than developing

technology which could be sold to a large farmer and then taken offshore and priced at a level that New Zealand agriculture industry wouldn't get any benefit out of it. (Respondent 28)

I take great delight in seeing processes and products that I've developed actually become used by industry in New Zealand. That's probably one of my biggest drivers, or one of my biggest satisfactions. (Respondent 32)

Probably the Porter project was the most significant thing in defining my working life. Do you remember it? I guess I was wandering around New Zealand thinking this country is going down the gurgler and I don't want this country that I love to go down the gurgler. And the only reason it's going down the gurgler is we've got the wrong paradigm about what we're doing. And we're exporting bales of wool and pounds of butter and importing pharmaceuticals and aeroplanes and you don't need to be an economist, add up any numbers. You can just look at that and say it doesn't don't add up. We're a third world economy, or we were a third world economy with a first world standard of living in that we were dreaming. And I didn't like what that meant in terms of what we were leaving to our children. And so I worked for a number of years just trying to encourage change to more highly value, or intellectually dense products. And this business is a consequence of that I suppose. (Respondent 40f)

In some cases organisational mission is also highly motivating.

My sole focus is for the organisation, I don't care about myself personally. My driver is I want the ... if the programmes succeed and our projects succeed, then I succeed. And I put my, my balls on the line all the time when I go to the Board and present to the Board. But I'm not doing this job for my own self gratification, I'm doing it for because I believe in what we're doing. Well whether I call myself an entrepreneur, I don't, I don't really think, I probably don't think so, I just do my job, which I like. (Respondent 11)

Others are motivated by the need for independence and not being answerable to people.

There's the independence and also if you're reasonably successful that brings a certain financial security as well which takes you back to have more independence again. (Respondent 31f)

You try to look for a unique and novel patch where you've got no-one on your back where you can carve out, and you can move forward without having to look over your shoulder all the time. (Respondent 12f)

Respondent 31 is also motivated by a wish to “not let opportunities slip” – in other words to avoid regret:

If there are things out there that I think we can do and that we can achieve, and we don't do it, it's very disappointing for me. So I don't like wasting opportunities. (Respondent 31f)

Related to this, another is motivated by a fear of failure, and desperation is a great motivator:

Well, we just plunge along. I always say that our science hero, for Christ's sake should be someone like Bruce Willis in Die Hard. Desperation is a great innovator, source of innovation and you haven't got time to bugger around with the niceties, you've got a scientific problem you've got to attack, we haven't got time. You've got to attack the nuggets, the key thing, you haven't got time to figure out how to get of this burning roof when you've got a helicopter down there shooting at you, you've got to do something. You've got to do something like jump off, it's a bloody good idea, let's try it and jump off with the fire hose wrapped around you. If the door won't open you shoot it open. (Respondent 37f)

Scientific entrepreneurs may be more likely to eschew the recognition sought by a scientist:

He's creating a little kind of scientific community where they're able to fund their intellectual endeavours and their other things that give them satisfaction. And they are rewarded in that they can get good incomes and do those things at the same time. He's interested in having a solid reputation but he's not interested in being a Nobel Prize winner. (Respondent 33)

Other respondents are motivated by the need to “prove the nay sayers wrong” or in the case of two female scientific entrepreneurs, to overturn sexist stereotypes and expectations. The desire for “challenge” is also a motivator for some, as is “enjoyment” of business and fun. But motivation is not always critical – things just evolve for some:

I think speaking personally for me scientific entrepreneurship is about a maturing process for me. It's about me growing to a different stage in my life, wanting to do different things. (Respondent 34)

Nevertheless it can be concluded that any model of scientific entrepreneurship will need to reconcile tensions between scientific and entrepreneurial motivations. There are also a number of other thematic factors which will need to be addressed, as described in section 5.5 below.

5.5 Themes

5.5.1 Risk

Risk is an example of a cross-cutting theme - that is it could be a feature of either the vertical layers of the extended competency model, or the horizontal dimension, or even of life histories. Echoing the findings of the literature review (section 2.7)

respondents see the propensity to take financial risk is a key attribute of entrepreneurs, and a prime discriminator between entrepreneurs and non-entrepreneurs. Some also emphasise that the financial risks taken by entrepreneurs are personal risks – i.e. related to their own capital or money they borrow – rather than to the money of an employer.

Other types of risks are also commonly taken, but are not so clearly differentiating. For example all sets of respondents may take reputational risks, by asserting an unpopular point of view or carrying out a project in opposition to conventional wisdom or without full authority. Some also risk jobs, relationships and health. But not all risks are characterised negatively, and a number of respondents speak of risks in terms of accepting new challenges, for example by travelling overseas.

Perhaps the major underlying risk in entrepreneurship is that of failure, and there are indications that fear of failure (or of regret) are heightened by social attitudes. But very few respondents actually mention failure or regret. Where there is social stigma attached to failure, people are naturally inclined to be risk averse and the opposite effect is likely to occur in a context where failure is accepted without opprobrium (the United States is most commonly mentioned as an example in this regard). In New Zealand, it may be that scientific peer pressure heightens fear of failure and aversion to entrepreneurial risk taking:

Your reputation is damaged with other scientists because you look like a big poser, you know because you've - you know they say oh well look at her there she's off doing you know being a sales agent basically. She mustn't know much about science then. And so for your peers it's damaging because then when you do come back crawling down to that level - I shouldn't say down to that level (laughter). When you do kind of look like a complete pillock and come back down to earth again it's hard for them to trust you because you've got to be damn careful you don't - you know you've got to be careful that

you don't rock the boat as you're leaving it. Because you might have to be back in that boat and then you know you need their help again. And you might need their help even when you're out of the boat you know to come back and say look this is a problem that I'm having with the product. Can we you know is there any ideas to help push it along. So you cannot have this sort of oh well I'm off, see you kind of attitude. It's kind of stressful. (Respondent 1)

But cultural attitudes are not the only differences between the United States and New Zealand in terms of risk mitigation:

I think if we looked at the discouragements to innovation it would be the fact that there's too high a price for failure in that there is - if people have to put their job, their livelihood on the line to do it. There isn't a backstop in terms of people, whereas in the States although there's not a physical backstop, there is a sufficient variety of job opportunities that there is a backstop. (Respondent 29)

There may also be systemic barriers to *scientific* risk taking:

Yes, in New Zealand that's getting harder and harder to do too (take scientific risks). To get funding you virtually have to have your answers worked out before you can get any funding. (Respondent 7f)

The risk is huge, by leaving an institute, a CRI, set up a company, it's even worse now with the long term funding for the CRIs the risks are huge, the benefits are small compared to the States and the risk reward ratio is completely upside down. (Respondent 37f)

As suggested by this last comment, on the other side of risk of failure is the prospect of success and reward and the risk-reward trade-off, which is either implicit or explicit in entrepreneurial behaviour, is seen as a crucial one for policy-makers to consider:

I think one of the ways to do it is to provide a better reward for the scientists without them having too much risk and then wrap that up a little bit so you've got a little bit of risk, no risk and a little bit of reward, a little bit of risk a bit more reward, those who want to take a bit more risk again get a larger reward and provide that opportunity. I think you'd get a huge response if we actually had a conscious sort of policy of working like that. Which means that the way we've structured our organisations, you can't set that policy, you can't dictate that's what happens. (Respondent 19)

The odds of succeeding in New Zealand in scientific entrepreneurship are much smaller than they are in America or Britain where there's much more money, much more opportunity. And the rewards are smaller so that's the wrong ratio. You've got to figure how to tip it and the way to tip is to reduce the risk, you can't change the reward. (Respondent 37f)

Rewards can be financial, although this is less likely in New Zealand, or come from some form of recognition. But for many respondents, their principal reward (feeding into motivation) comes from the activity itself, especially the satisfaction of being successful or seeing something they create put into the market place.

As in organisations in other fields, it is possible to shield employees from most financial risk, but at the expense of entrepreneurial behaviour. In some cases, employees get the best of both worlds:

We're developing a strategy here like any business. If that strategy is unsuccessful and if I was at a University - it's like "who cares?" They just go on teaching. Whereas at CRI it's no money, see you later. So from that point of view there's a lot more rides on your capabilities. (Respondent 29)

One respondent deals with "fear of failure" by putting his business risks in perspective after undergoing a medical procedure which could have resulted in his death. Risk management strategies include legal structures to separate personal

finances, sharing risk with partners and having contingency projects operating in parallel rather than in sequence. One respondent ensures he has only “upside” risk by accepting equity in a start-up company rather than payment in return for IP, while retaining a salaried position. Another obvious risk management strategy is to gain full knowledge of the marketplace (reduce uncertainty) and some do this very carefully. Taking risks in increments as knowledge and experience grows increases the probability of success. But not all entrepreneurs work this way, and not all manage the risks they take:

When I say there's a level of stupidity, I was only half joking. There's probably an element of not knowing what you don't know and therefore you're prepared to take risks that someone who is probably better educated won't take. (Respondent 24)

There are suggestions from some respondents that younger scientists are more likely to appreciate the need to take risks, and more inclined to take them.

As businesses get bigger, measures such as audits are introduced but at about this point the dynamics are probably no longer of an entrepreneurial nature. Business planning is not seen as a way of managing entrepreneurial risk:

The mistake I think we tend to make is that we tell the entrepreneur to go away and write a business plan. What a disaster that is. They don't know how, they won't take the patience to learn, and they're not the people to write the business plan. They're the people to make a business case in broad terms and we need to assist them with professional advice. (Respondent 9)

Conclusions on the theme of risk, drawing on both the findings in this section and the literature review (section 2.7.2) are contained in section 6.2.4 and, along with findings

on “opportunity” as described below, feed into the opportunity model shown in figure 6.2.

5.5.2 *Opportunity*

This second thematic node codes for characteristics of a commercial opportunity (not other sorts of opportunities such as career opportunities) and how it comes about. Opportunity is defined as more than simply an idea. Rather, it is an idea plus a potential pathway to application⁶⁹. In a number of cases an original idea has been applied in a way that is different to the one originally envisaged – reinforcing the discrete nature of these two elements of opportunity.

Sometimes opportunities are “discovered” as they emerge and are perceived by the discoverer(s), and sometimes they are deliberately “created”. The following quote stands out as a classic example of scientifically entrepreneurial thinking.

I didn't know what the answer was, but I understood the question. And it all comes down to some particular bioactive proteins and some very subtle structural components of the active sites on those proteins and how they interact with another class of compound. And I could see from the literature the certain class of compound interacting within one way and another class acted another way. And that some compound between those two would probably most likely act in the way that we wanted. (So I made it) and it did.
(Respondent 40f)

This is an example of the use of ideas as “tools” as described by Watson (2005). In most cases of entrepreneurship reported by respondents there are elements of both discovery and creation and for an individual, the process of identifying opportunity (insight) can happen in an instant or it can take a lifetime.

⁶⁹ An inventor might have an idea and create a product or service but not take it to market. An entrepreneur goes one step further

Scientists and entrepreneurs both have the ability to discover and create opportunities in their respective realms but in a commercial sense, an opportunity is seen to be a gap in the marketplace, a chance to develop and sell a product or service more effectively than anyone else previously.

Insight as to what constitutes opportunity can occur at any time and being in the right place at the right time has played a part for some respondents. Organisations on the other hand use systematic processes to identify their opportunities, such as environmental scanning, technology forecasting, strategic planning and investment in research platforms. As has already been discussed, such processes are not always compatible with entrepreneurship, creating challenges for management as described in section 6.4.3.

