2008

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Publication details

Senyard, JM, Pickernell, D, Clifton, N, Kay, A & Kease, RL 2008, 'Extending the knowledge spillover theory of entrepreneurship for analysis of the Australian biotechnology sector', in L Iadnoli (ed.), *Proceedings of Technology-Driven Entrepreneurship : How Technology Shapes the Way Entrepreneurs Start and Run Their Business*, Cardiff, UK, European Council for Small Business and Entrepreneurship (ECSB).

EXTENDING THE KNOWLEDGE SPILLOVER THEORY OF ENTREPRENEURSHIP FOR ANALYSIS OF THE AUSTRALIAN BIOTECHNOLOGY SECTOR

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ABSTRACT

Current research suggests that the process of knowledge creation is both networked and iterative. Synthesising the literature highlights a range of factors for analysis in knowledge-based industries. These factors are then used to examine the biotechnology sector in Queensland Australia, utilising available secondary literature, interviews with a range of broad stakeholders and 3 case–study companies. The results highlight issues regarding government policies for biotechnology, due to potential weaknesses in the network of relationships and governance between the key stakeholders (particularly within universities), the absence in some cases of relevant education (training and learning) for academics, and issues of entrepreneurial orientation and knowledge management in the use of created knowledge.

INTRODUCTION

The multi-faceted nature of innovation processes highlighted by Leyesdorff (2000) suggests that this phenomenon involves a range of relationships (e.g. with other firms, government agencies, universities) and learning and innovation occur through interactive, iterative and networked approaches (Weick, 1990; Cooke, 1998). The supply of such knowledge and its characteristics, also requires capable knowledge users and effective knowledge transfer/translation (Cooke et al., 1997; Braczyk and Heidenreich1998) to create commercialised outcomes in terms of product and process innovation and improved firm capacity and growth.

The arguments surrounding this can be encapsulated within the knowledge spillover theory of entrepreneurship. This argues, essentially, that knowledge developed in some institutions might be commercialized by other institutions, and that entrepreneurship is one way that the 'economic agent with a given endowment of new knowledge' can best appropriate the returns from that knowledge (Acs et al. 2004). Audretsch and Lehmann (2005) demonstrated, for example, that the number of new firms located close to a university is positively influenced by it's knowledge capacity. The complexity of knowledge intensive entrepreneurship, however, often creates barriers to exploitation. This may be result from (1) failure of private firms and public institutions to generate new knowledge; (2) failure of that knowledge to be disseminated efficiently; (3) failure of individuals to exploit new knowledge; (4) a range of other factors that make entrepreneurship difficult.

Spatial proximity also often positively affects knowledge spillovers from firms and research organisations, reinforcing the asymmetric economic geography of prosperity and accomplishment (Cooke et al, 2005). There is also evidence, however, that knowledge-creating collaborations as well as disseminating mechanism can be non-local in nature. A recent study into the effects of social capital found that both faster growing and more innovative small firms tend to make greater use of non-local networks (Cooke et al. 2005). In addition, Acs et al (2007) highlight that new knowledge can be imported into a region through the activities of foreign multinationals.

This paper, therefore, examine these issues, using the knowledge-intensive biotechnology sector in Australia as a case study, due to its nature as a knowledge-intensive industry, with clear knowledge spillovers potential in domestic and international markets, and strong government policies at both national and regional levels. The paper is structured as follows. First the literature surrounding the creation, dissemination and utilisation of knowledge, and the role of geographical proximity highlights a range of inter-related factors for analysis. Second, the methodology section evaluates the biotechnology industry against these factors, to establish its relevance, and the methods for analysing the Australian biotechnology industry specifically are outlined. Third, the results from the Australian biotechnology industry are then analysed in terms of knowledge creation, dissemination, and utilisation. Finally, conclusions are drawn concerning future policy for this his industry, and the potential focus for future research is discussed.

LITERATURE: KNOWLEDGE CREATION, DISSEMINATION AND UTILISATION MECHANISMS AND THE IMPORTANCE OF PROXIMITY

Knowledge Creation: Government, Universities and Industry

Etzkowitz and Leydesdorff (1997) developed the ‘Triple Helix’ framework, arguing that innovation creation occurs at the intersections between government, university and industry. Frenz et al (2005) discovered, however, that the level of UK firm-UK university cooperation is very low, concluding more generally, that firms must have a certain level of absorptive capacity (defined by the proportion of science and engineering graduates in the workforce, level of firm R&D expenditure, and organizational capability) before entering into cooperation with a university. Once established, however, this cooperation was found to have a positive and significant effect on innovation. They also argued that the most consistent finding to come out of regional total factor productivity growth studies was that the stock of human capital enhances the absorptive capacity of firms, facilitating local technology transfer, local and regional knowledge spillovers and growth.

In the knowledge-spillover theory of entrepreneurship (Acs et al. 2004), however, it is also argued that levels of knowledge-based entrepreneurship might be affected by (1) the ability of private firms and public institutions to generate new knowledge; but also by (2) the degree to which this new knowledge is disseminated to the wider economy as well as (3) the degree to which individuals and firms are able to exploit this new knowledge. The absence of a domestic industry base and/or the absence of domestic knowledge-creating institutions, such as public research institutes, might mitigate against the emergence of knowledge-based entrepreneurship (Audretsch and Lehmann 2005), as might the absence of foreign multinationals in a region, able to import such knowledge from outside.

