Graduate School of Business

A Multi-Level Investigation of Australian Innovation in Sustainable and Regional Development: Generation of a Practical Policy Model

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: ………………………………………….

Date: 31/08/11

Abstract

Australian innovation is driven by policies promoting university, industry and government cooperation. The success of such cooperation for regional and sustainable development in light of the triple helix model was measured at CRC, SME and regional levels. Particularly in CRC-based activities it was determined that greater stakeholder involvement in the form of government, university, NGO and industry strategist input on the practicality of these models would lead to improved business and academic productivity.

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I would like to thank the following people for their contributions to this thesis:

- Professor Peter Galvin, my DBA supervisor, for his input and comments on the work incorporated into this thesis;
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- Professor Rene van Berkel for training me in Cleaner Production up to a level at which I could confidently write a publication on the topic and his input as co-author into the journal article incorporated into this thesis;
- Myles Strous of the Monash University, Gippsland Library for assisting me in using the EndNote programme to compile the list of references;
- Erica Matthews for consolidating the various documents that make up this thesis.

List of Publications Included as Part of this Thesis

1. Cooperative Research Centres and Industrial Clusters: Implications for Australian Biotechnology Strategies
   Alan R. Howgrave-Graham and Peter Galvin
   (Chapter 5 in: New Regionalism in Australia (2005) pp. 88-101)

2. Assessment of Cleaner Production Uptake: Method Development and Trial with Small Businesses in Western Australia
   Alan R. Howgrave-Graham and Rene van Berkel
   (Volume 15 (2007) in: Journal of Cleaner Production, pp. 787-797)

3. An Innovation and Development Model for Regional University Campuses
   Alan R. Howgrave-Graham
   (Volume 5(1) in: The International Journal of Technology, Knowledge and Society (2009) pp. 76-88)

4. An Interdisciplinary Knowledge Transfer Approach to Facilitate Sustainable Development: Australia as an Example
   Alan R. Howgrave-Graham
   (Volume 4(4) in: The International Journal of Environmental, Cultural, Economic and Social Sustainability (2008) pp. 11-16)

5. The Composition and Productivity of Australian Cooperative Research Centres, with Emphasis on their Participation In Biotechnology, Regional and Sustainable Development
   Alan R. Howgrave-Graham
   (Volume 6(3) in: The International Journal of Technology, Knowledge and Society (2010) pp. 67-81)

6. Case Studies on Environmental Sustainability in Australia: A Multi-level Review
   Alan R. Howgrave-Graham
   (Volume 7 in Press: The International Journal of Environmental, Cultural, Economic and Social Sustainability (2011))

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Statement of Contributions of Others

1) Professor Peter Galvin's contribution to the book chapter "COOPERATIVE RESEARCH CENTRES AND INDUSTRIAL CLUSTERS: Implications for Australian Biotechnology Strategies" published in this thesis was approximately 15%, limited to some of the theoretical framing in the early stages and focussing the ideas at the very late stages.

2) Professor Rene van Berkel's contribution to our publication in the Journal of Cleaner Production "ASSESSMENT OF CLEANER PRODUCTION UPTAKE: Method development and trial with small businesses in Western Australia" was that he provided the conceptual and methodological foundations for this exploratory research and that he collaborated with me on the resulting research paper.

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A MULTI-LEVEL INVESTIGATION OF AUSTRALIAN INNOVATION IN SUSTAINABLE AND REGIONAL DEVELOPMENT: Generation of a practical policy model.

Introduction

This is a dissertation by publication in which one book chapter and five journal articles have been compiled to form the thesis component of a Doctorate in Business Administration for which the coursework component has been completed.

The intention is to describe the existing level of innovation applied across Australia from the firm to the national and state government levels then propose an improved framework, test the models so generated for practicality and finally present a tested model that can be used to drive innovation policy. It is a primarily positivist study in which the government policy mechanisms implemented are related to outputs, both commercialisable and academic.