5.5.3 *Training*

While there are equal numbers of positive and negative comments about formal education, there is a considerable degree of scepticism about the effectiveness of business courses and training for entrepreneurship in particular:

I think that Universities actually narrow people down, by providing processes and identifying risk management, and all the good things that you go to University for, for example, learning processes. University degrees often give us boundaries and limitations through the processes that we should follow. (Respondent 8)

There's many budding entrepreneurship courses now, master of entrepreneurship and all that. That's the Universities and training providers jumping on the bandwagon to fleece people for money. What you can teach anybody is business skills. Some will apply them, it will make them bigger entrepreneurs. But certain of those traits, the way they deal with

the risk, the way they chase a dream, that's part nurture part nature. They saw it, they were formed that way through their parents, peers. Good mentors in their life. People who influenced them and having that personality trait. (Respondent 38)

I don't believe that you can run a University course and select an entrepreneur, because they come out of all walks of life - your own local garage operator might be one...how you teach entrepreneurs, and how do you identify them because it's not what you teach, it's not a course, it's almost an attitude...(Respondent 22f)

One respondent is strongly of the view that it is not possible to make entrepreneurs out of scientists, and another describes how scientific training militates against entrepreneurship. Yet change is possible and two respondents are a little more optimistic about the prospect of using proactive measures:

My sense is that scientists either get with the programme or it won't work for them. It takes a few years, maybe 4 or 5 years before you become an industrial scientist after you come out of your training, your PhD and your Post-Docs, interns, that sort of situation. I was very fortunate. I think they were very tolerant of that process. You were able to be nurtured through into that change of mindset. And then I think there's another change of mindset to become market driven and market orientated. So you can still be an industrial scientist but thinking technology is driving everything and to actually switch that around to become market orientated I think is another transition and not all make that transition. (Respondent 26)

It's easier to teach a scientist about business than to teach a businessman about science simply because the volume of the knowledge required, you know you're talking about scientists who've been in school for 10 odd years odd compared to 2 or 3 years in business school and some practical experience after that. It's those types of things I think that is required to combine those two, it's got to start early, it's got to start in education, it's got to start in providing environments where both things can exist. Commercial internships for scientists, scientific internships for people in the business and financial sectors, things like that. You've just got to create a common environment where they can co-exist. (Respondent 17)

Others echo the view that the best way to sequence science and business training is “science first” (although one respondent vehemently disagrees). Contemporaneous training is even better.

In contrast to formal learning for entrepreneurship, mentoring is seen as the most effective method, followed by “learning by doing” or exposure to what others are doing, for example through international industry fairs. Self directed learning is seen to be relatively important and going overseas is also an important thing to do.

As discussed in the next chapter, all of these findings have implications for public policies aimed at developing the competencies of scientific entrepreneurship.

5.5.4 Connections

The connectedness theme is also important. This node incorporates comments on communication skills and networks of users, scientists and others that facilitate scientific entrepreneurship. The ability to build and tap into networks is clearly a key attribute of both scientists and entrepreneurs, although by definition the networks of scientific entrepreneurs are broader and six primary respondents speak of their connections with “end users” or industry partners. One full scientific entrepreneur speaks of the support gained from networking with kindred spirits – other scientific entrepreneurs (suggesting that one way to find them may be to watch for them to gather!):

There's a lot of people who like to mow the tall poppies down because we don't fit comfortably in either group but we're too science focussed and too wild thinking for your traditional business model and too commercially and market focussed for your traditional

science model, I guess that's why you end (up) being friends we've become close friends and if we're in each other's cities we have dinner and talk science all night or talk [about] what we're doing or what we could be doing or just knocking ideas around, introducing each other to other people in the networks sort of thing. (Respondent 4f)

5.5.5 *Obstacles/Perseverance*

Consistent with the literature review in section 2.7, there are many comments on the obstacles that get in the way of the successful implementation of entrepreneurial ideas and the perseverance, persistence and problem-solving that entrepreneurs need to show in order to overcome or go around those obstacles. But these are attributes that are shared with scientists:

The attributes of a good scientific researcher are a person who is patient, and perseverant, and very organised and very creative. And the two there that are in common with entrepreneurship is persistence or - perseverance and creativity. (Respondent 17)

Perseverance is not all about doggedness – it can spring from optimism, and being able to “duck and weave” is also important (Respondent 29).

You've got to remember that the entrepreneur is the one that succeeds, that removes obstacles, and removing obstacles is nearly always having a bag of tools to try, because the same trick won't work every time. (Respondent 46)

In some cases, obstacles are not seen as such or are regarded as merely something to be expected as part of the entrepreneurial process.

If you are confronted with things, it's a fact of life - there's no use just sitting in it and really questioning why did this happen, or anything like that. If you're confronted with a problem you have to solve it. There's no alternative basically. (Respondent 31f)

For others, the overcoming of obstacles may be the prime objective. Certainly these things are both motivating and rewarding:

I've made presentations in conferences where people have turned round and said "you can't do that, it's not possible". "Sorry we've just done it, here it is". That's a real buzz too...a little bit perverse (laughter). (Respondent 33)

It is acknowledged that there is sometimes a fine line between perseverance and doggedly hanging on to a wrong-headed idea, and "knowing when to let go" is also important.

5.5.6 Knowledge

There are more references to business knowledge (and skills) than to technical knowledge and skills, possibly because the latter are taken for granted by respondents. Entrepreneurs are able to acquire essential business knowledge either through formal programmes or experience along the way:

Obviously the MBA was a huge help really because it gave me tools, analytical tools that I otherwise wouldn't have had, and a lot of confidence. I guess it really gave me the confidence that I wouldn't have had otherwise to go out and do something like that. (Respondent 7f)

Things such as understanding both management accounts and financial accounting, that's essential. Understanding the process of investment in, certainly early stage, ventures that's something I just learnt through study and experience along the way. Understanding the way in which you structure start up ventures and shareholdings acquired by your investors and so on. So there's a lot of learning there which I think can be simply gained by experience and study along the way. (Respondent 25)

But scientists often lack this knowledge:

That's really I think where a lot of scientists who come up with fantastic ideas and they say wow, I've invented this thing, it's fantastic. And then they go to the jump to be the entrepreneur - unless they've had in their background somewhere a view of the nuts and bolts of how business functions and how businesses are managed, they don't have the framework for developing their business. They don't know what they don't know. (Respondent 29)

The first time a scientist steps outside the lab and tries to commercialise something, unless he's got bloody good advice, he's going to make mistakes or he's going to overlook doing things or he's going to do it in the wrong order. It may not be fatal mistakes but there's a sort of ground plan, Business 101, that you need to go through to get a firm up and running. If the scientist concerned is prepared to take advice from a bunch of other folk who don't have to just be the lawyers and accountants, they can be a whole bunch of other folk, then it may work, but it helps to either have training or an instinct for it certainly. (Respondent 36)

The missing knowledge can be provided by others through structural mechanisms, but core scientific or entrepreneurial knowledge is essential:

It's really what you surround them with in terms of a support structure in terms of access to information and knowledge. Probably most importantly access to expertise in terms of people with connections into markets and in terms of support, in terms of just how you structure and grow a company, so it's making sure we give these people the best chance at success. (Respondent 18)

There is no boiler template for commercialisation of the IP in science and I think the reason is actually that - if you don't have an appreciation of that technology, you're going to find it very hard to work out how to exploit it properly. (Respondent 2)

You have to have know-how, knowledge and insight into the areas in which you are going to operate. (Respondent 46)

This tension about the extent to which key attributes can be added to an entrepreneur has already been canvassed in section 5.3.4. In a particularly appropriate twist on the New Zealand setting, two respondents comment on how their scientific knowledge is complemented by the different, but equally valuable knowledge that has been developed by farmers, and one thinks that this is of strategic significance:

I've found that most of what I know about I've learnt from farmers, not from University. It's a different set of knowledge. You come out of University thinking that you know a lot but I found that I didn't really know much at all. So what you learn as a scientist is a process that you can apply but in terms of actual knowledge you don't know very much at all until you get out, get your feet on the ground. (Respondent 7f)

I think that the context is incredibly important, so I'm a firm believer that in New Zealand our science in the agricultural sector has a much better chance of succeeding than it does in the straight pharmaceutical sector. Than in telecommunications engineering sector. Why? Because we have so much more knowledge in these sectors, so the context is there. (Respondent 46)

This comment reinforces the importance of context which is identified in section 2.6 and carried through into the concluding chapter six.

5.5.7 Skills

There are differences in opinion as to whether the skills required for science and business are different or essentially the same, and the model shown in figure 6.3 allows for the following sentiment to be incorporated:

I think the skills required to be a successful businessman and a successful scientist are quite different, but it is possible to have them embodied in the same person. (Respondent 30)

5.5.8 *Vision, focus and “disfocus”*

There are many references to entrepreneurs having “vision” - a big idea of what can be achieved – and the ability to articulate it to others. Success also depends on entrepreneurs being able to “take people with them” – again reflecting the tension referred to in sections 5.3.4 and 5.5.6:

I think the difficulty tends to be that they believe pretty intensively in something, and tend to want to go and do it and don’t always take enough of the right people with them. (Respondent 9)

Focus, or the ability to concentrate on a particular path without being unduly distracted, is key for individuals who are aiming to commercialise research. Those who are either *overly* focused or easily distracted are less likely to succeed. Organisations also need to be focused. But focus might not be appropriate for idea generation, and two respondents describe how they deliberately employ a strategy of “disfocus”:

For something creative and something radically new you have to have a measure of disfocus, but it doesn’t mean to say you can’t have those two qualities in the same person. I think of the certain aspects of what I do today I’m very focussed but I actively try and maintain a level of disfocus so I can dream up ideas and pursue ideas. (Respondent 33)

The other way of doing things is to straddle the areas, and we've been successful as well by straddling areas, and this is contradictory to the idea of focus which we think is a great idea for everybody except ourselves (laughter). We really recommend focus but not for a fundamental research company like we are. Because if you focus you throw away heaps of good opportunities. (Respondent 37f)

As exemplified by the last comment, a few respondents refer to the importance of having fun in their work.

5.6 Recognition

The research question is about how scientific entrepreneurship is recognised, but the highest number of responses to questions about “how scientific entrepreneurs are recognised” describes how such people are *not* recognised. Compared to 33 comments along these lines, there are just six to the effect that recognition is adequate. However, a number of respondents point out that they don't particularly *want* to be recognised.

Scientific and business peers and managers are the most common roles occupied by those in a position to recognise scientific entrepreneurship, followed by employing and funding organisations and “oneself”. However, there is very low level of self-awareness on the part of primary respondents that they might be described as scientific entrepreneurs. There are also some cases where respondents unconsciously contradict views espoused earlier in their interview, throwing useful light on the mental models they use to recognise (or more accurately to not recognise) scientific entrepreneurship.

Customers and venture capitalists are the least mentioned “recognisers”, with community and professional agencies in the middle.

Attributes are most commonly “what” are detected. The visible signals detected are mainly behavioural – “modus operandi” followed by publications (for scientists) commercial behaviour (for business people and entrepreneurs) and “track record”. A handful of respondents recognise “something of themselves” in others that tells them particular attributes are present. The stereotypical view of entrepreneurs as being mavericks or unconventional in their behaviour does not find much support.

The way in which signals are detected is mainly through close observation, although organisations tend to use more systematic measures. Networking and competitions are not frequently mentioned. In terms of *responses* to particular types of behaviour, awards and prizes are the most common, followed by general acknowledgement and funding (many of the respondents in this research have received public funding for their scientifically entrepreneurial activities). Management support is also mentioned (though by only one primary respondent, a level of response inconsistent with findings from “life stories” and “context” about the importance of managerial intervention) as are other responses that might be expected – qualifications, increased wealth from commercial activity, invitations to events, greater responsibility in the workplace and so on. Only one comment refers to a share of IP as a response.

Five primary respondents comment on “negativity” as a response and this seems consistent with the notion of the “tall poppy syndrome” and is one of the obstacles that some entrepreneurs are required to overcome:

There are a few working in an entrepreneurial and export kind of oriented sense that actually have enormous potential to add value to this country. And you bump into them. Usually you can tell them because they've got old clothes and they drive a dumpy old car. And they're broke. But they're putting their heart and soul into it. And some of them make it. And those are the people that I think this country has to figure out how to support a whole lot better....if you were kind of a benevolent dictator and you took over New Zealand tomorrow morning and controlled all sorts of things that no one person could, but if you could, what would you do? I think I would somehow begin with an attitudinal thing and actually try and create mechanisms by which society recognised those people.

(Respondent 40f)

Other identified gaps are in the availability of incentives for scientifically entrepreneurial behaviour and organisational structures that are enabling of such behaviour.

I think the real challenge inside institutions in recognising such people is to value them, to understand that they just might think a little differently about things. They're not just out to rig and rot the system. (Respondent 9)

The second one would be incentivisation of the staff. This myth out there that if you're a public employee then you're supposed to work for peanuts and you're not supposed to be a millionaire otherwise you're ripping the taxpayer off. So there isn't a lot of incentivisation. (Respondent 29)

I don't think you can ever get the promotion system at a University to actually incentivise commercialisation but you should be able to tweak it to remove the disincentive. (Respondent 36)

I think the first gap starts with attitude towards them. If somebody wants to leave with an idea let them leave. Give them a licence to that idea even if he's worked for me and it doesn't fit with my - to set that person free. People are too much worried about the loss rather than worried about the gain. (Respondent 38)

These specific findings on recognition are further reflected on in section 6.3. Also following in chapter six is a synthesis of all the preceding chapters and conclusions on their implications for public policy, management and the methodology used in this research.