Additionally, however, individuals or organizations with market knowledge or other resources may not be aware of the new knowledge because of a lack of dissemination, and therefore fail to invest, or under-invest, in the knowledge or in new firms (Audretsch, 2004). Individuals may also fail to commercialise new knowledge via entrepreneurship, if they underinvest in commercialization activities or fail in their attempts to commercialize due to a lack of market knowledge, ability to manage the new knowledge effectively or insufficient entrepreneurial ability. As regional knowledge and innovation systems are dynamic and evolving, these issues can also be affected by the nature of the region itself.

Knowledge Dissemination: Structures, Learning and Governance

The role of knowledge and its characteristics therefore also needs to be evaluated through the lens both of the capabilities of knowledge users and effectiveness of knowledge transfer/translation (Cooke et al., 1997; Braczyk and Heidenreich, 1998). Links between entrepreneurial growth, innovation, and networking, for example, has also led to an increasing focus on entrepreneurial firms networked together in various ways (Asheim and Coenen, 2006), Gordon and McCann (2000) identifying three sets of advantages in geographically based clusters and networks, derived from agglomeration (i.e. from external economies of scale, scope and complexity).

Crucial here, are issues surrounding the management of networks, the structures and forums in which the actors operate and the role of education and training and processes of learning, to enable networked knowledge processes (Pickernell et al, 2008). There are a range of forums and structures, for example, in which and through which knowledge creation, but also dissemination can occur, including direct spinouts of companies, and collaborations with various stakeholder groupings from industry supply chains, government institutions and universities. Cluster and network-based approaches also suggest a range of other formal and informal mechanisms in which knowledge creation and dissemination can also be encouraged. The suitability of the structures and for a used, however, will be factors of crucial importance in determining the success or otherwise of the knowledge creation and dissemination process.

Encouraging the take-up of new innovations through dissemination via education and training-based processes also allows individuals to be provided with knowledge about the innovation itself, as well as being inspired and convinced of the possibilities for success and mutual gain (Goffin, and Mitchell 2005). Such explicit, codified knowledge can, however, be encapsulated in formats and transferred to users who are able to interpret and utilise it independently from the context in which it was created, (Howells, 2002). The transfer of codified knowledge is not seen as strongly dependent on geography as codified knowledge can be transferred across geographic regions fairly readily, and reductions in costs and improved communications increase access to codified knowledge, rendering it less important as a source of competitive advantage. Tacit knowledge, it has been argued, however, does not always travel well, making it a key source of 'the *geography* of innovation' (Asheim and Gertler, 2005). This includes knowledge flows between firms, research organisations, institutions and public agencies that are embedded in a regional context. Frenz and Ougthon (2006), therefore, argue that, since proximity facilitates the transfer of tacit knowledge transfer and learning - both of which are important determinants of innovation - innovation activity takes on a strong regional dimension that may be reinforced by agglomeration economies in production and pools of skilled labour/human capital.

Effective and appropriate management of innovation creation and diffusion structures and forums are also vital to this process. In this respect, the three basic modes or mechanisms that can be applied are hierarchical state or corporation based, or the market, or social networks (Lowndes and Skelcker, 1998). Markets are sometimes, however, perceived as unable to adequately bundle the relevant resources and capacities between science and industry, and the complete vertical integration inherent in hierarchy restricts flexibility and incentives (Menard, 2002). Conversely pure networks of relationships based on trust and reciprocity are often insufficient forces to secure necessary directed outcomes (Rhodes 1997; Keast, and Brown 2002). Hybrid approaches therefore have the ability to limit or balance out the negative effects of an over-reliance on one governance mode (Menard 2002), through exhibiting a number of possible combinations and re-combinations of contract and trust to form effective strategic partnerships (Schaeffer and Loveridge 2002). Again, the suitability of the management mechanism used in the situation at hand will be important in determining the success or failure of the creation and dissemination process, particularly given that there are a range of processes and motivations of importance when examining these issues, depending on the nature of the network being utilised.

The relationship between learning, structures and governance modes provides the mechanisms to bring participants (and the various stakeholders) together to share resources and knowledge that are present in individuals or organisations. One scenario, for example, might see a myriad of key stakeholders from industry, government, and institutions (including universities and government research departments), utilising these interconnected mechanisms to generate and disseminate knowledge, innovation, skills, and training, and to operate management and governance structures appropriate to their own particular circumstances.

Knowledge Utilisation: Knowledge Asymmetry, Knowledge Management and Entrepreneurial Orientation

In order to exploit knowledge created and disseminated through networks, there is also the crucial role that entrepreneurship itself plays in the process. In particular, entrepreneurs require appropriate personal 'knowledge', resources and management abilities, encapsulated in the factors of entrepreneurial orientation, appropriate strategic evaluations seen in asymmetric knowledge provision between existing activities and the innovation, and appropriate knowledge management (Senyard, 2007). The issue of knowledge asymmetry, however, is a complex one as new knowledge by its very nature creates knowledge asymmetry (or lack of proximity between old and new knowledge – Boschma, 2005). This asymmetry cannot be too large for firms receiving knowledge, however, as they will be unable to use the knowledge received, and some symmetry of information is thus critical for relationships development and success as it develops trust (Fukuyama, 1995, Baranson, 1990), which positively affects decisions to maintain the relationship and creates stability through shared understandings and norms. Knowledge asymmetries exist because of differences in knowledge, business processes and resources (Brooksbank et al. 2007). Cimon (2004) further evaluated and categorised asymmetries as (1) information asymmetries; (2) knowledge asymmetries; and (3) learning asymmetries, with all three recognised as having a role to play in the process of organizational knowledge creation (Nonaka and Takeuchi, 1995; Ancori *et al.*, 2000), and arising from differing resource endowments (e.g. Barney, 1991) and absorptive capacity (Cohen and Levinthal, 1990).