This study could thus be best described as one on science, technology and innovation policy for economic growth (STIG), as described by Aghion, David and Foray (2009), and discussed in more detail in the next chapter. It is aimed at overcoming a major challenge raised by these authors (that policy structuring is potentially politically charged) by introducing balance in the form of greater stakeholder involvement than ever proposed before. It is one in which the framework proposed is an evolutionary one and works towards sustainable innovation as suggested by Morlacchi and Martin (2009) when they highlighted future research needs for science, technology and innovation (STI) policy development (also to be discussed in more detail with other pertinent literature in the next chapter). The ultimate purpose of this thesis thus aligns with that of STI policy development in that it aims to serve the ends of society by helping to construct more effective policies for science technology and innovation as suggested by Morlacchi and Martin (2009). In this study it is to be achieved through research and development of a practical framework that incorporates greater stakeholder involvement and thus wider applicability as a policy guidance tool. This work should be viewed as the derivation of another, more rigorously tested map that these authors suggest are needed and should help the policy community navigate (but not universally define) the solving or ameliorating of societal problems. The intention is to include all categories of stakeholder that should be identified and canvassed in policy making or individual strategy development and incorporate a wider range than in previous models. Whether all stakeholders are relevant in future policy decisions, whether at the regional or national level, is less important than omission of one or more that could precipitate policy failure. Introduction of a wider stakeholder pool is intended to prevent the uncertainty and political issues reported by Nill and Kemp (2009) to constrain STI policy development, by increasing the knowledge base.

This main body of this thesis begins by investigating, in light of the literature, the current status of innovation in Australia. Results of surveys on stakeholders that would contribute to the developing or capitalising upon innovation are then related to the theoretical models so that the theory-policy gap that pervades the literature can be addressed. An example of how this is achieved here is by linking the theoretical triple helix model on university-government-industry links for innovation (to be elaborated upon in section 1.4) to its shortcomings as listed by subsequent authors when applied to policy development, then incorporating misgivings determined as the result of a study described in this thesis to finally propose of a new innovation model (or framework) with a greater chance of success when formulating policy. To ensure that a greater catchment of stakeholders contribute for formulation of the practical framework/model to be described in the final published chapter of this thesis; firm-level analysis (previously well documented and cited to some extent in this chapter and in later ones); regional-level analysis on Western Australian (primarily) SMEs and Latrobe Valley (Gippsland) stakeholders; and national-level analysis on Australian Cooperative Research Centres (CRCs) was conducted in light of the relevant literature on each of these topics.

This study is the first multi-level investigation in which national and state innovation within the current government CRC programme is described in terms of composition, funding, environmental sustainability practices, regional development and productivity. At the lower (below government and policy) levels, small to medium enterprises were evaluated in terms of environmental sustainability practices and awareness while innovation models developed on the basis of these studies were tested for suitability at the national and regional levels using senior Latrobe Valley organization respondents as a regional ‘sounding board’. It is a progressive study in which lessons from preceding articles in this thesis and emerging literature are used to move to the next level. It starts with a description of the Australian biotechnology landscape in terms of the knowledge network infrastructure underpinning it. Next the innovation practices of SME’s (small to medium enterprises) were investigated telephonically, particularly related to their environmental and economic sustainability. Findings in these two papers combined with innovation model literature allowed the formulation of a framework that was proposed in the next two papers, the first one to underpin sustainable development and the next one expanding upon the knowledge diffusion mechanisms to drive regional development. At this stage the models were only proposals based upon the previous two chapters and the literature. The next step in this thesis was to test these models by canvassing stakeholders at the national and regional level. The last two papers in this thesis convey the findings and a final model was proposed which overcome the errors identified in the literature and those embedded in the models initially proposed here. As such, this study is thus a progressive in that each successive paper builds on the errors identified in the literature or on the results of the preceding paper. It could be said that the thesis evolved on the basis of a Delphi study rather than having been thoroughly mapped out at the beginning.

The focal points of the thesis are environmental and economic sustainability, regional development and achieving economies of scale to enhance both academic and commercialisable outputs. The innovation models proposed in the publications submitted here are advances upon earlier ones in the literature and modified to incorporate the research findings of this study. These findings were determined using systematic testing and manipulation of the models until a unified framework was reached in the final publication chapter that could be considered suitable for practical application.

The literature review is structured in such a way that the published chapters are listed and described below, before a literature-based overview of innovation is given as the overarching theme of the thesis.