CHAPTER SIX: CONCLUSIONS

6.1 Introduction

In chapter one, the following underlying questions are posed:

- What is scientific entrepreneurship?
- What are the key attributes of scientific entrepreneurs?
- What indicates the presence of those attributes?
- What means are used to detect the existence or non-existence of those attributes within the broader innovation system?
- What are the systemic responses to the presence or absence of scientific entrepreneurship?

These questions are subsumed within the overall research question: *how is scientific entrepreneurship recognised in New Zealand?*

The research is located within the New Zealand context because of its strategic importance and the interests and experience of the researcher, and because of the need to take into account the unique effects of a single national innovation system. Because contextual influences are so important, the specific research findings are not necessarily transferable to other national systems. However some key principles

and concepts are generalisable, for example relating to the identification of scientific entrepreneurship as a phenomenon, the use of a competency model and the methodological framework used for research.

Chapter two locates the research academically within the current literature and provides the basis for a framework and tools to further address the questions raised. The analysis of and findings from two sets of data are contained in chapters three and five respectively. The documentary analysis in chapter three supports some of the key assumptions upon which the research is based while the findings in chapter five show there is a high degree of consistency between the themes of the literature review and the analysis of respondent interviews.

This concluding chapter brings together common threads from the foregoing in answering the questions listed above. Discussion on the five subsidiary questions has been reduced here into two main sections, reflecting their correspondence with the main parts of the overall research framework shown in figure 4.3. Specifically, discussion on the first two bullet-pointed questions above, relating to the extended competency-based model, is combined in section 6.2 and the final three bullet points, which are effectively an “unpacking” of the phases of recognition, are addressed in section 6.3.

Section 6.4 describes the implications for policy and management that arise from the research findings. Section 6.5 contains conclusions on the efficacy of the methodology used, and possible avenues for future research are proposed in section 6.6.

6.2 What is scientific entrepreneurship and what are the key attributes of scientific entrepreneurs?

6.2.1 Life histories

The life histories of primary respondents in this research are so varied that there seems little hope of recognising future entrepreneurial behaviour by studying early experiences, either contemporaneously or in retrospect. This finding is consistent with those that emerged from the review of literature on entrepreneurship (see section 2.7) but there may have been a flaw in the interview questions used. Rather than asking about early life experiences it would probably have been more fruitful to have asked about *interests* as described by Wylie (2006) and others in their competent learners project. Unfortunately this literature was discovered too late to be included in the interview process.

Many respondents support the proposition that there are significant generational differences with respect to attitudes towards entrepreneurship, with a tendency for younger scientists to be more amenable to ideas of commercialisation and personal involvement in that process. There is some support in the literature for the existence of this tendency given that it encompasses something of a paradigm shift (e.g. Kuhn, 1996) but in chapter five there are also cases reported of older scientific entrepreneurs. These, along with examples of scientists coming to entrepreneurship later and findings about the importance of attitudinal attributes and their amenability to change through training, suggest that it is possible to start building competencies at different points throughout careers rather than only from their beginnings. On the other hand over a lifetime there are greater returns from earlier investment.

There has been a considerable degree of job mobility and international experience among all respondents. While this may simply be a feature of modern careers of all types, international knowledge and connectedness do seem to be important. Contrary to what might be a stereotypical view of entrepreneurs as mavericks, on the whole and partly because of the characteristics of modern RS&T, successful scientific entrepreneurs are more likely to be good at working *with* systems rather than against them. As conjectured in the development of the horizontal dimension of the extended competency model and confirmed here, they are skilled at building and using social capital.

Although Roberts (1991) concludes that entrepreneurs are very likely to have had self-employed fathers (sic) it may simply be that early exposure to some form of commercial enterprise is what is influential. There is also a possibility that experiences of leadership enable the development of key attributes.

Apart from these features, some interesting issues emerge from a consideration of life histories to assist in building theory on scientific entrepreneurship and understanding of the process by which scientific entrepreneurs might be recognised.

The tension between breadth of knowledge and depth of knowledge remains, but it can be concluded that deep and broad knowledge are *both* necessary for scientific entrepreneurship and neither is sufficient on its own. The learning of deep knowledge for example in a University setting can be complemented with the breadth that comes from various kinds of non-formal learning. Schooling apparently made little impression or difference on the propensity of respondents in this research for scientific entrepreneurship.

In terms of interventions by other people, respondents scarcely mention teachers, other role models or financiers. Parents are clearly important, but in different ways and sometimes not at all. It would seem that managers in the workplace are most often important. This is consistent with the contextual and applied nature of the competencies under discussion.

Overall, life history has played a part in some respondents' propensity to engage in scientific entrepreneurship but its effect seems somewhat random. Thus it is not sensible to attempt to *shape* life experiences to increase the probability of development of desired competencies. A better approach is to detect and respond to signals of underlying attributes as they emerge and are expressed as behaviour in particular contexts.

6.2.2 *Contextual factors*

Analysis of the interview transcripts reported in chapter five shows that current context *is* important for its effects on scientific entrepreneurship and confirms the need for context to be considered as part of a competency model. Context is made up of a number of aspects, many of which are unsurprising given the findings of the literature review, and indeed most are already included in the model. However, the strength of feeling about the public funding regime for research in the New Zealand system suggests that it might be separately incorporated. There is less comment on the availability of finance for commercialisation, perhaps reflecting either the predominantly public nature of the system or the adequacy of capital markets for the degree of commercialisation being undertaken. The impact of context on careers is also something that is not explicitly allowed for in the original model and it needs to be included, although a question arises as to whether careers should be included in the longitudinal or vertical dimension of the model. The answer is probably both.

On most aspects of context there are some dominant themes but seldom unanimous views. Rather, there tend to be majority views expressed on key points with minority, converse views in each case but little scattering of these into orthogonal dimensions, suggesting that key contextual impacts vary according along a continuum (evoking Strauss and Corbin's *dimensions* - see section 4.11.1). But the issue here is not so much whether one set of views or another is correct (the methodology is not designed for such a purpose). What is important is whether the model and the approach used are useful as tools for organising and focusing thinking on the research question (see section 6.5 for discussion on this point).

At the highest or outermost level of context, New Zealand's size and geographical isolation are seen as having both advantages (e.g. forced self-reliance) and disadvantages (distance from markets). National culture is clearly important, especially attitudes to risk and failure in comparison with other countries. There is strong consensus - in part based on experiences of other jurisdictions and not merely conventional wisdom⁷⁰ - that New Zealand is deficient in this regard. Indeed, the general tenor of comments on the current contextual state is far more negative than positive. In terms of how to make this more conducive to scientific entrepreneurship, there are comments which are the obverse of some of these negative aspects, particularly with respect to changing attitudes to risk and failure, creating a freer environment for the generation of ideas and funding those ideas, reducing risks in some cases and creating better incentives for entrepreneurship. Other comments also refer to a need to create a more collaborative model and to build research infrastructure.

⁷⁰ There are many commonly expressed but not necessarily proven anecdotes about what is right or wrong with New Zealand in comparison with other countries

There are few references to sub-national (regional or sectoral) factors but the value of proximity of researchers and business and clustering of capability is often mentioned in relation to other contextual elements.

Organisational context is key, particularly management style. Good management of innovative science revolves around allowing the expression of creativity in research and people needing to be given a certain licence to operate - consistent with the views of Ziman (1994) reported in section 2.3.7. A common refrain about negative management concerns constraints it places on creative thinking or risk-taking. A freer approach might be more appropriate for organisations attempting radical rather than incremental innovation. The Universities are seen as having particular strengths here, but managing entrepreneurial behaviour within them brings its own challenges. Other aspects of organisations that are seen as critical (usually explained in terms of their inadequacy) are size and critical mass. By definition, large corporate bodies and entrepreneurship seldom fit well together although organisational incentives can bring about changes in behaviour.

At the level below organisations, teams are critically important for entrepreneurial behaviour. Successful entrepreneurs are not archetypal “loners” but sometimes “stars” create teams to which others gravitate and there are similarities between business and science in this respect. In creating scientifically entrepreneurial teams the prevailing way to provide missing competencies is by substitution through organisational means such as technology transfer companies (i.e. assembling competencies or building capability) rather than by building individuals’ competencies through measures such as training. A broker model may also be employed (see section 2.8.2).

Apart from a few reported cases of direct scientist-to-business contact, the tendency is to keep scientists away from “downstream” commercialisation. There appears to be some stereotyping of scientists, despite the science workforce being quite diverse. For example, despite there being a commonly-held view that scientists and business don’t mix, there are a few instances reported where scientists have proactively taken IP out of a research institution and themselves driven the growth of the ensuing company - showing that such behaviour is possible.

More commonly a traditional technology transfer model is employed and it appears that though it is seldom explicitly mentioned, this model remains very powerful in shaping respondents’ perceptions of competencies – particularly among managers and policy personnel. However, the technology transfer model has many variations and is not always completely linear or necessarily incompatible with mobility of personnel.

Research ideas most often come about as a way of solving problems and they often also emerge strategically from platforms of core technologies capable of being taken in different directions. Platforms tend to be generated by “big” science – big teams, collaborations, budgets and (often) infrastructure. This leaves less room for individual discoveries although serendipity, intuition and insight still have their places - possibly in filling the gaps between steps in the larger, systematic process.

Opinions are divided as to whether there are clear distinctions between business, entrepreneurship, and science, although entrepreneurship is generally seen as a distinct subset of innovation by those who venture an opinion on this matter. While sharing the characteristics of business in general, entrepreneurship is regarded more specifically in terms of an individual seeing an opportunity and having a vision for doing something different in a commercial setting, taking risks and realising their

goal(s) through focus, perseverance and hard work. There might be multiple tracks towards achieving goals: either many attempts in sequence or multiple activities in parallel – a portfolio approach to managing risks.

Often, entrepreneurship involves the mobilisation of other people and their resources in pursuit of what the entrepreneur is trying to achieve. Indeed, a crucial difference between those who are scientific entrepreneurs and those who are not may be that the former can, if they have a vision, collect together the team they need (a proactive strategy) rather than having the team added to them through the agency of others (a relatively passive or reactive strategy to team building on the part of the central individual).

It might be concluded from this that by definition conventional technology transfer militates against scientific entrepreneurship occurring. That is, entrepreneurship involves an individual personally leading the process of an idea step by step through to application, as opposed to the passing of an idea from one individual to others as it is taken through subsequent steps. But entrepreneurs do not always make successful transitions to managing mature businesses.

Half a dozen mostly primary respondents comment on the similarities between science and business or entrepreneurship, in particular within the processes used in each realm. For example all pass through stages of evolution or development. Several perceive a sharp boundary between science and business but almost as many do not and there are parallels that can be drawn between the processes of entrepreneurship and serendipity and paradigm change in science. Entrepreneurship and science also have in common properties of unpredictability, emergence and path dependence. There would appear to be potentially four different mental models of the relationship of the two realms as in figure 6.1:

Figure 6.1 Models of contextual differences, similarities and boundaries between science and business

6.2.3 Attributes of scientific entrepreneurs

It needs to be stressed that the attributes identified through this research are those most prominent in respondents' minds at the time they were interviewed – this does not preclude the existence of other less prominent ones that may also be shared. For example scientists are seen as being methodical by some respondents. That entrepreneurs are not identified as having the same attribute does not mean that no entrepreneur is ever methodical.

Some attributes are innate and essential for scientific entrepreneurship but not sufficient on their own. They may or may not be influencible through nurture but it less likely they will be expressed if the context is not conducive. Nurture may also add other attributes throughout a lifecycle but the expression of these will be similarly affected by context and there is a large school of thought that it is impossible to turn scientists into entrepreneurs. There is also considerable scepticism about formal business courses as a means of training people to be entrepreneurs. Where it can be done, mentoring is seen as the most effective method, followed by learning by doing and exposure to what other entrepreneurs are doing.

In chapter five the major differences between scientists and entrepreneurs are seen to be in their respective readiness for market; the narrow technical focus of scientists versus the breadth of knowledge of entrepreneurs; modes of communicating; differences in knowledge bases and disciplines; approaches to risk; and motivations.

Interestingly, some of the most prominent, distinguishing attributes of scientific entrepreneurs are (independently) seen as resolving these very areas of difference. This suggests that the competencies of scientific entrepreneurs are made up from components somehow added together rather than attributes simply transferred from one realm into the other. These higher order attributes enable individuals to operate in the overlapping zone of scientific entrepreneurship shown in the Venn diagram in figure 2.6 and contribute to what are shown in figure 6.3 as *metacompetencies*.