The way in which this new knowledge is then managed will also be crucial for the strategic direction of the firm in many industries (Dyer et al., 2001). It is argued that firms should be able to increase their competitive performance through effective knowledge management, strategic learning and knowledge orientation, and that these are positively related to long term survival and growth (Salojarvi et al 2005; Matlay 2000). Salojarvi et al (2005) also state that firm success often depends upon an organisation's ability to create, utilise and develop knowledge-based assets. Despite this it is somewhat surprising that relatively few studies have examined the links between knowledge management and firm growth, instead concentrating on knowledge management alone (e.g. Kautz and Thaysen, 2001; Wickert and Herschel, 2001). Successful innovation requires managers to match 'technical' expertise, in areas such as technology and project management, with 'soft' skills in people management, to promote creativity. Few managers are either educated or experienced in both of these areas (Goffin, and Mitchell 2005, p. 27). Kirby (2004) thus advocates the use of Higher Education Institutions (HEIs) in promoting and reinforcing the development of such entrepreneurial skills in communication, creativity, critical thinking and assessment, leadership, negotiation, problem-solving, social networking skills, and time-management. These are all equally applicable to the creation and utilization of knowledge, the links with HEI also highlighting ways in which links can be made between external network and internal-firm-based processes.

Effective entrepreneurial behaviour is also necessary to prosper in competitive environments (Covin and Slevin, 1988, Lumpkin and Dess, 1996, Miller, 1983 and Zahra, 1993a). Within this context entrepreneurship, plays a pivotal role in facilitating links between research and industry (Abramson et al., 1997). Utilising Covin and Slevin's (1989) "basic uni-dimensional strategic orientation" concept a firm's behaviour can be categorised along a continuum that ranges from highly conservative to highly entrepreneurial behaviour in which a firm's position is referred to as its entrepreneurial orientation (EO) (see Barringer and Bluedorn, 1999; Lumpkin and Dess, 1996). The three main dimensions of EO are innovation, pro-activeness and risk. Previous studies (see Table 1) have consistently highlighted a positive relationship between EO and performance.

Table 1: Dimensions of Entrepreneurial Orientation

Author	**Dimension**	**Sample**	**Statistical Analysis**	**Study Conclusion**
Lee, et al (2001)	Innovation, Risk Taking Pro-activeness	137 Korean Tech Start Ups	Regression, Correlation	EO has positive, marginally statistically significant effect on performance.
Voss et al (2005)	Innovation, Risk Taking, Pro-activeness, Competition Scanning, Autonomy	324 US Theatre Groups	Regression, Correlation	Relationship between stakeholder influence and EO behaviours is transparent, managers develop reciprocal, strategic relationships that reinforce valued behaviours. When the interaction between stakeholder influence and EO behaviours is less transparent, managers must perform a balancing act to contend with complex, pluralistic and conflicting stakeholder demands and responses.
Zhou et al (2005)	Opportunity Recognition, Environmental Sensitivity, Environmental change and challenges	China 350 respondents to brand	Structural Equation Modelling Factor Analysis	EO has a more positive impact on tech based and market-based innovation when competition is intense
Wiklund and Shepard (2005)	Pro-activeness, Innovativeness, and Risk taking	465 Swedish Manufacturing and services firm	regression analysis and correlation	EO positively influences small business performance. High EO, high access to capital, and environmental dynamism did not increase performance.
Poon et al (2006)	Innovation, Risk Taking, Pro-activeness	96 small firms	Regression, Correlation	EO did not mediate the relationship between internal locus of control and firm performance. EO is a necessary mediator of the link between generalized self-efficacy and firm performance.

The Issue of Proximity: local and Cross Local Linkages

Despite the importance placed on geographical proximity in the literature (highlighted earlier for example in relation to tacit and codified knowledge), there is also evidence that knowledge creation, dissemination and utilisation processes can also have a wider geographical dimension. Boschma (2005), in particular, identifies five dimensions of proximity that can have an impact on learning and knowledge, and which, crucially, do not necessarily require geographical proximity. He argues that the need for geographical proximity for learning to occur is weak when there is a clear division of precise tasks that are coordinated by a strong central authority—organizational proximity—and the partners share the same cognitive experience—cognitive proximity (Boschma 2005: 69). He further suggests that spatial lock-in may be solved or even avoided by establishing non-local linkages. Findings from several empirical studies also suggest that non-local as well as local relationships are important sources for interactive learning (see Asheim and Coenen 2006, Jaffe et al. 1993, Feldman 1994).

Boschma (2005) suggests that shared formal institution structures [such as laws, rules and regulations that are the subject of governance] are not necessarily bound by geographic proximity. Instead, institutional structures can reflect a kind of balance between institutional stability (reducing uncertainty and opportunism) openness (providing opportunities for newcomers) and flexibility (experimenting with new institutions). To satisfy the need for co-presence to exchange tacit knowledge, cross-location networks could also bring people together through, for example, occasional travel (Boschma 2005). Asheim and Coenen (2006) argue, therefore, that there is a need for both local and distant networks for effective process and product innovation. This highlights the need, for factors related to knowledge (and its influence upon innovation and growth) to be examined within firms' entrepreneurial processes at both local and cross-local levels.

