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Harnessing Science For Business

A brief history of technology transfer

The New Zealand government has announced the creation of a new Advanced Technology Institute – since renamed Callaghan Innovation after the late Sir Paul Callaghan – to be launched in 2013. Callaghan Innovation's purpose will be 'to help get New Zealand's most innovative ideas out of the lab and into the marketplace more quickly and provide a high-tech HQ for innovative New Zealand business'.[1] This development is the latest in a long line of attempts to use research, science and technology to boost the country's economy (Palmer and Miller, 1984; Ministerial Working Party, 1986; Science and Technology Advisory Committee, 1988; Ministerial Task Group, 1991; Ministry of Research, Science and Technology, 2006, 2007).

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Twenty years ago the former Department of Scientific Research, 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 Crown (state) research institutes or CRIs. Each CRI was established with a focus on an economic, environmental or social sector,[2] in the belief that such an alignment would foster closer relationships, ensure better transfer of knowledge between researchers and users, and incorporate the business-oriented skills required to manage science-based innovation processes. There was also reform in the way policy was set and government funding allocated to research, with the establishment of the separate Ministry of and Foundation for Research, Science and Technology.

Over time there emerged considerable dissatisfaction with the performance of the reformed science system, particularly in relation to funding, structures, and connections between science and business

(Institution of Professional Engineers, 2004; Ministry of Research, Science and Technology, 2008; National Science Panel, 2008), so in 2009 the government set up a review which produced a number of recommendations for further changes. Most of these recommendations related to funding, ownership and governance matters, but it was also reiterated that technology transfer was 'a core responsibility for all CRIs and [that the government should] require CRIs to develop, invest in and manage intellectual property with the intent of moving that intellectual property from their balance sheet into the private sector as soon as possible' (Crown Research Institute Taskforce, 2010, p.12).

A further report on the high-value manufacturing sector (2012) led directly to the establishment of Callaghan Innovation. The panel of experts who prepared this report analysed primary barriers to technology and knowledge transfer, but also acknowledged the complexity of the innovation process. The panel was more nuanced in its view than many of its predecessors, and the establishment of Callaghan Innovation may provide an opportunity to reflect on the dominant model of technology transfer and to consider whether modifications or alternatives might deliver better economic outcomes.

A strong argument can be made that previous reforms of the research, science and technology system in New Zealand were premised on a mental model (Johnson-Laird, 1983; Ramirez, 2007) of science and business existing in inherently different realms populated by people with separate and mutually exclusive sets of attributes (Menzies, 2008). This thinking in part underpinned a view of technology transfer wherein ideas are created by scientists and passed to others along a chain of increasing application and commercialisation (Slaughter and Leslie, 1997; Evans, Kersh et al., 2004). This view makes 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 (Etzkowitz, 1998; Graversen and Friis-Jensen, 2001; Nås, Ekeland et al., 2001; Corolleur, Carrere et al., 2004; Murray, 2004; Abramo and D'Angelo, 2009). Scientific entrepreneurs are rare, though probably not as rare as policy makers and managers may think (Aldridge and Audretsch, 2011). As one such scientific entrepreneur put it, albeit a little awkwardly: 'I think a good scientist could be a good entrepreneur but – it's the same tools but a different mindset.' Better understanding of this 'different mindset' could be used alongside structural reform to support the development of systems and processes to increase the incidence of scientific entrepreneurship.

The potential of scientific entrepreneurship

The foregoing discussion does not mean to dismiss the efficacy of conventional processes of technology transfer in the presence of already-existing sectors with 'absorptive capacity' and capable of delivering very good returns on investment (Hall and Scobie, 2006). But where there is no absorptive capacity – for example, in nascent industries – the pure transfer model breaks down both conceptually and in practical terms (O'Shea, 2008). In New Zealand major barriers to the transformation of existing industries or the growth of new ones are low research intensity and inadequate absorptive capacity within the economy (Carlaw, Devine et al., 2003). Instead, New Zealand firms generally take an informal and incremental approach to innovation, and, rather than referring to research and development or groundbreaking innovations, most cite feedback from customers or employees (especially sales staff) and changing customer needs and values as important inputs (Knuckey, Johnston et al., 2002). It is a major challenge for research outputs to be taken up by a broadly unreceptive business sector.