Some of these individuals do not recognise themselves as having any special characteristics and consider they apply the same attributes no matter what context they are in. In this sense personal attributes dominate contextual influences such as the definition of self that comes from professional frameworks:

Friends went to vet school and thought “that’s what they had to be”. I didn’t go so I could be anything I wanted to be. (Respondent 4f)

Scientific entrepreneurs are identified as being able to combine scientific *depth* and entrepreneurial *breadth* of knowledge. It is not clear whether the development of these two sets of knowledge happens sequentially or in parallel but most respondents think it is science first, or at least science contemporaneously with business. Whatever the case the combination, along with the skills required to communicate *between* and *within* both the scientific and business realms are core attributes of scientific entrepreneurs and may be what further distinguishes them from a broker - often with limited knowledge of science - who acts as only an interpreter *between* science and business.

The breadth and depth distinction is repeated in the different types of motivations for scientists and entrepreneurs and the recognition they each seek and these different forms of recognition feed back into the two distinct sets of motivating factors.

Some motivations do not help discriminate between scientific entrepreneurship and other types, for example the desire for autonomy or independence, to prove nay sayers wrong or challenge discrimination or avoid failure, might be found in all other fields of endeavour.

While some entrepreneurs are motivated by making money, scientific entrepreneurs seem to be motivated more by “the project”. Money is probably a secondary motivator, as it is for scientists. Both groups see money as a means to an end, but there be a subtle difference in that scientific entrepreneurs also see gaining it as a by product or measure of success.

Scientific entrepreneurs once again seem to achieve synthesis of the two sets of motivation, beginning with an awareness of potential public good, linking to scientific knowledge, animating a desire for application and involving insight as to what the application might be. This is the *consideration of use* identified by Stokes (1997). Once these connections are made, the natural problem-solving proclivities of the scientist or entrepreneur come to the fore. Commercialisation could be regarded as one set of problem-solving processes, in which a scientist is able to engage if he or she is satisfied they have enough scientific knowledge and is not negatively inclined towards the idea of commercialisation. Missing knowledge can be gathered as required and as part of the problem solving process. Notwithstanding criticisms of the linear model of RS&T, it is likely that engineers and scientists working on “applied” science are more amenable to participating in scientific entrepreneurship, although others might be *tipped over* into such activities.

There are different approaches to planning but in general, the one that is adopted seems less crucial than the extremely proactive learning style described by several respondents, involving finding out where leading edge expertise relevant to their interest resides, and going to the source of that expertise. This could also be characterised as a type of problem solving behaviour and once again it is not possible to say to what extent these are peculiar attributes of scientific entrepreneurs. But the most obvious scientific entrepreneurs are not satisfied with being part of a jigsaw wherein every member of a team has only part of the overall knowledge required. They want to know the whole picture themselves, although this does not mean they know everything in the way of a renaissance scholar - an archetype that no longer exists (Carden & Murray, 2007: 230; 245-6). Rather, scientific entrepreneurs know what they need to know and build teams to fill gaps in their knowledge. They also tend to regard ideas as tools and knowledge as something to

be created rather than discovered, consistent with the views described in section 2.2.1.

There is some indication that the creative generation of ideas might be assisted through having insight into different domains of knowledge (disciplines) and two respondents described a deliberate strategy of “*disfocus*”, seemingly to allow this creative process to happen, as opposed to focusing on a problem using one consistent approach. This approach evokes the notions of *divergent thinking* (Carden & Murray, 2007: 223); *anomalous insight*⁷¹; *seeing this situation as that one* (Schön, 1983: 13) and “stepping outside of oneself” (see section 5.2.1). Herein lies a crucial process or set of processes. In an entrepreneurial setting, it may be that what is important is not so much breadth or depth of knowledge but rather the successful identification or creation of *opportunities* and taking advantage of them, as shown in figure 6.2.

6.2.4 Themes

Propensity for taking financial risk is the most important discriminator between entrepreneurs and non-entrepreneurs, but risk is also seen to be part of the environment within which entrepreneurship happens or doesn’t happen (McCarthy, 2000: 5). While there is some debate about the extent to which financial risk needs to be *personal* in order to qualify, there is a fair degree of consensus that it is not possible to be an entrepreneur within a company where it is the employer’s money that is risked. Thus it is difficult, even a contradiction, to engender entrepreneurialism within large organisations and outward movement is a necessary step in the entrepreneurship process.

⁷¹ Roy Stager Jacques, presentation on 7 November 2007

Personal financial risk-taking behaviour in particular is an attribute of scientific entrepreneurs not of scientists, even though scientists might take other kinds of risks such as with their reputations.

For entrepreneurs the rewards of risk taking are often intrinsic to the commercial activity being undertaken, i.e. the reward is a successful enterprise. There is an inherent risk/reward trade-off but the prospect of failure is not a deterrent and risks tend to be managed rather than recklessly taken. These conclusions are consistent with McLelland's (1961) view of n-Ach (see section 2.7.3) and have some interesting implications. For example that entrepreneurs are not motivated by risk per se but neither are they deterred by it. In other words such entrepreneurs do not primarily seek to take risks for their own sake, and measures to encouraging risk taking behaviour as a way of engendering more entrepreneurship may be too simplistic.

There is an alternative model of exploration which *is* based on the unmanaged seeking of risk seeking where an *expeditionary* entrepreneur heads out into completely unknown territory with such a high level of self efficacy that they believe they can succeed through sheer tenacity or luck. This is unlikely to be effective in the case of scientific entrepreneurship and it might be argued that people who are motivated solely by risk are dangerous to themselves and to others, whether in a business setting or any other.

It should be noted here that risk is not the same as *challenge* which is sought out by some respondents and probably relates more to a strong sense of self efficacy (see sections 2.7.3 and 5.5.1).

Opportunity is the second most commonly coded theme after risk and a lot of other comments can be related to it, particularly if a wider view is taken. Early in the

interview process there emerged a concept of *whole of picture insight* wherein entrepreneurial respondents seemed to be reporting an ability to see all aspects of an opportunity at once, from the scientific idea to its application. This insight might come in an instant - or form over time in the manner of filling in the holes in a Swiss cheese. As the interviews progressed, even though this whole of picture concept was prompted for, it did not gain strong enough support to be advanced as a common characteristic of the scientifically entrepreneurial process. But it still has explanatory power for some respondents' experiences, and its potential as a framework for theory and normative practice are worth exploring further.

Opportunities are more than visions or ideas since they also include pathways and for them to be brought to fruition requires a desire for application and actual problem-solving on the part of the entrepreneur. Rather than being separate from the entrepreneur, opportunity is at the interface between the individual and their context and, as with ideas, may either be *discovered* or *created* by the person concerned (Young, 2005). Some forms of opportunity recognition arise from the perception of anomaly and may share characteristics of serendipity in scientific research (see section 2.3.2) and of retroductive process (see section 4.6.3).

The following diagram draws heavily on the discussion of themes in section 5.5 and captures the key elements of what is required to create and realise opportunities through scientific entrepreneurship.

Figure 6.2 Conceptual model of “opportunity” in scientific entrepreneurship

The *connections* theme shows that networks of users, scientists and others are of great importance in scientific entrepreneurship. This is consistent with the literature on both scientists and entrepreneurs and the ability to communicate is likely to be a shared attribute. However, differences in *modes* of communicating provide an important distinction between scientists and business people/entrepreneurs and the ability to communicate in both modes appears to be a key attribute of scientific entrepreneurs.

6.2.5 *Metacompetencies*

There is a high level of consistency between the key themes of the literature review and the findings of the field research, but the latter make some things clearer. The competencies of the four groups under investigation (business people, entrepreneurs, scientists and scientific entrepreneurs) emerge as being different from one another, but the component sets of attributes are not mutually exclusive. Some attributes *are* unique to one particular group, but others are similar or shared. For example, there may be core attributes such as general cognitive ability (Kuncel, Hezlett, & Ones, 2004) and lateral thinking is seen by some respondents as an attribute of both scientists and entrepreneurs. Oates (2001) argues for adaptability as a root competence (see section 2.5.1) suggesting perhaps that the ability to have deep knowledge and also work broadly may be a skill or a strategy rather than being attributable only to having a complementary, broad knowledge base.

One way to characterise scientific entrepreneurs would be as entrepreneurs who happen to operate between science and business rather than in some other realm – i.e. it's their entrepreneurial attributes that are key and so entrepreneurs should be directed towards science to act in brokering ways.

However, without having a whole of picture insight based in deep knowledge it's difficult for an entrepreneur to understand what is scientifically possible and to fully exploit related opportunities. And since some of the attributes of scientists and entrepreneurs are effectively opposites, scientific entrepreneurs must have an ability to reconcile contradictions in attributes such as motivation, propensity to perfectionism and attitudes to financial risk.

They also have other higher order attributes which allow them to relate to opportunities as shown in figure 6.2, to communicate within and between the realms of science and business and to lead others towards the realisation of an entrepreneurial vision. These attributes, along with those that are shared by scientists and entrepreneurs, are the underpinnings of metacompetencies.

The term metacompetency is not a new one, but it has been used in different senses, for example to describe the management of tension between innovation and continuity (Rychen & Salganik, 2000)⁷² or in the sense of knowledge about the availability and use of one's own competencies to optimise learning and solve problems. In this view, metacompetencies operate at a different level than either separate or shared competencies.

Drawing on the model proposed by Sadler-Smith et al. (2003; see figure 2.4) the relationship of separate, shared and higher order attributes is shown in figure 6.3 below. This representation is at the level of individual attributes only. It does not include possible contextual relationships shown separately in figure 6.1, and it will be recalled that both context and attributes are required to activate metacompetencies.

⁷² Citing Haste, H. (1999) Competencies, Psychological Realities: A Psychological Perspective. *DeSeCo Expert Report*. Neuchâtel, Swiss Federal Statistical Office

Figure 6.3 Attributes of metacompetencies of scientific entrepreneurship

<u>Attributes of scientific entrepreneurs</u> Ability to reconcile differences in respective competencies High level communication skills within and between realms High level leadership and teambuilding abilities High level ability to realise opportunities for commercialising RS&T	
<u>Attributes for scientific realm</u> Motivated by knowledge for its own sake Deep knowledge Aversion to financial risk Incremental decision maker Tending to perfectionism Ability to realise scientific opportunities	<u>Attributes for entrepreneurship realm</u> Motivated by desire for application Broad knowledge Open to financial risk “Heuristic” decision maker Satisfied with ‘good enough’ Ability to realise commercial opportunities
<u>Shared attributes</u> Creative, lateral thinking Vision Seek out and create knowledge See ideas as tools Focus Problem solving Managed risk taking Connectedness (building and using related social capital) Perseverance High levels of self efficacy	

6.3 How are scientific entrepreneurs recognised in New Zealand?

6.3.1 Mental models

It is clear from the findings reported in chapter five and in section 6.2 that there is a high level of shared knowledge of what an entrepreneur is and does. But the concept of a scientific entrepreneur is not widely known. This may be because of the prevalence of deeply-held beliefs (from both directions) about the incompatibility of the two realms of science and entrepreneurship and the New Zealand science

system is based on models of technology transfer and public management which are still fundamentally linear. These factors need naturally to a bifurcation between the competencies of science and of entrepreneurship. The mobility of knowledge is still predominantly seen in codified terms. All these factors create a context – to some degree having the features of a mental model (Johnson-Laird, 1983) or even a paradigm (Kuhn, 1996: 11) neither of which easily allows for the recognition of scientifically entrepreneurial metacompetencies. There are indications that these blocking mental models are particularly prevalent among policy practitioners.

However, true scientific entrepreneurship is possible and does occur. It would also seem that it is a relatively rare phenomenon and the paucity of scientific entrepreneurs is likely to be due, at least in part, to the exigencies described in this chapter and more comprehensively in chapters three and five. A question for public policy is whether scientific entrepreneurship is of sufficient value for measures to be taken to increase its incidence. This question is discussed further in section 6.4.

6.3.2 Detecting signals

As pointed out in section 2.3.2, expectations of what exists in the social world very much depend on the mental models that are prevalent. So it is unsurprising that, given the prevalence of expectation that scientists can't also be entrepreneurs there is little systemic attention given to detecting signals indicating the presence of scientific entrepreneurs.

There are low levels of acknowledgement of scientific entrepreneurs in the broader public domain, although a degree of consensus on a short list of star performers. It is presumably easier to collectively notice such stars once they have demonstrated

certain obvious behaviours – e.g. they have become commercially successful. But often, even obvious scientific entrepreneurs do not identify themselves as such.

Hitherto, most emphasis in RS&T policy and management has been placed on conventional measures of stocks and flows of human capital such as qualifications and patents. While these conventional measures are important, they are insufficient for detecting signs of the tacit knowledge and other attributes that are essential for scientific entrepreneurship.