Summarising the Factors for Analysis

Synthesising these multi-faceted relationships between knowledge, how it is disseminated through the network, innovation processes and growth, creates a comprehensive range of factors for analysis, which can be listed under the following headings:

- *Knowledge-creation* relationships between firms, government and its agencies, and institutions, such as universities).
- How *knowledge-dissemination* occurs though the structures for disseminating knowledge (e.g. via spinouts, alliances, collaborative networks etc.), management and governance of the relationships between the sets of

stakeholders, and the education, training and learning required for effective dissemination.

- *knowledge-utilisation by the companies themselves for innovation-specific and more general growth-related outcomes*, by examining knowledge asymmetry (degree to which the knowledge is new / overlapping with existing knowledge), its management and synergy with strategic behaviours and plans that relates to entrepreneurial orientation in maximising the benefits of the knowledge.
- *Proximity issues* by evaluating the role and importance of local versus cross-local creation, dissemination and utilisation mechanisms

METHODOLOGY

In order to examine the absolute and relative importance of the identified factors, however, there is a need for in-depth study within knowledge-based industries. This requires a methodology that determines first a suitable industry for analysis, then a suitable region / nation, to provide a case study setting. Lastly, relevant methods of gathering the data are required.

Case-Study Industry Identification

Available literature recommends that owing to the myriad of stakeholders (governments, between university and within university relationships, external businesses including domestic and international partners, venture capitalists, contractors etc), and the complexity in both knowledge seeking and knowledge requirements, the biotechnology industry may be suitable for the in-depth study.
Governments assist in the development of a biotechnology industry through a policy framework aiming to compensate for market failures (Orsenigo, 1989). Access to resources and incentives, in particular financial resources from government, is of great importance in any theory explaining biotechnology (Harman & Harman, 2004),

as without this, the level of R & D spending may be less than the optimum for the economy (Erskinomics Consulting, 2003).

Knowledge in the biotechnology firm also often evolves as a result of synthesis of scientific, technological and business knowledge, and managerial skills, these knowledge systems coevolving as the firm develops (Liyanage & Barnard, 2003), often occurring between university and within university relationships. Therefore a firm's capability is a continuous synthesis of scientific, technological and managerial skills and knowledge requiring input from organisational learning and management strategies (Lane & Lubatkin, 1998; Zahra & George, 2002; Zollo & Winter, 2002) The advancement of the biotechnology industry is thus critically bound by knowledge and information asymmetries associated with scientific, technological and business related knowledge (Murray, 2002). Finally, in terms of the geography of relationships, Cooke and Laurentis (2006) found, for example, that UK universities and firms in the UK biotech sector, commonly enter into collaboration with overseas partners in addition to partners within the UK, for product innovation, distribution, licensing deals and supply contracts; and as such the UK biotechnology sector operates in a global marketplace. With specific regard to innovation, as distinct from other interactions such as research, joint patenting, purchasing or supplying, and other more informal collaboration, the act of commercialising new knowledge in the form of a product or service new to the firm or new to the market, Cooke and Laurentis (2006) found that UK biotechnology firms also innovate collaboratively. In the absence of distant spillovers from other sources, these firms often form collaborator relations with 'distant networks' to augment R&D knowledge for themselves. These occur broadly equally in the EU and North America, as well as more extensively in the home country itself.

This suggests that the biotechnology industry generally exhibits the knowledge generation, dissemination, utilisation mechanisms highlighted in the literature. In order to examine these processes in more depth, however, the cases were developed using Australian firms. Australia is often perceived to suffer from "smallness of domestic markets" (Felsenstein and Portnov 2006) and owing to this, their spatial proximity relationship profiles are of interest. This research and analysis occurred within the 2005-2006 period, when Australia's biotechnology industry was experiencing growth. Market capital as at December 2005 for biotechnology, medical devices and other healthcare companies whose stocks are listed on the Australian

Stock Exchange (ASX) is A$42.4 billion (157 companies) up from A$27.1 billion in 2004 (Australia Government Initiative, 2006). Partly as a result, Australia now has more biotechnology companies relative to GDP than any country except Canada (IMB 2005). In 2006, there were 427 core biotechnology firms with 625 firms in medical devices (Ausbiotech 2007). The majority of these being small to medium enterprises, recorded in the Australian biotechnology industry (Hopper & Thorburn 2005). There is, however, a relative paucity of research of this important industry in the Australian context (Senyard, 2007), and in particular, an evaluation of the factors of importance to government policy when seeking to encourage the industry's successful development and growth.