The following points indicate the major themes explored in the literature review:

- In section 1.1, an introduction of the term "innovation" and other terms relevant to this thesis are explored using the literature to outline theoretical gaps and the subjects studied for this thesis briefly introduced.
- Section 1.2 explores another new term used extensively in the literature, namely "science and technology policy research" and it explains why this thesis fits squarely within this paradigm, especially considering the focus on the preference for firm, industrial and national levels of analysis with growth as an objective.

- In section 1.3, the meanings of terms underpinning this thesis are explored in more detail to allow clear distinction between the meaning of innovators and entrepreneurs. This is especially important considering that all these role players (and their associated creativity) are essential in making innovation models workable and are included in the models proposed in this thesis.
- As this thesis builds upon earlier innovation models, it is essential that readers become familiar with existing models described in the literature to allow evaluation of the improvements made to them in the rest of this thesis – to this end further explanation is included in relevant later published chapters.
- Section 1.4 gives an historic overview of these models and innovation theory.
- Section 1.5 highlights why innovation is considered relevant to this thesis before the innovation studies described in the subsequent chapters are embarked upon.
- An introduction to the methods used for the research in subsequent chapters is introduced in section 1.6.

Publications (as they occurred in a book and journals) in support of this thesis are listed in the last section of this chapter. A brief summary of these in the order that they appear is provided below:

The first publication (Cooperative Research Centres and industrial clusters: Implications for Australian biotechnology strategies) is a book chapter on the background literature-based description of existing Australian CRC and cluster initiatives, using biotechnology as the example discipline studied, to form a background for the rest of the thesis. This publication is the first comprehensive description of the national and state drivers and strategies for developing Australian biotechnology competitiveness and compares the national and state systems to those overseas. In this paper, knowledge flows underpinning Australian biotechnology are depicted for the first time and lessons to be learned highlighted. An argument is proposed to broaden the definition of biotechnology to one encompassing any manipulation of living organisms for gain and this definition is used during the investigation for the two final publications in this thesis. The model of knowledge flows in this chapter is an important starting point as it gives an understanding of current systems and can equally be applied to other systems of Australian innovation involving CRCs. In this thesis, it forms a crude model to be built upon in later chapters to ones in which universities are seen to be more central in identifying and capitalizing upon opportunities.

The second publication (Assessment of cleaner production uptake: Method development and trial with small businesses in Western Australia) is the result of an investigation into environmental sustainability practices by small to medium enterprises (SMEs) primarily in Western Australia but also from other states, focusing on cleaner production and ecoefficiency. The questions asked of the SMEs were open-ended and broad enough to allow any innovations to emerge and responses were then sorted to determine whether they could be considered as sustainability initiatives. It forms an important contribution to this thesis as it tests a method considered (but then abandoned) for use in the rest of the thesis and introduces the sustainability aspect to be expanded upon and investigated later. Being a telephone interview with CEOs from a broad spectrum of SME industries in which the true purpose is not revealed until toward the end, it can be considered the first true reflection of SME awareness and implementation of sustainability initiatives in Australia as it eliminated social desirability error prevalent in preceding literature and discussed later. This study leads up to a later one in this thesis in which the level of SME involvement in CRCs is determined while the extent to which these SMEs were considered the innovators in CRC projects is investigated for the final two publications in this thesis. The first two publications discussed above can be identified as the cornerstones that underpin the rest of the thesis and the progression from this level to the next will be outlined below.

The third publication (An innovation and development model for regional university campuses) proposes a new innovation model for application in Australia and describes the knowledge networks that would assist in making it more practically applicable by policy makers. It was developed in light of the first publication in this thesis (about CRCs and clusters) and the literature especially on the triple helix model and its shortcomings. Although this publication came out after the next one included in this thesis (An interdisciplinary knowledge transfer approach to facilitate sustainable development: Australia as an example), it was listed earlier due to the knowledge networks described (applicable to both papers) and the focus on regional development. The innovation models depicted in these publications are similar (a point made by respondents in the final study of this thesis), with one focusing on regional and the other on environmental sustainable development. Both of these papers build upon the literature as they depict models that, for the first time, overcome shortcomings of earlier innovation models such as the triple helix model and draw the reader's attention to other opportunities for achieving economies of scale, allowing all stakeholders such as participating universities and SMEs to benefit, especially under time and funding constraints. These two papers also differ in that knowledge networks and Australian government initiatives in place to support regional development are focused upon in the regional development publication while the sustainability paper introduces three new types of environmental sustainability for development, two of which incorporate cleaner production and eco-efficiency as described and investigated in the preceding cleaner production publication in this thesis.