The response in the RS&T system has been to try harder to find better ways of measuring rather than to question whether a positivist, empirical approach is sufficient to capture all aspects of the quality of human capital. The education sector on the other hand is moving towards the adoption of a more holistic, competency-based approach to the development of human capital but it has to be said that the problem of how to measure competencies remains intractable. Their behavioural aspects are observable and relatively easy to quantify, but competencies are made up of many more connecting layers of attributes which, if they are to be fostered, need to be recognised as they are expressed holistically *in situ* rather than measured narrowly and retrospectively.

Detection of tacit attributes is a highly personal (possibly also tacit) process. Visible behaviours and their underlying attributes are inferred through close observation in the context where performance happens, i.e. managers and peers working closely together. In some cases, managers are able to detect these attributes after they identify something of themselves in a younger colleague.

6.3.3 Responses

Where there is a response to an individual, it is often through mentoring or an individual manager's decision to provide institutional support at a critical time. There is also a surfeit of funding, rewards and awards accruing to those who have demonstrated the behaviours of scientific entrepreneurship. The TBG scheme appears to have been quite effective in responding to and supporting such behaviour (see section 3.4.2) and as described in section 3.4.6 there are a number of targeted, non-governmental award schemes. These all tend to be retrospective measures, and their efficacy in recognising and fostering emergent attributes is uncertain. There is a deficiency in responding to signals arising from potential scientific entrepreneurs whose behaviour is not yet visible.

Put another way, scientific entrepreneurship seems to be reasonably well recognised once it has happened, but emerging scientific entrepreneurs are not. A key proposition of this research is that more appropriate mental models enable better recognition in all its phases and in the case of scientific entrepreneurship, acceptance of the metacompetency model *will in itself* result in more detection of the signals of the presence of the underlying attributes, and subsequently more response. Although it may not directly *create* more scientific entrepreneurship, improved recognition will also help underpin processes to foster development of the desired attributes, context and behaviour.

6.4 Implications for innovation policy and management

6.4.1 Rationale

As described at the beginning of the literature review in chapter two, there is a thread of connected outcomes and processes running through the rationale for this research, beginning with wealth creation that is underpinned by increased productivity. A way of achieving higher productivity is to innovate, and RS&T and entrepreneurship are two means (among others) of contributing to innovation. There are many kinds of entrepreneurship and the research has focused on a very specific and currently rare kind by using a competency framework which allows for the recognition of all of the attributes that make up high quality human capital. These attributes include those that are tacit and not easily amenable to conventional measurement. It is the formation and - up to a point - circulation of quality human capital that provides competitive advantage at the level of both organisational and national systems of innovation.

Despite this logic and the weight of opinion in the international literature, a sceptic might say that since most innovation in New Zealand is incremental and in any case not usually derived from RS&T (Knuckey et al., 2002) policies aimed at fostering the linkages between innovation and RS&T need not be accorded high priority. Furthermore, there is more economic gain to be had from the incremental growth of large, existing sectors than from breakthrough sectors arising from entrepreneurship (Ballingnall & Briggs, 2002b; Institution of Professional Engineers, 2004; Workplace Productivity Working Group, 2004). These are fair points but there are arguments traversed in sections 2.2 and 3.2 about the importance of diversity in the economy.

RS&T can create new knowledge to underpin development of high value, *low weight* products and services rather than bulky commodities which are expensive to transport, and either add to productivity in existing sectors or contribute to spin-offs from existing platforms. Entrepreneurs provide the necessary human capital for commercialising mushroom technologies (Healy & Côte, 2001). If avenues for alternatives are not fostered there is a risk of business practice becoming stuck in the status quo (Lundvall, 1998; Schumpeter, 1987; Smith, 2006). Given their separate importance, the creation of a nexus between RS&T and entrepreneurship is worth exploring.

Current New Zealand government policy does acknowledge RS&T and entrepreneurship as key, separate contributors to innovation although policies on entrepreneurship are still in their early stages of development. There is little intellectual acceptance of the concept of scientific entrepreneurship or systemic allowance for it to be expressed. The kind of entrepreneurship which is the focus of this research does not flourish within the current innovation system.

This represents a problem, given the need for radical and discovery based entrepreneurship (McGrath & MacMillan, 1995) aimed at creating new economic activity where there is little or no existing absorptive capacity for new technologies. In this light, the nature of new sciences such as biotechnology adds more weight to the argument that there is much to be gained from understanding and promoting the development of scientific entrepreneurship.

While it is not possible to plan extraordinary (Schumpeterian) entrepreneurship, it may be possible to create conditions within which it is more likely to emerge - an intelligent systems approach (Hämäläinen & Saarinen, 2004). There may be low

levels of scientific entrepreneurship in New Zealand, but it should be possible to blow on the embers that exist.

The conclusions reached in this chapter are not intended to excoriate the current New Zealand RS&T system. Current policies have been assessed only to the extent of determining their comprehensiveness with regard to human capital and their degree of fit with the theoretical concepts of scientific entrepreneurship, not in terms of their actual contribution to innovation of the current system.

Neither is it contended that different models or processes will necessarily be superior to those employed in existing systems of research and management, nor that they can lead to the complete replacement of current practice. To do so would be to fail to take into account the nature of modern science or the value of current structures in delivering RS&T-based innovation to existing industries.

Nevertheless the findings of this research do present major challenges to the prevailing structures, incentives and processes to be found in policy and New Zealand research organisations. At most, they suggest the beginnings of a paradigm shift. As a minimum, there is a need to trial new policies and schemes aimed at fostering scientific entrepreneurship *in parallel* with existing approaches. If the findings of this research are accepted, they will have a number of implications for policy and management.

First, it will be necessary to allow for the *possibility* of scientific entrepreneurship. This means rejecting artificial distinctions between science and commerce, and basic and applied research as discussed in sections 2.3 and 2.8, and the adoption of new mental models, such as the metacompetency model proposed here, which expand the overlaps between science and entrepreneurship.

Such changes in perception may be resisted, for reasons described by Snow (1963) and Schön (1983) in section 2.3, although not as much as was once the case (Slaughter & Leslie, 1997: 18). It is possible that current policy anticipates problems that do not exist and is consequently lagging reality on this point.

Before resistance can be overcome values such as the pursuit of knowledge for its own sake and for earliest publication will need to be reconciled with the values of commercialisation. This can be achieved if scientists are imbued with notions of consideration of use (Stokes, 1997) and have the desire, competencies and opportunities to move with their ideas as they progress to application and ultimately the creation of public benefit (Etzkowitz, 1998: 66). A focus on these underlying competencies is likely to bear more fruit than topic-based workforce planning which operates at the wrong level for addressing what is effectively an ontological challenge.

The expanded framework that has been used and refined in this research provides the basis for a switch in thinking. The layered competency model identifies the key contextual factors and personal attributes that make up scientific entrepreneurship, and the disaggregated phases of recognition show a need for a wider conception of the recognition process (within which measurement plays a part) and gives some guidance as to where useful interventions might be made.

It is acknowledged that these are still theoretical constructs and there remain a number of practical challenges to be met if they are to be useful to policy makers or operational managers. However, sections 6.4.2 and 6.4.3 are couched in terms of the implications of the findings of this research being accepted in their totality.

6.4.2 Policy challenges

Some scientific entrepreneurs are well recognised once they have succeeded and in general, these are people for whom no additional policy intervention would make any difference to their propensity for entrepreneurship - although it might be possible to influence the timing of their success. Conversely there are those engaged in valuable scientific research who do not have any of the innate attributes of entrepreneurs, and in whom it would be counterproductive to try to engender scientifically entrepreneurial behaviour.

The group that is of interest is made up of those who have the necessary innate attributes but not others such as key knowledge, skills and attitudes that are able to be influenced through the creation of the right context and various other developmental measures. If these individuals can be better recognised as their competencies of scientific entrepreneurship *emerge*, it will be possible to design policies aimed at *tipping them over* into scientific entrepreneurship and increasing its overall incidence within the national innovation system.

Hitherto, there have been considerable efforts made in creating an appropriate context for the commercialising of RS&T, not only through the structural reforms of the 1990s (see chapter three) but more widely, for example in attempting to engender culture change and in making linkages within the system. This activity is presumably intended to generate desired behaviour and to be applauded, but it is insufficient in and of itself. All levels are important in a competency model and it is at least as important to work from the bottom upwards. Yet as chapter three shows, innovation policies directed at the attributes layers are inconsistent and in their infancy. A competency approach can assist in simultaneously nurturing desired attributes and creating the appropriate context for them to find expression. The

approach taken in the New Zealand science reform has been instead to first create institutional frameworks and then give attention to how human capital will fit within them.

A holistic concept of competence building systems (Tomlinson, 2001a: 33) is required, implying a broadening of the conception of the National Innovation System to include agencies dealing with schooling and tertiary education. The competency-based approach is consistent with international trends in education and general management, but before it can be accepted in RS&T and innovation policy more broadly, there will first need to be deeper and more consistent consideration given to the nature of human capital. This includes acceptance of the view that merely measuring conventional indicators of human capital is insufficient for recognising its quality (section 2.4.7). While such measurement remains important, it is a particular feature of centralised systems and needs instead to be embedded in a broader view of the process by which quality is recognised.

Chapter three shows a current lack of alignment between various policies for human capital development even though their aims are not dissimilar and there is convergence. A common language of competencies will help facilitate a faster move towards integration, and provide the basis for broader, innovative approaches to the creation of quality in human capital. Current approaches to developing deep scientific knowledge are probably appropriate as they are, but traditional, content-based training is unlikely to bring about the attitudinal change and breadth of knowledge that are most likely to underpin the tipping over process described above. New models (already being employed in some places) connect learners with the contexts within which they simultaneously create and apply new knowledge. Experiential, cross-disciplinary learning and a developmental approach (Ellstrom, 1997) and apprentice-style (relational) approaches to competency formation are

likely to be more effective (see section 2.5.1). Specifically, attention needs to be brought to bear on recognising the key attributes underlying metacompetencies as shown in figure 6.3.

However, the characterisation and assessment of competencies is still problematic because most of their underlying attributes are tacit and invisible to conventional methods of measurement. The solution is to devolve responsibility for recognising these attributes to research organisations, while retaining centralised measurement of aggregate outputs and outcomes.

At the same time as the broadening of the national innovation system happens, and in contrast to past experience, there needs to be a clear delineation made with respect to responsibilities in each subsystem. Different approaches will need to be employed for emerging, new generation scientific entrepreneurs and those that are already graduated and working in RS&T commercialisation. Each generation has potential and should receive attention, but the human capital theory suggests that the greatest returns will be gained from investing in the younger generation.

Policy makers are responsible for conveying objectives to crown-owned or funded research organisations, and for CRIs in particular these objectives need to be clear in terms of what is expected in terms of human capital development. Ideally, CRIs should be given a more explicit brief to collaborate *or even merge* with Universities in this regard so as to break down the artificial boundary that currently exists between the relative anarchy of the Universities and the sector focus of the CRIs.

Along with the brief for developing desired human capital, increased responsibility will need to be devolved to managers. This does not need to sacrifice research relevancy on the altar of provider capture. It should still be possible to signal broad

directions for government and industry expenditure and to develop alternative approaches to accountability such as performance audits and the market valuation of new ventures.

CRIs' performance measures will need to be changed accordingly, for example to incentivise the spinning out of technologies – the method most suited to facilitating scientific entrepreneurship from this source. It is true that the associated loss of human capital will pose a risk to the viability of CRIs, as mobility may have negative effects (Graversen, 2001; 123) and spinouts can result in public investments leading to private gains. However, in such cases there will still most likely be spill-over benefits to be gained in the economy from the creation of successful new RS&T-based enterprises, and the risks of increased mobility will need to be transferred away from individual research organisations to the innovation system as a whole.

University graduates are the most mobile form of human capital (Graversen & Friis-Jensen, 2001: 47) but it is unrealistic to expect postgraduates to spin directly out of their studies into their own science-based enterprises. There exists a major career gap for scientific entrepreneurs in the New Zealand economy. It has been shown in the USA (Roberts, 1991) that such people become successful in their mid-to late-thirties after a period in industry building deep and broad knowledge and identifying opportunities before launching into their own businesses. The findings of this research suggest that the same applies in New Zealand but given the lack of domestic, RS&T-intensive industry there are few opportunities to get the needed experience in salaried jobs in New Zealand (though this may be changing). Incubators and CRIs provide potential substitutes but the latter are focused on serving their respective sectors and incentivised to retain human capital rather than to develop it to be mobile. The above-mentioned proposals for changing incentives and merging organisations could go some way towards filling the career gap.