Scientific entrepreneurship offers the potential to create radical, 'technology-push' innovations and underpin the development of new economic sectors (Workplace Productivity Working Group, 2004; Göransson, Maharajh et al., 2009). To help come to grips with this phenomenon, it's worth starting with the literature on the various components, beginning with that on entrepreneurship.

Entrepreneurship

The study of entrepreneurship faces an inherent difficulty, which is how to analyse a process which cannot be foreseen by most people and is generally recognised only in retrospect (Baumol, 1983). Nevertheless, from past cases it is possible to identify a priori indicators of entrepreneurial success and contextual factors or individual attributes that contribute to entrepreneurship. Several studies have shown a cluster of personality traits common among all successful entrepreneurs, including the need for achievement (McLelland, 1961) as well as persistence, innovative outlook, low need for conformity, high energy level, risk-taking and efficiency (Belt, 1990). The factors which empirical evidence most strongly links to entrepreneurial success are: high self-efficacy; ability to spot and recognise opportunities; high personal perseverance; high human and social capital; and superior social skills (Markman and Baron, 2003). Meta-analysis by Zhao and Seibert (2006) indicates significant differences between entrepreneurs and managers on four personality dimensions, such that entrepreneurs score higher

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on conscientiousness and openness to experience and lower on neuroticism and agreeableness. Hansemark (1998) claims that only two psychological attributes have shown any significant relation to entrepreneurship: need for achievement and locus of control.

Risk is a major recurring theme and 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). Opportunity recognition is also seen by many as a key behaviour (Smart and Conant, 1994; Baum, Locke et al., 2001), although opportunity recognition might also be seen to be driven more by the distinctive knowledge possessed by individual entrepreneurs than by their personality traits (Shane, 2000). Entrepreneurs often challenge existing wisdom and reconcile opposing forces, moulding external information with their individual decision-making processes. Nevertheless, entrepreneurs need a considerable amount of social and interpersonal skill to build and cultivate networks and other social capital which will enable them to glean the information and resources they need (Cromie, 1994; Baron and Markman, 2000; Shane and Stuart, 2002; Audretsch, 2003; Aldridge and Audretsch, 2011). They have to be able to organise and lead others if their endeavours are to be successful.

Science and entrepreneurship

Science differs from entrepreneurship in that it is often regarded as being based on a particular set of norms and a sociology which create a difference from the world of business in general (Merton, 1973; Ziman, 1984, 1994; Bortagaray, 2009). But many of the traits required by scientists are not inherently different from those required by people working in many other realms – imagination, self-criticism, diligence and curiosity, for example. Scientists are considered to have a devotion to truth and respect for the public literature, and to be motivated by the science itself rather than by external rewards. In this respect they are quite similar to many entrepreneurs.

Like entrepreneurs, scientists spot opportunities and take risks, albeit these are less likely to be of a financial nature. They also at times challenge conventional wisdom (Kuhn, 1996). Scientific effort is motivated by the crucial aim of being original (adding something to the body of knowledge that was not known before). Recognition of originality and the associated rewards are of critical importance to scientists and signify that the institutional aim of science has been fulfilled. It could be argued that entrepreneurs are also motivated by a desire to be original (by exploiting a hitherto undetected opportunity), although they work in a different 'recognition market' (Musgrave, 2009).

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 that this is an attribute high-performing scientists lack. Even those aspects that 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 painstaking review processes. 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 judgement, and is judged retrospectively by results in the marketplace.