The two publications discussed in the previous paragraph set the scene for the research that forms the final two publications of this thesis. Before discussing this link, a lesson learned from the cleaner production paper should be mentioned. The methods used for these final two papers were changed from that used in the second cleaner production paper. This was because it was not deemed necessary use structured telephone interviews or to word questionnaires so that the purpose of the survey was not revealed until later in the interview to avoid "social desirability error", during which Bryman and Bell (2007, p.235) reports that respondents would state what they think the interviewer wants to hear. Besides, the phone interview questions were too vague with some respondents replying to a question such as "What innovations are you aware of that your company has implemented to improve operation efficiency and cut cost over the last three years?" with a list of innovations unrelated to cleaner production or eco-efficiency. This, and the issue of too much subjectivity in the cleaner production study, was addressed by broadening the scope of questions for the final two papers in this thesis using internet surveys e-mailed to the contact person for every CRC listed on the CRC website quoted later as well as paper surveys testing the above innovation models (and subsequent interviews if necessary) submitted to senior Latrobe Valley executives. In the e-mail survey to CRCs, examples of what the CRC is doing in support of its responses on environmental sustainability were requested, and follow-up interviews were conducted to clarify the largely open-ended questions and their responses from senior government, industry, university and NGO representatives consulted. USB memory sticks were given as an incentive to improve response rates and the questionnaires are included as appendices to this thesis.

The final two publications in this thesis report on the findings determined during the above studies. The first one (The composition and productivity of Australian Cooperative Research Centres, with emphasis on their participation in biotechnology, regional and sustainable development) gives an overview of these findings, giving more insight into the composition and operation of Australian CRCs and relating this to their productivity in terms of both commercialisable and academic outputs, thus reflecting on the extent to which the economies of scale proposed in the published earlier innovation models of this thesis apply. As important in this chapter is the revelation that individual business, farms or companies formed the largest proportion (by far) of “champions” and “innovators” in the CRCs, making revelations during the earlier cleaner production paper on SMEs especially relevant as opportunities for improvement can be determined and the role that universities or specialist centres can play in realizing these identified. This paper also reflects upon the level of clustering in CRCs as highlighted in the first publication in this thesis on the topic.

The final publication here (Case studies on environmental sustainability in Australia: A multi-level review) is one in which findings for the previous publication is expanded upon using unpublished data and focusing more on the three versions of environmental sustainability proposed in the earlier published chapter on sustainable development. A major contribution of this paper to knowledge underpinning innovation policy development is the modification of the models proposed in the earlier published chapters of this thesis to eliminate not only shortcomings of earlier models reflected in the literature but also reflect findings here on key government, industry, university and NGO strategist opinions in an Australian region reliant upon natural resources, namely Latrobe Valley, Gippsland. The final purpose of this publication is to bring together the research findings of this thesis in such a way that the results could be used to drive policy for regional and sustainable development. Opportunities for universities, centres, NGOs or other stakeholders (depending upon the nature of individual projects) to use “creative problem solving” (discussed later) to maximize innovation outputs through economies of scale and serendipity are highlighted.

As this thesis is one grounded in innovation as it applies to science and technology and related to policy development, it is important that these terms, together with other relevant concepts such as sustainability and knowledge networks get some attention in the literature review (next chapter) and in the relevant later publications.

1. Literature Review

1.1 Overview of Innovation and other terms relevant to this study

The title of this thesis alludes to the fact that innovation is its key concept as it is the driving force behind both the regional and sustainable development which are discussed in detail throughout the thesis. The models proposed and practices investigated at the "multiple levels", namely regional, SME and national are all those related to the relevant organisation's innovation practices, while other investigations, such as those concerning the organisation's composition or funding, are to be related to the its innovation output, hence the need to describe innovation as it pertains to this thesis.