Another alternative is for New Zealand graduates to be encouraged to find work in industry overseas and for them to return once they have sufficient experience. Several of the respondents in this research have followed this path. The policy challenge is to attract such returnees back to New Zealand, and it appears that this may not be insurmountable, despite some conditions being poorer here than overseas, where the advantages of working in New Zealand can be capitalised on and an appeal made to the inherent patriotism of expatriates.

6.4.3 Management challenges

New Public Management Theory has been very influential in the design of research organisations “from the outside in” rather than from the “inside out”, i.e. without beginning from a consideration of the kind of contexts that scientific entrepreneurs need in order to operate. The linear model of science and technology is still paramount and organisational structures, the treatment of knowledge and human capital and other management processes are predicated upon it. Most policy and practice aimed at the entrepreneurial connection of science and business relies on brokering between the two. The ability of scientists to engage directly with the marketplace is quite restricted and the negative consequences of such disconnection has been well described by Stokes (1997: 116; see section 2.3.3). The corollary is that scientists have to be immersed in the market as well as the laboratory.

The findings of this research indicate that recognition of scientific entrepreneurship is more likely to be effective if focused on real time behaviour and with reference to a sensitising mental model. It is multi-skilled mentors in commercial contexts who are in the best position to recognise and tip over emergent scientific entrepreneurs. The competency model provides a tool for the further training and development needed in

order to be able to manage tacit knowledge and other attributes, and to infer entrepreneurial behaviours and manage their development.

Where scientific entrepreneurs *are* recognised, they will need to be given opportunities to lead the commercialisation process, with the discretion to create the teams and other capabilities they need rather than those capabilities being assembled by others who do not have the required whole of picture insight. The corollary will be a reliance on managers' reflective judgement (Schön, 1983) and resources placed at their discretion yet no increase, and probably a diminution, of measurement-based reporting on how those resources are deployed.

Changed management practices will be possible only given the right organisational context (Bryson & Merritt, undated; Ziman, 1984; , 1994). Entrepreneurial decision making is heuristic (Barney, 2004; Forstater, 1999) and not particularly compatible with corporate processes. Indeed, it is more than likely that scientific entrepreneurship in its pure form is incompatible with the current missions and organisational requirements of large research organisations. This does not preclude increasing degrees of scientifically entrepreneurial behaviour within current structures or completely different corporate objectives as outlined above. The nature of high technology industry is also such that there is room for different size firms, depending on the strategy that is used.

Whichever degree of change occurs, given the diversity of the workforce, organisations will need a high level of corporate management skill to create an environment that will incentivise and allow for both entrepreneurial and non entrepreneurial behaviour, and to allocate appropriate levels of risk and reward. There will also need to be managed changes in the sociology of science (Ziman, 1984; , 1994) so that commerce is seen as not inherently bad, and scientists affirm

rather than create negative peer pressure on their fellows who engage in it (Walton, 2003: 157)⁷³.

For some scientific entrepreneurs there is great value to be gained from networking together (they are good at recognising each other). Modelling their behaviour on that of successful exemplars can assist scientific entrepreneurs recognise their *own* competencies, thereby enabling them to follow the same path.

Wherever possible then, scientists need to engage directly with the market and mobility within networks and careers and risk taking and spinouts need to be encouraged. These measures will help create a more conducive context for scientific entrepreneurship and new young firms and for potentially attracting more venture capital investment from international as well as domestic sources.

6.5 Conclusions on methodology

One of the most gratifying aspects of this research is the coherence of the methodology and its fit with the topic, the research framework and the research question as explained in chapter four, and actual research practice. Critical realism reconciles different ontological and epistemological approaches and provides a foundation for a strategy and a research framework that is neither too tight nor too loose in the development of grounded theory (Glaser & Strauss 1967: 3, Miles & Huberman 1994: 16). It allows for purposeful, disciplined and integrative interdisciplinary research (Mansilla, 2006: 19).

⁷³ Citing Arndt et al. (1997). Subliminal exposure to death-related stimuli increases defense of the cultural worldview. *Psychological Science*. 8, 379-85

In the final analysis, there are just a few attributes which are key for scientific entrepreneurs - albeit these attributes are in themselves complex. In this respect there has been achieved the ideals of (1) *parsimony* of variables and formulation and (2) *scope* in the applicability of the theory to a wide range of situations, while keeping a close correspondence of theory and data (Glaser & Strauss, 1967: 111; emphases in original).

There is still an element of circularity and self-fulfilment of the definition used to gather a sample of respondents but the research is reflexive and the use of iterative, parallel processes avoids early closure on findings and allows holistic understanding to emerge. The literature review draws on an existing body of knowledge and analysis of organisational reports and policy documents is particularly important for testing the rationale for the research and some of its beginning assumptions. The groundedness of the research is also demonstrated in a number of ways:

- The original definition of scientific entrepreneurs being modified in light of preliminary findings;
- Since respondents seldom recognise themselves as scientific entrepreneurs they are unlikely to bias their responses to open-ended questions about attributes;
- Despite the interview instrument being semi-structured, coding is drawn from unpatterned transcripts;
- The relative objectivity of the researcher is demonstrated by the emergence of some factors not included in the initial model (e.g. careers) and a number

of “surprises” (e.g. patriotism as a motivation) and early assumptions – possibly prejudices - that are not supported by the collective experience of respondents (e.g. the random impact of life experiences, the real nature of the problem with the prevailing technology transfer model);

- A feature of critical realism is that the “nature of things” emerges out of the things themselves (Fleetwood & Ackroyd, 2004: 10; Outhwaite, 1987: 37-8) and the experience here is that the narrative structure emerges out of the coding that is grounded in transcripts derived from respondents. Thus it is possible to trace an “audit trail” that is independent of the researcher; and
- The multi-dimensional, matrix nature of the expanded competency model provides a degree of validation of findings.

Other risks do not come to pass. There are few problems in gaining a sufficiently sized sample for instance. In practical terms, the competency/recognition framework is robust and very effective in helping to organise masses of literature from different fields and to focus the research. The use of the NVivo software tool helps to distil multiple themes from a huge volume of transcribed text and to then aggregate them into a set of core attributes with broad implications for policy.

There is also throughout a line of enquiry as to whether the methodology is efficacious for producing results that can reliably inform policy development. The proof of this particular pudding is in the eating (see the discussion of trustworthiness of findings in section 4.10.3) but the research framework and its component model is now tested, illuminated and confirmed as being useful for increasing understanding of the complex phenomenon of scientific entrepreneurship. That understanding is related to existing knowledge and practice and theory has been developed. “Reality

checks” with policy and industry groups are positive and the overall methodology bears repeating for other policy questions having similar characteristics.

There are some weaknesses however. For example if the research were to be repeated there might be more specific questions on early *interests* and experiences of leadership and not all of the three basic steps involved in a critical realist approach, as outlined in section 4.5, have been fully addressed:

- The postulation of a possible mechanism;
- The collection of evidence for or against its existence; and
- The elimination of possible alternatives.

(Outhwaite 1987: 57).

The first two of these have been satisfied, but while the phenomenon of scientific entrepreneurship has been proposed as one means for delivering commercialisation of RS&T, and evidence has been gathered from respondents to show that the phenomenon exists, the actual link between scientific entrepreneurship and commercialisation outcomes is taken on trust rather than being explored in and of itself. This could be the trap identified by (D. T. Smart & Conant, 1994; see section 2.7.2) but Smart and Conant’s own work has established links between entrepreneurship and commercial outcomes and some of the respondents were popularly identified as scientific entrepreneurs as a result of the outcomes they had achieved.

Other possible explanations for such outcomes have not been eliminated, but given the breadth and complexity of the topic this was never the intention of the research. Instead, the research has focused on a niche part of the system and produced an *alternative* concept of the commercialisation process, extending into proposals outlined in section 6.4 for further action to promote the incidence of scientific entrepreneurship.

An explicit point of difference in the methodology is the focus on *individuals* from the scientifically entrepreneurial milieu rather than to study their technologies or firms (much to the surprise of some respondents whose enterprise has been the subject of considerable prior study). The focus on individuals and their attributes, supplemented by other means to study context, is what allows the identification of a deeper mechanism in the form of metacompetencies of scientific entrepreneurship.

It is here that there is a curious conflation between methodology as a means of both research and solving the problem of how to increase scientific entrepreneurship. If it is argued that the solution depends largely on the adoption of a different mental model of the relationship between scientific and entrepreneurial competencies, so as to aid better recognition, then in its wider sense as defined in this research *the process of building better recognition of scientific entrepreneurship is itself one of retroduction*.

If so, the inappropriateness of positivist approaches to understanding scientific entrepreneurship is confirmed. It is not something that can be measured, nor can anything about it be *proven*:

Social research should place much more emphasis on conceptualisation and description than positivism assumes, and (that) the search for regularities through quantitative

analysis becomes relatively downgraded (though not redundant). Critical realism implies that we need to distinguish between generalisation, which is about finding out how extensive certain phenomena are, and may give little explanation of what produces them, and abstraction and retroduction, which are needed to explain what produces particular stages and changes, but which do not necessarily indicate much about their distribution, frequency or regularity. Both are needed in social science, but their differences imply a reconsideration of many common views of the respective roles of surveys and case studies, which see the former as explanatory and the latter merely exploratory or illustrative (Fleetwood & Ackroyd, 2004: 11)⁷⁴

Taking into account the qualifications outlined above, the methodology used in this research helps to build *understanding* of the social phenomenon that is scientific entrepreneurship. Whether the tension between depth and breadth of study is managed in this account is for the reader to judge. Suffice it to say that the intention throughout has been to maintain an overview of the whole landscape rather than being diverted into the crevasses of multiple sub-questions (e.g. what is the real nature of vision, passion or self efficacy?). This has the effect of creating even more new questions (see section 6.6) but perhaps they can be addressed in future within a more unified theoretical framework.

6.6 Implications for further research

There is still much to be done to fully develop the competency concept but the framework used in this project provides a map to guide broader and deeper research. There is more investigation to be done into the congruence of entrepreneurial processes with retroduction. Opportunity recognition in particular seems to have retroductive elements and this connection is acknowledged by members of the Austrian school of economics (Forstater, 1999; Steele, 2005). Given that opportunity

⁷⁴ Citing Sayer 1992: chapter 9, 200b; 19-26)

recognition is at the heart of scientific entrepreneurship, the connection would bear further research. Indeed, the other key attributes (high level leadership and communication skills) might be seen to be subsumed within the opportunity rubric shown in figure 6.2. It would be interesting to know the extent to which scientific researchers think deductively, inductively or retroductively. If the latter strategy were employed (or taught) would the shift to entrepreneurship potentially be easier?

There is also an opportunity-related question as to how broad knowledge is accessed, and whether there is a common or ideal sequence of obtaining deep and broad knowledge.

A question is posed in chapter one as to *whether there are inherently low levels of scientific entrepreneurship within the population, or the levels are potentially higher but expression of the phenomenon is inhibited by some systemic failure*. While it appears that there are low levels of scientific entrepreneurship in New Zealand and these are probably due at least in part to systemic constraints, the research has not set out to determine what those absolute levels are. But its findings provide an expanded model to guide further research – both in looking more deeply at critical attributes such as self efficacy and more broadly at contextual implications.

For example, while it would be inconsistent with the overall approach that has been espoused in this project to attempt to use the metacompetency model as a basis for directly measuring levels of scientific entrepreneurship, it should be possible to design a process for gathering feedback on trends in its recognition. This feedback could come particularly from managers, and test the effectiveness of new mental models in changing attitudes towards scientific entrepreneurship and increasing its incidence. More generally, if the changes outlined in section 6.4 were implemented, their effects on commercialisation of RS&T would need to be evaluated.

Finally, it would be interesting to continue to test and refine the efficacy of the methodology for answering public policy questions through its use and refinement in another suitable project.