Table 2: Summary of Case Study Firms' Background Data

Title	Case One (TT)	Case Two (PB)	Case Three (GT)
SUMMARY DATA:			
Type of Firm	Start Up (R & D)	Private	Ceased Operating
Fora for Knowledge	University	Industry	Incubator
Knowledge (IP)	Patents Secured	No Patent until later	8 Patents
Product Definition	Platform is a patented, defined, set of protein complexes	Diagnostic technical platforms includes enzyme-linked immunosorbent assay (ELISA), indirect fluorescent antibody test (IFA) and rapid lateral flow devices	Blood-based monitoring tests for performance animals, initially the performance horse
Stakeholders	Academic Scientist Director Commercialisation Manager	Scientist/CEO, Founding Members, Board of Directors	Academic Scientist, CEO, Board of Directors
University Role	Positive Start Up, Continuing Relationship	Negative Prior Start Up Experience with University	Minor prior commercialisation role at university , Indirect use of university resources (knowledge) translated to own IP
Government Role (Funding)	Yes	Yes (later)	Yes
Board of Directors	Scientist did not want to be on Board	Scientist is currently on Board	Scientist wanted to be on the Board but did not
Strategic Orientation	Technology Driven: Target: Big Pharmaceutical (further funding)	Customer Driven, Target End customer (Hospitals	Technology/Market Driven. Target: Equine Industry

Data Selection Methods

A 3-stage data selection process was chosen to examine the issues in the Australian context, with questions concerning proximity also built into each of these stages. First analysis was conducted into available secondary literature sources, to establish the knowledge creation environment. This was combined with (15) in-depth face-to-face semi-structured interviews, to explore knowledge dissemination. The interviewees were purposively selected (e.g. see Patton, 1990), according to their differing roles in the management and governance, fora and structures, and learning processes which surround knowledge dissemination. These stakeholders in the 'triple helix' came from Industry (industry association Ausbiotech members, commercialisation managers, venture capitalists, biotechnology employment specialists, entrepreneurial managers of established start ups) Government (both Federal and State-level), and University (science academics, commercialisation managers).

Finally, 3 case study companies (again purposively chosen, this time for their divergent experiences, summarised in table 2) were also analysed in-depth, to examine the role and importance of the internal firm-level activities in knowledge utilization (commercialisation) processes.

The three case studies of firms show varying stages of firm development.

The first case study is still conducting clinical trials and is publicly listed on the Australian Stock Exchange. It retains close links with its affiliated university (who retains share ownership) and is, at present, looking for large global pharmaceutical partners to continue product development.

The second firm, the most established of the three, has been very successful in the global markets and continues to develop new products.

The third case study evaluates a business which no longer operates. The cases were purposively selected to highlight different outcomes, product definition, age, and provide a snapshot of knowledge utilisation behaviours (entrepreneurial orientation), knowledge asymmetry, and knowledge management characteristics of the companies.

The three key individuals chosen for interview from each case-study company were: the scientist who developed the science/technology and sought to commercialise the product/service; the individual who provided the key relationship for business information and processes during start up; and the current CEO.

The case-research again used a semi-structured interview guide on topics of knowledge asymmetry, entrepreneurial orientation, relationship characteristics including proximity themes and impacts on relationships developed.

Data Gathering and Analysis

Bothe the secondary literature review/industry interviews and cases including interviews were used to examine knowledge creation, utilization and dissemination processes. First, owing to confidentiality arrangements, the individuals and companies are not explicitly identified in the results. The interview-based research in industry interviews and case interviews developed protocol that included open-ended questions to allow a natural conversation flow around the common set of issues (Patton, 1987). The interviews conducted lasted between one and a half and two hours. Individuals sought were first telephoned, explaining the request and research being conducted. This was followed up by an e-mail document and request for interview. A follow up telephone call the week after the e-mail was sent guaranteed a high response to requests. Interviews were then conducted during the two weeks following the follow-up telephone call where possible, in environments that were suitable for the respondent, in most cases, their offices.

The interviews were recorded on mp3 audio. This was transcribed into a hard copy format. Where necessary, the initial interview was followed up by a further interview to clarify responses. A database of responses was then created, containing the answers of all the interviewees to the specific topics. Analysis of the interview data was then undertaken using the five stage analysis process suggested by McCracken (1988). The first stage involves treating the statements in the interview on their own, without making connections to other parts of the interview. In the next stage observations are developed, individually, then according to the evidence contained within the interview and then according to the literature. The third stage involved interconnecting these developed observations by use of previous literature. The interview schedule/transcript was then used only to check the ideas as the observation comparison process is undertaken. The fourth stage involved collective analysis of the collected, developed observations and statements, to subject them to analysis, to investigate any consistent themes or inconsistencies which may be developed. In the fifth and last stage, these themes and patterns were investigated through the interview programme as a whole, to examine the themes amongst the interviewees.

Table 3: Official Knowledge Creation Strategies

Package	Overview	Total Funding and Duration	Key Knowledge Support Strategies
Backing Australia's Ability (BAA I and II)	General science and Innovation package, focused on three key elements in the innovation process: • strengthening Australia's ability to generate ideas and undertake research; • accelerating the commercial application of ideas; and • developing and retaining Australian skills.	Total duration: 2001-11. Total Funding: $8.3billion.	**Developing and Retaining Skills** The package supports the long-term sustainability of Australia's skill base in the enabling sciences and the encouragement of positive attitudes toward science and innovation in the community. It promotes this by: • Funding an extra 5740 higher education places in ICT, mathematics and science at Australian universities ($350.5m) • Improve teaching in Innovation, Science, Technology and Mathematics ($38.8m) • Enhance capabilities of government schools to build stronger scientific, mathematical and technological skills of Australian students and to encourage school-based innovation ($373m). • Questacon Smart Moves: an initiative to raise awareness of science and innovation among young Australians and encourage participation in science and innovation industries ($15.1m) • Science Connections Programme: initiative to raise awareness of the contributions of science and innovation in the broader Australian community ($25.8)
National Biotechnology Strategy (NBS)	Provides a framework for the development of biotechnology in Australia. The strategy addresses six key themes: • Biotechnology in the community; • Ensuring effective regulation; • Biotechnology in the Economy; • Australian biotechnology in the global market; • Resources for biotechnology ;and • Maintaining momentum and coordination	Total duration: 2000-08. Received initial funding of $30.5m in 2000, followed by additional contributions of $66.5m and $20m through BAA I and II.	**HR for Biotechnology Development** The key objectives are: • enhance management skills in the biotechnology sector; • attract high quality researchers and experienced leaders; • encourage entrepreneurship; and • monitor demand and supply for specialist skills. The key strategies are: • Improve management of research, intellectual property and technology within established firms and new enterprises; • Develop, attract, motivate and retain high quality researchers, particularly in those fields where Australia has strong capacities to commercialize research outcomes; • Maximize technological awareness and capabilities throughout industries that will be developing and applying biotechnology • Develop programs and systems to foster entrepreneurship • Monitor emerging skills needs in the biotechnology sector and develop appropriate responses.