Human capital and the competency movement

The fields of science and entrepreneurship may have differences, but they are both human activities which may be employed for the purposes of economic innovation. In order to understand the overlapping phenomenon of scientific entrepreneurship, therefore, it seems sensible to draw on the knowledge base related to human capital – a subset of the economics literature which originated with Becker (1964) and Schultz (1971). Much human capital development, particularly in the sciences, is cumulative – i.e. new elements build on what has gone before (Ziman, 1984) – and tends to move incrementally rather than in leaps and bounds. There is an implication 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, it is better to embed desired attributes as early as possible in the life cycle (Durbin, 2004; Keeley, 2007).

Policy work on science and technology human capital has tended to focus on quantitative measures of stocks and flows represented by traditional indicators such as qualifications or codified knowledge such as patents (Schibany and Streicher, 2008; Royal Society, 2009). While undoubtedly important, these measures are not adequate for recognising the increasingly important tacit knowledge (Polanyi, 1967) and other attributes which are coming to assume greater significance within research, science and technology-based innovation (Cohen and Levinthal, 1990), and particularly in the commercialisation of scientific research (Buenstorf, 2009; Fagerberg, Mowery et al., 2009; Póvoa and Rapini, 2010). The *quality* of human capital is measured only indirectly, although there are trends towards assessing what people are actually capable of doing and the

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degree of matching of those abilities with future needs. A competence 'movement' has arisen out of controversy over the validity of measures and insufficient correlation between measured intelligence and life outcomes (Brophy and Kiely, 2002), and one 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 national innovation system (Tomlinson, 2001).

A useful model of effective performance based on fit between the individual, a job's demands and the organisational environment has been developed by Boyatzis (1982). Specific actions or behaviours lie in the overlap between the three domains. In Boyatzis' 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 that he or she uses. The existence and possession of the above characteristics may or may not be known by the person who has them (an idea which owes much to Polanyi (1967)).

Given different schools of thought as to whether competencies are characteristics of an organisation, a job (or role) or an individual (Ellstrom, 1997; Brophy and Kiely, 2002; Lawson, 2004), the value of the Boyatzis model is in its recognition of all these elements and their interaction within a context, thus enabling whole-system thinking.

Figure 1: Attributes of metacompetencies of scientific entrepreneurship

Attributes of scientific entrepreneurs

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

Attributes for scientific realm	Attributes for entrepreneurship realm
Motivated by knowledge for its own sake	Motivated by desire for application
Deep knowledge	Broad knowledge
Aversion to financial risk	Open to financial risk
Incremental decision maker	"Heuristic" decision maker
Tending to perfectionism	Satisfied with 'good enough'
Ability to realise scientific opportunities	Ability to realise commercial opportunities

Shared attributes

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

Research

The research on which the rest of this article is based comprised interviews with 26 people who closely matched a working definition of scientific entrepreneurship. They came from a range of organisational and scientific backgrounds: biotechnology, the physical sciences, and information and communications technology (ICT). Four were women. All were interviewed using the same basic semi-structured format to discover their perspectives on how their own and others' scientific entrepreneurship had been recognised, by themselves, by others and by the system at large. The interview transcripts were then analysed using precepts of constant comparative analysis (Strauss and Corbin, 1998) and a software programme (NVivo) which is closely modelled on the application of grounded theory. From this analysis a series of thematic 'nodes' was derived within which relevant comments were gathered, and the nodes organised to show the underlying attributes of scientific entrepreneurs (Figure 1).

As can be seen, the attributes of entrepreneurs, scientists and scientific entrepreneurs emerge as being different from one another, but the sets of attributes are not mutually exclusive. Some attributes are unique to one particular group, but others are similar or shared.

Discussion

Policy challenges

Scientific entrepreneurship is not proposed as a 'magic bullet' alternative to current practice. However, new policies and schemes aimed at fostering its development could be introduced in parallel with existing approaches. In that case, it will first be necessary to allow for the *possibility* of scientific entrepreneurship. This means rejecting artificial distinctions between science and commerce (and between basic and applied research), and the adoption of new mental models which expand the overlaps between science and entrepreneurship.