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APPENDICES

Appendix One Sample typologies of competencies

1.1 *Dominique Simon Rychen, Laura Hersh Salganik: Definition and Selection of Key Competencies; a contribution of the OECD programme – Definition and selection of competencies: theoretical and conceptual foundations, INES General Assembly 2000*

http://www.statistik.admin.ch/stat_ch/ber15/deseco/background-paper.pdf

Three Generic Key Competencies

- Acting autonomously and reflectively
- Using tools interactively; and
- Joining and functioning in socially heterogeneous groups

Four Conceptual Elements of Key Competencies

- Key competencies are multifunctional
- Key competencies are transversal across social fields
- Key competencies refer to a higher order of mental complexity
- Key competencies are multidimensional
 - It is also useful in the conceptualisation of key competencies to consider them as being composed of multiple dimensions, representing mental processes. They are composed of “know how”, analytical, critical and communication skills as well as common sense. These five dimensions are:
 - Recognising and analysing patterns, establishing analogies between experienced situations and new ones (coping with complexity)
 - Perceiving situations, discriminating between relevant and irrelevant features (perceptive dimension)
 - Choosing appropriate means in order to reach given ends, appreciating various possibilities offered, making judgements and applying them (normative dimension)
 - Developing social orientation, trusting other people, listening and understanding others’ positions (co-operative dimension)
 - Making sense of what happens in life to oneself and others, seeing and describing the world and one’s real and desirable place in it (narrative dimension)

The three generic key competencies, together with the four conceptual elements, are proposed as a potentially productive avenue for exploring and studying concrete forms of key competencies as manifested in actions, behaviour, and choices of individuals and groups in different social fields (such as personal, social, economic, political and cultural life) at different stages in life, and in different cultural contexts.

1.2 *From Frances Kelly and Marion Norris, New Zealand expert paper*

http://www.statistik.admin.ch/stat_ch/ber15/deseeco/sfso_deseeco_ccp_newzealand_19122001.pdf

Section 3.9 Competencies specifically important for New Zealand

3.9.1 Economic

In terms of the future economy, the possibilities for New Zealand will call for people who do not have the well-rehearsed answers but can ask the important questions, and be willing and empowered to take risks – that is how to get breakthrough ideas, innovation, entrepreneurial vision and drive.

More specifically, New Zealand's economy is a small economy, resting essentially on biological foundations, enhanced by technological applications.

New Zealand must continue to be an early adopter of technologies, particularly when they have assisted in overcoming barriers of physical distance. Benefits of such adoption have shown to date in ways as diverse as frozen food export in the 19th century to current Internet technologies.

Biggest gains will come from turning the full power of knowledge, creativity and innovation to adding value and applying new technologies to those areas in which we have traditionally excelled. Examples have included:

- Producing food and textiles
- Developing niche products and markets that build on natural advantages
- Biological developments to enhance animal, plant and human health

To take advantage of this, and to overcome current barriers, people will need to be innovative, entrepreneurial, risk takers and problem solvers, and at a more disaggregated level, with competencies for:

- New venture and product development
- Integrated technologies (communications, information, electronics) and their applications in existing industry and business (including media) in developing fields such as advanced materials, intelligent devices, genetics and biotechnology, as well as in areas previously mentioned
- Marketing and selling, strategic marketing and branding (to control value and production chains and distribution channels)
- International languages
- Environmental management
- Leadership and general management

3.9.2 Social

At the level of community and social development, New Zealand's unique history and cultural mix calls for:

- Competencies based on self-knowledge, tolerance and respect, to enable New Zealanders to accommodate the diverse range of views, philosophies, traditions, backgrounds and cultures and through this build a socially cohesive nation

- Competencies, determined by Maori, related to Maori language, culture, values, protocols and practises
- Competencies, determined by Pacific peoples in New Zealand, related to Pacific languages, cultures, values, protocols and practices

New Zealand needs to continue to operate as a national entity, not seeking finality in any sense but journeying towards better understanding, common goals, and continuous improvement for the individual and collective lot.

Appendix Two Respondent characteristics (attributes and values in NVivo terms)

Attributes				Values			
Type of Respondent	Primary	Secondary	Tertiary				
Gender	Female	Male					
Employment	CRI	University	Own Company	Others' Company	Joint Venture	Government Policy or Operational	
Field of Science Business	Biotechnology	Physical Science	ICT	General			
Career Stage	Emerging	Middle	Mature	Distinguished			
Risk	Not Including Financial	Includes some Financial	Includes Major Financial				
Role in Commercialising Intellectual Property	Commercialising Own IP	Commercialising Others' IP	Others Commercialising IP	Creating New IP in a Business			
Extent of Scientific Entrepreneurship	Full	Partial	Scientist	Intrapreneur	Broker/Manager		
Mobility	Different Organisation, Different Field	Different Organisation, Same Field	Same Organisation, Different Field	Same Organisation, Same Field			
International Experience	Working Overseas	Experience of Overseas Science	Experience of Overseas Business	Experience of International Science Business	Internationally Connected	International Reputation	Little or None
Scientific/Technological Background of 2 ^o and 3 ^o Respondents	Some	None					

Appendix Three Organising framework for nodes derived from analysis

Vertical			
Horizontal	Contextual layers	Attribute layer	Longitudinal
Characteristics	NZ Broad; Characteristics of business;	Attributes of scientists; Attributes of business	Life Histories
Connections/disconnections (gaps)	Characteristics of RS&T; Organisational aspects	people/entrepreneurs	<ul style="list-style-type: none"> • Own life histories • Others' life histories
Differences	Science-business models	Attributes of scientific entrepreneurs	
Similarities	Differences Science and business	Differences; Scientists and business people/entrepreneurs	
Boundaries	Similarities Science and Business	Similarities: Scientists and business people/entrepreneurs	
Comparisons	Boundaries	Boundaries	
	Other systems	N.A.	
Cross-cutting themes Obstacles/perserverance Risk Motivation New Zealandness Connections Opportunity			
“External” Recognition Role of observer What is detected Signals How detected Response			

Appendix Four Coding on in the contextual layers

4.1: Science-Business Models

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Technology Transfer	11	9	8	28
Broker Involved	4	4	5	13
Direct Scientist to Business or User	4	3	4	11
Formal Partnership	4	2	1	7
Licensing out Intellectual Property	1	1	0	2
Ideas Have to be Sold Internally	1	2	0	3
Incubators	0	2	0	2
Tedious Process	0	1	0	1
Spin Out	10	7	1	18
Add Business Capability to Scientist	5	8	4	17
Founder Created and Driven	13	2	0	15
Market Pull	8	3	1	12
Growing Organically into a New Space	7	4	0	11
Science and Technology Push	6	3	1	10
Contracting Out Research	4	3	0	7
International	3	3	1	7
Selling Science & Technology Services	4	1	2	7
Human Capital Linkages	2	2	2	6
Founder Exit	2	2	1	5
Venture Capitalist	2	1	0	3
Add Science Capability to Business	0	1	1	2
Suite of Products/technology Platform	1	0	0	1

4.2: NZ Broad

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
NZ Innovation System	17	11	7	35
Gaps Problems and Barriers	14	9	7	30
Positive Aspects	8	4	5	17
Proportion of Entrepreneurs	1	1	1	3
Ideas for Improvement	11	8	7	26
Negative Environment	14	8	3	25
Positive Environment	9	5	1	15

4.3: Organisational Aspects

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Teams essential	17	10	5	32
Positive management	15	10	3	28
Negative management	14	6	4	24
Entrepreneur won't let go	2	2	0	4
Mobility/exit	5	5	4	14
Scientist separate from commercialisation	8	1	2	11
Careers	1	0	2	3

4.4: Characteristics of RS&T

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Systematic process	8	3	3	14
Idea came out of research base	5	4	2	11
Codifying ideas	2	4	2	8
Seamlessness	6	0	0	6
Sociology of science	3	1	2	6
Accountability	2	0	0	2
Peer pressure	1	0	0	1
Disseminating ideas	2	1	2	5
Origin and progression of ideas	3	0	1	4
Ideas take a long time to develop	14	2	2	18
Many different approaches tried	5	1	0	6
Ideas are a response to problems	9	4	3	16
Free environment	6	1	2	9
Applying ideas	5	1	1	7
Ideas pop out of nowhere	2	0	0	2
Whole of picture insight	4	0	0	4
Having many lines of enquiry at once	4	0	0	4
Serendipity	3	0	1	4
Science moves quickly	3	0	1	4
Many sources	2	0	1	3

4.5: Characteristics of Business

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
What is Entrepreneurship	14	8	6	28
Running Own Business	0	2	1	3
Radical	2	1	0	3
Spectrum	1	1	0	2
Incremental	0	0	0	0
What is Innovation	0	2	4	6
Entrepreneurship is a Subset	0	1	4	5
Innovation Comes before Entrepreneurship	0	0	1	1
Value Propositions	3	3	1	7
What is "Standard" Business	1	2	1	4
Firm Evolution	2	1	1	4

4.6: Other Science and Innovation Systems

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
More Conducive Culture	7	7	3	17
More Tolerant of Risk and Failure	2	4	0	6
Greater Opportunities Rewards There	8	2	3	13

More Venturing Help	3	4	1	8
More Government Incentives	3	4	1	8
Less Conducive Environment	2	3	0	5

4.7: Differences: Science and Business/Entrepreneurship

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Motivations are Different	6	4	3	13
They are Quite Different	7	3	2	12
Processes are Different	4	4	3	11
Science is More Analytical	4	0	0	4
Bigger Monetary Rewards in Business	1	0	0	1
Science Careers More Secure	1	0	0	1
Business Customer Centred	1	0	0	1
Business More Exciting	1	0	0	1
Business More Stressful	1	0	0	1
Business Involves More People Skills	1	0	0	1

4.8: Boundaries

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Boundary between Science and Business	7	4	0	11
Ways of Spanning Boundary	4	2	0	6
No Boundary between Science and Business	5	2	1	8

4.9: Similarities: Science and Business/Entrepreneurship

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Similar processes	7	2	1	10
They are similar	5	1	0	6

Appendix Five Coding on in the attributes layers

5.1: Attributes of Business People

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Self starter	1	1	0	2
Unsuccessful Entrepreneur	2	1	1	4
Held on too long	2	0	1	3
Loner	0	1	0	1
Have a good reputation	1	0	1	2
Goal oriented	0	1	0	1
Entrepreneurs	24	13	8	45
Risk taker	15	7	6	28
Managed risk	7	2	1	10
Determination	14	8	4	26
Realise the market opportunity	8	9	6	23
Passion	10	9	1	20
Tenacity	7	10	2	19
Drive	9	6	4	19
Think outside the square	8	7	4	19
Overcome or go around barriers	9	6	3	18
Good people person	10	7	1	18
Ability to sell vision	5	8	4	17
Confidence	6	3	2	11
Balanced	3	6	1	10
Has vision	1	5	4	10
Limited technical background	5	3	0	8
Sceptical	4	4	0	8
Rule breaker	2	3	2	7
Energy	3	2	2	7
Eccentric, difficult	5	1	1	7
See the big picture	5	1	1	7
Marshals resources	4	2	1	7
Leaders	2	4	1	7
Jump from one thing to another	1	5	0	6
Good self-knowledge	3	2	1	6
Ambition	2	1	2	5
Charisma	1	2	2	5
Networkers	3	1	1	5
Knows the sector well	3	1	1	5
Makes the right judgement	2	1	1	4
Poor managers	2	2	0	4
No patience with bureacracy	3	1	0	4
Ahead of everyone else	1	1	1	3
Can do attitude	2	1	0	3
Tinkerers	2	0	0	2
Courageous	0	1	1	2
Follow one thing to its conclusion	1	1	0	2
Good at timing activities	0	1	0	1
Self Deprecating	0	0	1	1

5.2: Attributes of Scientists

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Driven by curiosity	9	2	1	12
Poor appreciation of business	2	5	4	11
Deep technical knowledge	4	5	2	11
Introspective	5	3	2	10
Skilled in analysis	6	2	0	8
Methodical	3	1	4	8
Perfectionist	1	2	3	6
Very autonomous	3	2	1	6
Hang on to IP	1	4	1	6
Realise concept or idea	4	1	0	5
Cross-disciplinary	2	1	1	4
Risk averse	2	1	0	3
Behave according to scientific ethos	1	1	0	2
Curious	2	0	0	2
Impartial	0	1	0	1
Passionate	1	0	0	1

5.3: Similarities between Scientists and Business people/entrepreneurs

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Same competencies	9	4	0	13
Lateral thinkers	6	2	2	10
Creativity	1	0	1	2
Problem solvers	1	0	0	1
Some things the same	2	5	1	8
Metacompetencies	4	3	1	8

5.4: Differences between Scientists and Business people/entrepreneurs

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Readiness for market	7	3	3	13
They are different	6	3	2	11
Narrow vs broad	5	4	2	11
Modes of communicating	4	2	1	7
Different knowledge bases	1	1	2	4
Different approach to risk	3	0	0	3
Different disciplines	2	1	0	3

5.5: Boundaries between Scientists and Business people/entrepreneurs

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total

Entrepreneur works across boundary	3	1	1	5
Scientific entrepreneurs don't see boundary	1	2	0	3
Entrepreneur works on boundary	1	0	0	1