Source: Stephens et al (2006)

RESULTS

Knowledge Creation: Overall Context

The results of the industry interviews conducted are now briefly outlined in terms of examining the context and role of the 3 main sets of stakeholders (the industry and its firms, government and university). In terms of the Australian biotechnology industry's stakeholders and knowledge creation policies, there has been a particularly strong Australian federal government policy in place, in conjunction with university institutions and the government, as highlighted in table 3.According to Stephens et al (2006), Australian biotechnology, has a research strength underpinned by its universities, its federal research body (Commonwealth Scientific and Industrial Research Organisation (CSIRO), and other leading institutions. The majority of Australian biotechnology firms in 2004 (60 per cent) are less than six years old (Department of Industry Tourism and Resources, 2004) and the industry is developing through small, dedicated entrepreneurial firms staffed mostly by scientists (Curtis et al, 2006). Australian State Government initiatives have also shown an increased focus on biotechnology research creation, dissemination and utilisation agendas. Specifically, current programs developed by the Smart State Strategy (Queensland Biotechnology Strategic Plan 2005) include:

- Smart State Innovation Projects Fund: Consists of $60 million over the next four years to support national and international alliances and collaborations between research organisations and industry.
- Biotechnology Commercialisation Pipeline: Assists new biotechnology firms to access private sector finance and enables them to progress along the commercialisation pathway.
- BioStart Fund: Provides access to early stage financing for startup firms.
- Current commercialisation training opportunities will be extended through the
- Mentoring for Growth and Innovation Start-Up Scheme program.
- Queensland Biocapital Fund: Through the QIC to l stage later venture capital financing to ensure the establishment of globally competitive bio-businesses.

- The Government will raise investor readiness by encouraging participation in the Commercialisation Bootcamp and Masterclass Program through the Australian Institute for Commercialisation.
- Smart State Innovation Skills Fund: Providing A$ 12 million to attract and retain leading scientists and build skills in Queensland.

The biotechnology industry provides a context of strong government support and policy initiatives related to the creation and use of knowledge, with a strong potential role for universities in developing the industry, but also with key governance issues concerning how these knowledge processes can be managed and developed for the most effective outcomes, given the different stakeholders involved, both domestically and internationally.

Knowledge Dissemination Processes

Interviews with (15) key industry stakeholders indicated question marks over the (strong) role of government hierarchical-based management in focusing university agendas in particular, in biotechnology and commercialisation. As previously shown, governments through financial provision to biotechnology programs also influence knowledge dissemination processes through funding reporting requirements that impact what type of information is disseminated, to whom and frequency of this dissemination. An inability to satisfy these reports places doubt on future funding and further development. Traditionally responsible for funding basic vs applied research, governments are now shifting greater commercial responsibility on universities and a focus on managing outcomes:

> '*The main change has been really almost foisted upon universities by government policy and that is the sense that they have to manage the outcomes of their research, which was never ever something that was really on the agenda in universities. Ten years ago it was that there would be papers published, there would be a contribution to the academic arena, but there would not be necessarily be any transfer of that information into commercial value or into industry.*' JC

Unsurprisingly, therefore, management and governance conflicts occur between the commercialisation agenda and the university bureaucracy and traditional social agendas:

> '*There are additional pressures of managing the conflicting roles within academia. It's actually very difficult to be entrepreneurial in a professional bureaucracy and universities are the classic professional bureaucracy…Essentially universities as professional bureaucracies have really got to – well the mantra is that everybody is equal, okay. But in business, everybody is not equal and that's the dilemma that you have when you're an entrepreneurial scientist in a university.*' JC

The more-market based current approach to exploitation of university knowledge, in a university model otherwise characterised by more hierarchy-based mechanisms also highlights the key role of the commercialisation manager, who has to act as a conduit between government and university policy, and the needs of industry and academic scientist. The process of undertaking this role, however suggested much greater use of network-based governance for commercialisation managers, particularly with regard to their relationships with academic scientists.

> '*Researchers understand that they've got to have a conversation with someone that's knowledgeable before they take that particular publication. [However] clearly you can't have a commercialisation officer company vetting every publication.*' AMB

The university context also adds another dimension that affects the relationship between the scientist and commercialisation manager, because the commercialisation process is an additional role to the one traditionally carried out by academics.