According to Nonaka (1994), innovation can be conceptualised as a process in which organisations create and define problems and then develop new knowledge that can be applied to solve these problems. This definition is one that particularly suits the theme of this thesis as creative problem solving is central to the models proposed in the later chapters. However, in the models proposed, the problems are often not "created" by the organizations but are ones that the organizations need to address, such as decay of timber or failure of the waste treatment process. Innovation is needed to overcome these problems and this thesis focuses allowing the process of solving these problems to create alternate commercialisable opportunities through serendipity or what Tidd (2006, p.4) referred to as 'lucky accidents". The new knowledge would thus be applied to solve the problems but sometimes also used to realize unexpected opportunities. Bellini and Piccaluga (2000, p.122) indicate how, in the "knowledge economy" (referred to as the consolidation phase in capitalist development) in which competitive advantages are determined by accumulating knowledge and translating it successfully into innovative processes. The Australian Commonwealth Government (2008) (Department of Innovation, Industry, Science and Research) succinctly describes innovation as "good ideas put to work" (p15) and indicated that being innovative incorporated the processes of creative problem solving or solution seeking – designed to produce practical outcomes. These approaches are good in that they are holistic and suit a national innovation drive. However, McFadzean et al. (2005) among numerous other authors report that there is still enormous diversity in the views and approaches as to what actually constitutes innovative activity. It has been widely reported as a firm-based one and strongly skewed towards commercialisation activities but a wider approach is preferred here in light of the diversity of activities to be covered, such as in applying cleaner production or environmental conservation which may not necessarily have commercialisable outcomes but, as will be seen later in this thesis, have groups or CRCs dedicated to them in Australia.

The introduction of peripheral concepts such as paradigmatic shift and creative thinking by Cannon (1993) and Gurteen (1998), and marketing and entrepreneurial philosophies by Koontz and (1990) and Zahra (1995) have created some confusion in trying to develop a universal definition of innovation. For this reason, and because of the regional and national policy focus of this thesis, innovation is going to have the simplest of meanings as described by the Department of Innovation, Industry, Science and Research (2008, p.15), "putting good ideas to work". Using this definition allows this thesis to go beyond the firm-centred approach described by many authors such as Peneder (2010) in which innovation as a term has been channeled through various process models to have different phases such as idea generation, research design and development, prototype production, manufacturing, marketing and sales (Dooley and O'Sullivan, 2001; Knox, 2002). This broader definition allows inclusion of innovation related to major focuses of this thesis, namely innovative policies for regional and sustainable development.

The innovation models proposed in the literature and discussed later in this chapter are suitable for innovation in manufacturing but are less applicable where innovation in other fields such as conservation and education are concerned. In combining these models in which innovation is considered a process and incorporating considerations of the product, McFadzean et al. (2005, p.353) developed another definition of innovation, namely "a process that provides added value and a degree of novelty to the organization and its suppliers and customers through the development of new procedures, solutions, products and services as well as new methods of commercialization". Allowing the term "organization" to mean any grouping of collaborating organisations, a state, or even a nation and depending upon the definition of 'commercialisation', this definition may also be applicable to this thesis. For this definition to work here, commercialisation must fit the definition proposed by the Australian Institute for Commercialisation (2006, p.21). It states that "Commercialisation is the transformation of ideas into economic outcomes. They could be in the form of a product, a service, a process or something of value to the community". Only with these provisos could McFadzean and colleagues' definition of innovation be applied in this thesis as commercialisation is seen as something beyond the deliverables of combinations of patents, licenses or start-up companies. In this thesis, cleaner production technologies are included in the expanded definition (in Chapter 3[1]) and a focus of conservation-based cooperative research centres (CRC's) in Australia is discussed in Chapters 6 [2]and 7[3]. It would, however, be a disservice to consider the non-commercialisable outcomes and cleaner production as not being innovative because of their different focuses.

[1] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80
[2] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[3] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

Due to the importance of innovation in driving organisational and national advancement, publications are constantly being generated that explain the underlying rationale of innovation and that describe case studies in which innovation has been more or less successfully applied. Numerous authors have also generated models while others have tested and modified these to fit different circumstances, such as the development of the triple helix model for government, university and industry collaboration and determination of its suitability for developing countries as will be discussed later.