5.6: Attributes of Scientific Entrepreneurs

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Able to see the big picture	6	4	2	12
Very rare	2	6	3	11
Interested in applied science	3	3	2	8
Confident	6	0	2	8
Deep knowledge & skills	4	2	0	6
Can take it only so far	4	1	1	6
Broad knowledge & skills	3	2	1	6
Skills to communicate in both modes	3	2	0	5
Not academic high flyers	1	1	1	3
Highly committed	2	0	1	3
Calculated switching from one mode to another	2	0	0	2
Dual personality	1	0	1	2
Bridge building	1	0	1	2
Ability to play with thoughts and ideas	2	0	0	2
Misfits	1	1	0	2
Insight	0	1	1	2
Analytical	2	0	0	2
Network together	1	0	0	1
Technology timing	0	1	0	1
Leave the science behind	1	0	0	1

5.7: Motivation

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
For scientific entrepreneurs	22	7	4	33
For scientists	15	11	4	30
For individual respondents (i.e. self-reported)	23	3	0	26
New Zealandness	15	1	2	18
Doing it for New Zealand	13	0	0	13
Choose to be in NZ	4	1	2	7
Personal circumstance	3	0	0	3
Peer esteem	11	4	3	18
For entrepreneurs	7	5	4	16
Enjoyment of science	10	4	1	15
Making money	11	3	1	15
Knowledge for its own sake	9	3	3	15
Making a difference in the world	9	4	2	15
Lifestyle	10	2	1	13
Application of knowledge	9	2	2	13
Growing a business	7	2	1	10
Enjoyment of business	6	1	0	7

Solving problems	3	1	0	4
Career ambition	2	0	0	2
Fear of Failure	2	0	0	2
Emulate others	1	1	0	2
Tenure	0	1	0	1
Business needs	0	0	1	1
Personal benefit	1	0	0	1

5.8: Personal Attributes of Respondents

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Good communicator	5	2	1	8
Self effacing	2	0	2	4
Organiser	3	0	0	3
Potential entrepreneur	2	0	0	2
Entrepreneur	1	0	1	2
Positivist	1	0	0	1
Empirical	1	0	0	1
Competitive	1	0	0	1
Not confident	1	0	0	1
Optimist	1	0	0	1
General intelligence	0	0	1	1

Appendix Six Coding on for themes

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Risk	24	11	6	41
Non-financial risk	13	9	4	26
Considered risk	14	5	2	21
Entrepreneurs take financial risks	15	2	3	20
Risk Aversion	8	4	0	12
Scientists' risks	5	3	0	8
Opportunity	24	11	3	38
Both	20	4	2	26
Created	6	2	0	8
Discovered	4	1	0	5
Training	17	13	6	36
Sequencing	11	7	5	23
Mentoring	3	9	1	13
Formal training positive	3	5	3	11
Formal training negative	4	6	1	11
Placements in industry	4	3	3	10
Self directed learning	4	1	1	6
Go offshore	3	0	1	4
Connections	15	11	4	30
Building and tapping networks	11	9	2	22
With clients & end users	7	0	0	7
Communication skills	7	7	1	15
Finance	18	7	4	29
Enough finance available	9	4	2	15
Lack of finance a barrier	6	3	1	10
A lot required	4	0	2	6
Comes with high accountability requirements	3	0	1	4
Comes with loss of ownership	3	0	0	3
Enabled ownership	1	0	0	1
Obstacles/Perserverance	16	3	3	22
Knowing when to give up	1	0	1	2
Knowledge	13	5	4	22
Required business knowledge	8	2	1	11
Required technical knowledge	3	1	0	4
Skills	9	6	3	18
Required business skills	4	3	1	8
Required technical skills	4	0	0	4
Reward	9	4	2	15
Satisfaction	5	1	2	8
Departmental funding	2	1	0	3
Low remuneration	3	0	0	3
Satisfactory Remuneration	0	1	1	2
Stimulation	1	0	0	1
Vision	6	5	2	13
Focus	3	3	2	8

Focus important	2	2	1	5
Focus inappropriate	1	1	0	2
Insufficient focus	0	1	1	2
Fun	4	1	0	5
Regret	4	0	0	4

Appendix Seven Coding on for recognition

7.1: Non-recognition

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Non recognition	20	11	2	33
Gaps	7	7	2	16
Science or entrepreneurship not recognised	5	7	0	12
Ideas for improved recognition	7	3	1	11
Recognition not wanted	6	1	2	9
Stereotyping	1	0	0	1

7.2: Recognition

Child nodes	Number of Respondents			
	Primary	Secondary	Tertiary	Total
Role of observer				
Peers	12	5	3	20
Manager	7	7	1	15
Employing body	5	3	2	10
Funding body	3	2	2	7
Self	2	2	2	6
Companies	4	2	0	6
Local community	4	1	0	5
Teacher	3	2	0	5
Media	4	0	0	4
Societies	2	1	0	3
Teaching body	2	0	0	2
Policy person	0	0	2	2
Supervisor	1	0	0	1
Venture capitalist	1	0	0	1
Student	1	0	0	1
Customers	1	0	0	1
What is detected				
Attributes	12	9	2	23
Scientists/engineers	8	3	3	14
Entrepreneurship	6	3	2	11
Scientific entrepreneurship	4	4	1	9
Commercial potential	3	4	2	9
Good science	4	2	2	8
General success	6	2	0	8
Team contribution	0	1	0	1
Signals				
Modus operandi	10	6	3	19
Publications	2	4	2	8
Commercial behaviour	6	1	0	7
Commercial success	3	2	2	7
Track record	3	2	1	6

Something of myself	2	4	0	6
Left Field Behaviour	3	2	0	5
Proposals	3	2	0	5
Failure	2	0	1	3
Multiple	1	2	0	3
Patents	1	1	0	2
Enjoyment	1	0	0	1
Transcript	1	0	0	1
Performance indicators	0	1	0	1
Citations	0	1	0	1
Personal history	1	0	0	1
How detected				
Observation	11	6	1	18
Systematically	6	7	2	15
Networking	3	1	2	6
Competitions	3	1	0	4
Intuition	2	2	0	4
Aha moment	1	0	0	1
Response				
Awards, prizes	8	3	0	11
Acknowledgement	6	3	1	10
Funding	2	5	2	9
Management support	1	4	2	7
Qualifications	5	1	0	6
Negativity	5	1	0	6
Wealth	3	1	2	6
Invitations	3	1	1	5
Given greater responsibility	2	2	0	4
Prestigious fellowships/appointments	2	1	1	4
Employment	2	1	0	3
Teaching support	2	1	0	3
Surprise	1	1	0	2
Profile	1	1	0	2
Share of IP	0	1	0	1
Provided with commercialisation vehicle	1	0	0	1
Rewards	0	1	0	1
Scholarships	1	0	0	1
Selection as a teacher	1	0	0	1

Appendix Eight Research instruments

8.1 Letter to respondents

Date

Address Fields

Dear

Invitation to Participate in a Research Project: Recognising Scientific Entrepreneurs in New Zealand

I am a PhD student in the School of Government at Victoria University of Wellington (VUW) with a long-standing interest in the operation of the New Zealand science and innovation systems. My PhD research seeks to discover more about how that system identifies scientific entrepreneurs and fosters their development.

Through this research I aim to identify any gaps that may exist in current practice, and to generate conclusions and recommendations for increasing the incidence of scientific entrepreneurship in New Zealand.

I have interviewed a number of people who more or less fit my description of “scientific entrepreneur”⁷⁵. However I am also interested in talking with science managers and policy people who might provide further insight into the development of competencies for scientific entrepreneurship and how these are recognised. I believe that you could shed some light on these questions and invite you to participate in my research. This would involve an interview of around 45 minutes.

Informed consent

Ethical approval for this research has been obtained as required by Victoria University. If you are willing to participate I must first gain your informed consent, and to this end a consent form is enclosed for you to consider, sign and return to me. The following explanation aims to ensure that you are fully informed as to what that consent would entail. However if you have any questions or require further information before deciding whether or not to sign, please do not hesitate to contact me. My details are at the end of this letter.

What participation entails

I should like to be able to interview you at a place of your choosing for around 45 minutes⁷⁶, using a semi-structured format. Ideally (but not necessarily) I would

⁷⁵ Individuals who have taken some degree of personal financial risk in commercialising a product or service based on their own scientific research, whether successfully or not

⁷⁶ My initial group of interviews have consistently averaged this length

record the interview on audiotape for later transcription. You can decide whether or not to be recorded, and have the option of checking any transcript for accuracy before I proceed with my analysis. You would also have the option of withdrawing from the research at any time before final analysis and, if you did so, all data collected from you would be returned or destroyed as you wished.

Confidentiality and security of information

All responses will be treated in strictest confidence (known only to me, the individual respondent and possibly my PhD supervisor and examiners). I will also be using a professional service with the highest level of confidentiality for transcribing interviews. All information gained through the research process (interview notes and tapes) will be kept in a locked file with access restricted to myself only. All electronic information will be kept in a password-protected file and access will be restricted to me in my role as investigator. Within two years of acceptance of my thesis, all interview notes, tapes and similar materials will be destroyed.

The write up of results will be at an aggregated level, i.e. there will be no identification of individual participants in the research, nor their associated agencies. Quotations may be used, but there will be no any attribution of information or opinions that would allow sources to be identified.

The proposed output of the research is a PhD Thesis but I should also like to draw on the information obtained a basis for conference presentations or the publication of papers in academic journals. Were you to participate, I would be very happy to provide you with copies of any outputs of the research, or informal feedback as you wished.

Contact details

I look forward to your response to my invitation. I can be contacted by any of the following means:

Email	Malcolm.Menzies@vuw.ac.nz
Phone (DDI at work)	04 463 5102
Phone (Home)	04 383 5804
Post:	5 Don Street Island Bay Wellington

My PhD Supervisor is Dr Jane Bryson:

Email	Jane.Bryson@vuw.ac.nz
Phone	04 463 5707
Post	Victoria University P.O. Box 600 Wellington

Yours sincerely

Malcolm Menzies
Victoria University of Wellington

8.2 Consent form

Consent to Participation in Research for a PhD

Title of Project: Recognising Scientific Entrepreneurs in New Zealand

Researcher: Malcolm Menzies

I have been provided with adequate information relating to the nature and objectives of this research project, I have understood that information and have been given the opportunity to seek further clarification or explanations.

I understand that my participation will consist primarily of a semi-structured interview, which may be audio taped with my permission. I have the option of checking any transcript for accuracy.

I understand that I may withdraw from this study at any time before the final analysis of data without providing reasons. If I do so, all data collected from me will be returned or destroyed as I wish. I understand that any information or opinions I provide will be treated in confidence, stored securely and reported only in an aggregated/non-attributable form.

I understand that the information I provide will be used only for the preparation of a PhD thesis, or for conference presentations or publication in academic journals. I may request copies of any of these outputs or informal feedback as I wish. I understand that all information provided will be destroyed within two years of the acceptance of the PhD thesis.

I agree to participate in this research

Name:

Signed:

Date:

Thank you for signing. Please return this form to:

Malcolm Menzies
5 Don Street
Island Bay
Wellington

Or let me know that you are happy to pass it over when we meet for our interview by either: emailing Malcolm.Menzies@vuw.ac.nz, or phoning 463 5102 (work hours) or 383 5804 (outside work hours).

8.3 Interview questions

Semi-structured interview

Recognising Scientific Entrepreneurs

Proposed Questions for Primary Respondents

1. What does the term Entrepreneurship mean to you?
2. What are the attributes of an Entrepreneur?
3. What are the characteristics of Scientific Research (in comparison to the characteristics of Entrepreneurship)?
4. What are the attributes of a good Scientific Researcher?
5. What is required to combine “the ways of science” with “the ways of entrepreneurship”? How is it done? (How have *you* managed to do this? What motivates you to do so?)
6. Looking back, what is your earliest memory of combining science with entrepreneurship? What was it that enabled you to do that?
7. What other instances of combining science and entrepreneurship can you recall?
8. Has your ability to combine science and entrepreneurship been recognised⁷⁷ by other people or by “the system”? How?
9. What gaps do you see in the ways that scientific entrepreneurs are recognised? How would you fill those gaps?
10. *(N.B. See information sheet and consent form)*

Are you able to identify other people (e.g. family, former teachers) whom I might approach to interview and gain further insights as how you have developed as a scientific entrepreneur?

⁷⁷ The process of recognition can be seen to encompass a number of levels:

- Knowing what something is, and what distinguishes it from other things;
- Becoming aware of something's presence or absence – “making it out” or detecting direct or indirect signals which may be measured; and
- Acknowledgement of presence – a response.