> '*Remember as business manager, commercialisation manager, you've got no power to make people do anything, particularly in universities. I mean in business you say "Okay, if you don't want to do that, you'll have to leave the*

> *organisation." In the universities "If you don't want do that, I can't stop you." There's no power within the system.*' JC

This highlights the varying motives and outcomes that the commercialisation manager has to manage: the scientist and their motive to publish, the university and their motive to dissuade the scientist to publish if it will reduce the value of the IP and potential returns for the university, and the motives of the commercialisation manager who wants to manage the information to give industry and government a compelling proposition to attract significant funding. Developing a cooperative culture between the business units, universities, and government was therefore recognised as integral to the relationships needed:

> '*So you need people in universities – and there are not many of these people – who can bridge that gap between the science and the science culture and the business and the business culture*.' PR

In contrast to the hierarchical governance push on universities and industry from government, commercialisation can occur through spinouts as a way of disseminating knowledge seemed to be more towards a market-based approach than hierarchical. An examination of the commercialisation structures utilised by universities themselves, also highlights a focus on more market-based governance modes, separated from other parts of university management, with continuing conflicts between this and more traditional university approaches.

> '*Commercialisation is not a core business for the University. That's why – I think that's why [a University name omitted] puts it out into [its commercialization unit name omitted], because it's not actually a core business. Whereas their core business is education, teaching*.' JC

In terms of the impacts on learning processes, however, the inherent challenge for the academic scientist however, is how to manage the additional commercial responsibility produced by these changes:

‘*There’s always this tension. When you’re outside the system you think “why don’t they do this? Surely they want to commercialise what they’ve done”. But when you’re in a university you’re fighting for grants, you’ve got PhD students, you’ve got your teaching work, you’ve got your research, you’ve got your administrative duties, and then they want you to commercialise. Yeah, and you’ve got insecurity of tenure. …*’ AMB

This also had a knock-on effect on perceptions of the structures and fora for dissemination in place. Specifically respondents recognised similar results in start-up behaviour in universities, questioning the “forum” (i.e. starts- ups), as a result being utilised for knowledge dissemination (and utilisation) :

‘*And part of [the university] their charter was to create X number of spin-outs in a certain amount of time…Whether any of them would be useful or not is another thing and also the state government at that stage had a particular funding scheme that allowed, [name omitted], to set up spin off companies and get funding for them. …They have a certain amount of intellectual property; they’re managed by the head of the [name omitted, commercialisation unit] plus a commercial development officer who’s working on it part time and it’s pretty much a cart without wheels. It just sits there and does nothing*.’ RIB

The appropriateness of the allocation of funds to public institutions including universities for research and developments versus private institutions and research centres was therefore questioned by several industry respondents:

‘*You look at the major recipients of funding out of government. Go back and look at the last seven years, since they announced in 1999 that they were going to concentrate on biotech. Have a look at all the funding for life scientists you'll find about 95 percent has gone to universities*.’ KA

Following this agenda, government funding and start-up programs have reflected in changes of start-up behaviour. Several respondents argued that this may just be an indication of being able to access funds, rather than the policy creating sustainable firms or growth.

'For instance, the state government in grants that invest in commercialisation of new technologies have to be granted to a company. So you see universities doing things like forming a small, really, shell company, so they can take an $80,000 ISIS grant or a $100,000 COMET grant because they have to, not because it's necessarily the right vehicle to put that piece of IP in at that point in time.' AMB

The evidence presented therefore highlights a number of different knowledge governance modes at work simultaneously in this industry in knowledge dissemination processes. Specifically, a strong government hierarchical mode is seemingly in place between the main stakeholders of government, industry and universities. Simultaneously there appears to be an incomplete move towards a more market-based regime for universities in dealing with commercialisation, and seemingly more reliance on network-based modes within universities between the scientists and the commercialisation manager, to deal with the additional emphasis for universities to commercialise their knowledge.

Table 4 : Knowledge Utilisation Processes: Case Study Results

Process	Case One (TT)	Case Two(PB)	Case Three (GT)
Knowledge Asymmetry	No	No not for management team, Yes between scientist and board	Yes Various forms
Knowledge Relationship EO: Risk Taking for Scientist	Calculated (Remained in position, though uncertain outcomes, support by stakeholders)	Very High Risk (Customer/market driven) Market Leader	Very High (Scientist left job, International set up)
Knowledge Relationship EO: Proactiveness	Very High (Prioritised)	Very High (Left job, mortgaged house)	High (Opportunities recognised, difficulty with timing and funding)
Knowledge Relationship EO: Innovativeness	Suite of Potential Applications for Platform	Very High (Customer/market driven) Market Leader	Product Definition failure
Knowledge Management: Trust	Yes	High between founding members	None (Board and CEO)
Knowledge Management: Communication	High Weekly, Informal	High, Weekly, Informal at commencement, Reduced as progress (Board vs Management) More Structured as more established	Low ties with Board (proximity?) High level of communication between staff and management
Knowledge Management:	High	High commitment at commencement	High at commencement Low at cessation

Commitment			

Knowledge Utilisation Processes

The case study firms exhibited different outcomes, product definition, age, and thus provide a snapshot of differing categories of knowledge asymmetry, knowledge relationships seen through entrepreneurial orientation and knowledge management. This did allow, however, analysis of how the factors highlighted as of importance to knowledge utilisation worked differently in the 3 case study examples, as table 4 illustrates

In comparing the three cases in terms of the key constructs of knowledge asymmetry, entrepreneurial orientation and knowledge management, the following key differences can be noted.:-