Such changes in perception may be resisted, for reasons described by several authors (Snow, 1963; Schön, 1983; Musgrave, 2009), although not as much as was once the case (Slaughter and Leslie, 1997). It is possible that current policy problems that do not exist and is consequently missing reality on this point.

Before any 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) or integrative thinking (Martin, 2009), 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). This suggests a change in incentives for CRIs to facilitate the exit of entrepreneurs (with safety nets for those who fail) rather than holding onto them tightly.

Some scientific entrepreneurs are well recognised once they have succeeded 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, some are 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 most interest is made up of those who have the necessary innate attributes but not acquired ones, 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, thereby increasing its overall incidence within the national innovation system. For this to happen, there will need to be an 'undoing' of existing ways of working (Carroll, Levy et al., 2008).

In several countries there have been considerable efforts made at creating an appropriate context for the commercialising of research, science and technology, not only through structural means but more widely: for example, in attempting to engender culture change and in making linkages within innovation systems. This activity is presumably intended to generate desired behaviour and is 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 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.

A holistic concept of competence-building systems (Tomlinson, 2001) is required, implying a broadening of the conception of national innovation systems 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 research, science and technology, 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. 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 (Menzies, 2008).

A common language of competencies will help facilitate a faster move towards policy integration, and provide the basis for broader, innovative approaches to the creation of quality in human capital (Bilton and Cummings, 2010). 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 desired tipping-over process. New approaches (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 (Gonczi, 2002). Specifically, attention needs to be given to recognising the key attributes underlying meta-competencies as shown in Figure 1.

It has to be acknowledged that the characterisation and assessment of competencies is still problematic because most of their underlying attributes are tacit and invisible to conventional methods of measurement. More research is needed, but an interim solution is to devolve responsibility for recognising these attributes to research organisations, while retaining centralised measurement of aggregate outputs and outcomes at a higher level. This will raise new challenges for the ways in which science and its commercialisation are managed.

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Management challenges

Policy and practice aimed at the entrepreneurial connection of science and business frequently relies on brokering between the two. The ability of scientists to engage directly with the marketplace is quite restricted, and perceived deficits in their entrepreneurial competencies are rectified through the agency of others (a relatively passive or reactive strategy to team-building on the part of the central individual). But successful 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. This implies a whole new approach on the part of senior management to building 'renaissance teams' containing 'integrative thinkers' (Martin, 2009).

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 approach 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 – as they are in Sweden (Etzkowitz, Ranga et al., 2008; Leong, Wee et al., 2008) – 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-picture insight (Göktepe-Hultén, 2008). The corollary will be a reliance on managers' reflective judgement (Schön, 1983), and resources placed at their discretion yet no increase in, 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 (Ziman, 1984, 1994; Bryson and Merritt, undated). Entrepreneurial decision-making is heuristic (Forstater, 1999; Barney, 2004) and not particularly compatible with corporate processes. Organisations 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 (Göransson, Maharajh et al., 2009). There will also need to be managed changes in the sociology of science so that scientists affirm, rather than create negative peer pressure on, their fellows who engage in commerce (Walton, 2003). For some scientific entrepreneurs there is great value to be gained from networking together (it seems that they are good at recognising each other). Modelling their behaviour on that of successful exemplars can assist scientific entrepreneurs to recognise their own competencies, thereby enabling them to follow the same path.

Sir Paul Callaghan was himself a consummate scientific entrepreneur, although he came to realise this late in his career. It is to be hoped that his example will inspire creative approaches to developing entrepreneurial human capital at the institute which now bears his name.

1 See www.irl.cri.nz/newsroom/advanced-technology-institute-announced.

2 AgResearch for the pastoral sector; Crop and Food and HortResearch (since merged) for cropping and horticulture; ESR for environment and health; Forest Research (latterly renamed Scion); Geological and Nuclear Sciences; Industrial Research Ltd for the manufacturing sector; Landcare for the land-based natural environment; and the National Institute for Water and Atmospheric Research. A social research CRI proved to be unviable and was soon disestablished.

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