- The failed case (3) displayed more knowledge asymmetry, compared with other two. In terms of knowledge relationships, the failed case exhibits, in particular, a product definition failure in innovativeness, compared with the other cases. In terms of knowledge management, trust and communication were particularly poor in the failed company compared with the others. Knowledge asymmetric behaviour was exhibited in two cases, both between the scientist and the board of directors with restricted information flow on strategy and science. This lack of communication has further implications for accurate strategic decision making and the 'best way forward' with the potential to make less effective decisions as a team.
- All three cases show high levels of knowledge relationships through entrepreneurial orientation. This is not unusual based on the inherent nature of the biotechnology industry. High levels of pro-activeness and risk taking behaviours were seen in cases two and three, with the first case shown moderate risk behaviour.
- There are interrelationships not only between knowledge management characteristics of trust, communication and commitment but also between elements of communication and commitment and asymmetric behaviours, risk and trust constructs, and knowledge asymmetry and perceived risks.

To summarise, therefore, unlike cases one and two, case study three experienced faults particularly in knowledge asymmetry, knowledge relationships and knowledge management characteristics. The three cases also highlight the complexity of the interrelationships between the factors in these biotechnology firm start-ups.

Proximity Issues

In terms of the role of local and cross-location national and international linkages with a variety of stakeholders for knowledge creation, there are specific issues related to attracting and retaining talent in the Australian biotechnology industry highlighted by Stephens et al (2006). Fontes (2006) has also recently highlighted that biotechnology firms also form collaborator relations with 'distant networks' (Fontes, 2006) to augment access to their own research (often-non networked) knowledge spillovers from their own localities.

Knowledge Dissemination Overall

In terms of knowledge dissemination, the interviews with key industry stakeholders highlighted that the role and importance of geographical clustering of the industry was not clear-cut:-

> '*What is happening is that with the [name omitted] and the [name omitted] and a few other smaller features we are getting clustering but it's not in the like industry. So you are going to get a few biotechnology firms coming together and we are still getting minor cross fertilisation and some synergy but not to the extent of the actual clustering theory*.' JK

This also highlights the use of universities in knowledge spillover indirectly through the provision of centralised facilities, education and training. This may assist in innovation dissemination in ways other than spinouts, university proximity also being discussed in terms of providing (agglomerational) access to resources.

> '*You are also finding more satellite-like clusters coming out of universities. I don't think it's an issue of dependency on the universities. It's more like a security blanket, of the university is right there, and from the scientists who utilise not only the human capital but also the equipment capital*.' JK

Knowledge Dissemination Cases

Finally, in terms of knowledge dissemination, table 5 below indicates that for cases one and two international linkages seemed to be beneficial to utilization. For case three, however, the cross-local linkages seemed to increase knowledge asymmetric behaviours, re-emphasising the lack of effective knowledge management in this case.

Table 5: Proximity Issues in the Case Studies

Title	Case One (TT)	Case Two(PB)	Case Three (GT)
PROXIMITY ISSUES			
International Linkages	Use of International and bonding networks (informal) in product development, bridging networks in business development	During start up, limited international links as business developed further extensive links including international markets and further links including international partners in continuing product development	International bonding for processes for product development, and sought international markets. Potential to move internationally with pressure from the board increased asymmetric behaviours within the team and created further complications during business development.

Thus, the role and importance of proximity seems to differ depending on whether the process in question is knowledge creation, dissemination, or utilization based. In addition, for utilization processes, it may also be interdependent with knowledge asymmetry, EO, and knowledge management processes at work within individual companies.

CONCLUSIONS

These results indicate the heavily government-influenced nature of Australian biotechnology industry-policy both in knowledge creation and knowledge dissemination mechanisms, the evidence suggesting a very hierarchy-based approach from government. This contrasts with the more market-based approach towards which university management of spinout processes seems to be moving, and the seemingly more network governance based approach that commercialisation managers are employing in their dealings with the academic scientists, highlighting hybrid governance currently at work, with respondents questioning the effectiveness of such behaviour. Commercialisation managers are the conduit of information flows between government and policy, the central university research program and academic scientist. They therefore need to separately manage a plethora of complex relationships being generated from disparate motivations and stakeholders seeking differing outcomes, using and being affected by different governance modes. These include the relationship between the commercialisation unit and scientist, the relationship between the commercialisation unit and the central university research programs. In terms of knowledge utilisation processes, the case-study evidence indicates that the factors identified in the literature were of both of relevance and are interlinked both with each other and also with issues related to the impact of local and cross-locational linkages.

Broadly, the data presented indicates that the factors identified from the literature in terms of knowledge creation, dissemination and utilisation are of relevance. There is, however, also a clear need for further research which allows a more developed understanding of how the factors interact with each other and with issues of proximity. In particular, a wider range of firm cases needs to be examined in order to examine more fully the constructs of knowledge asymmetry, entrepreneurial orientation and knowledge management, in order to both analyse their importance and their interrelationships with knowledge creation and dissemination mechanisms.

In terms of policy for the Australian biotechnology industry, however, the results as they stand suggest the need for improved dialogue between the stakeholders in such new firm development, both in the external environment and internal to the firm itself. Recognising differing research agendas, expectations and motivations of knowledge creating actors involved, and their perceptions of knowledge dissemination processes, may also create better appreciation and understanding of knowledge utilisation outcomes. The role of the university commercialisation manager seems one key area for focus, as is, potentially, knowledge management within the firm itself.

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