According to Evangelista et al. (1998) at the time of their writing, many national policies for innovation were based upon idea that firms face only one problem in innovation which was the scale and finance of research and development. To this end, so-called linear models, in which innovation occurs in a roughly linear progression from research to invention to innovation and the diffusion of new techniques were developed and adhered to. As mentioned by Mytelka and Smith (2001) while describing the history of the innovation literature, challenges such as productivity growth in the 1980s, increased competition in the 1980s and problems associated with equity in the 1990s clearly highlighted the insufficiencies of early innovation theory. These authors also concluded that innovation studies should remain an area of intellectual vitality and advancing innovation will require clear recognition of and willingness to overcome existing limits and weaknesses to the theory. Evangelista et al. (1998) identified that industries and firms face a variety of quite different problems, creating the need for a wide range of innovation models beyond the linear models to be discussed later. Since these authors indicated the shortcomings in earlier innovation models, there has been a flurry of publications in the innovation literature. The purpose of this thesis is thus to build upon current innovation literature by addressing perceived shortcomings of more recent models, to develop new models that overcome these shortcomings and determine the suitability of these new models in the Australian context for policymaking at regional and national levels in light of the corporate and national innovation culture. Mytelka and Smith (2001) indicated that social scientists had brought theory closer to policy by emphasising the contextually specific nature of innovation processes but had not yet entirely bridged the gap. This thesis is directed at narrowing the theory-policy gap by expanding upon the innovation theory and relating it to the Australian context.

As the title of this thesis suggests, a variety of themes emerge which would need to be investigated to allow better, more informed strategy and policy development for innovation and advancement of sustainability, regional and national development.

The field of biotechnology is touched upon throughout the thesis as the author has experience of numerous examples that can be used to clarify the premises proposed.

Sustainability and innovation (as already defined) for national and regional development is the main focus here with commercialisation and research outputs, attitudes and research being measured at the small to medium enterprise (SME), national and regional levels using the Australian regulatory and cultural environment, and support structures for innovation stimulation as a backdrop. Some regions in Australia would be defined by the presence of resources present such as minerals or agricultural products while other services or products present occur as secondary outputs, with banking and some biotechnology initiatives as examples.

Gippsland, the focus of the regional level innovation for this thesis is specifically identified with its brown coal energy generation, dairy farming and pulp and paper processing. Latrobe Valley is geographically central in this region and representatives within this shire were the subjects in one study conducted for this thesis. Australia is used as the country studied at a national level, with special focus on the CRC program. SMEs were the third level studied, and sourced mainly in Western Australia and were investigated for their incorporation of sustainability programmes especially cleaner production in their businesses.

Innovation at all three levels was measured for this thesis although, as discussed, a broader definition of innovation is required than historically considered appropriate because of the focus on sustainability and regional development rather than just new products and services, production processes, marketing procedures or organisational set-ups as cited by Sorensen et al. (2010). As will be seen later, several terms relevant to this thesis are closely linked with innovation, such as entrepreneurship (to be discussed in this chapter because innovation relies upon the action of entrepreneurs), science, sustainability, commercialisation biotechnology, regional development and competitiveness. All of these terms, except entrepreneurship and science, are dealt with in detail in the relevant chapters in this thesis with a tendency to adopt broader definitions and will thus not be expanded upon here as well. Entrepreneurship will be covered in more detail in this introductory chapter due to the important roles of these stakeholders in implementing the models to be proposed in this thesis. Science and technology are discussed elsewhere (see Howgrave-Graham et al., 2009) and are only relevant in the discussion of the Science, Technology and Innovation (STI) policy research to be introduced in the next section so will also not be discussed in any detail here.

Although this thesis focuses on policy as applied to technology by government and can be limited to a region or city council, it can equally be narrowed to allow the formulation of strategy at a business, region city or council level since the strategies discussed are beyond the intra-firm ones to encompass networking between all the role-players/stakeholders in a geographical region. As such this study could be considered science, technology and innovation policy research (as described by Morlacchi and Martin, 2009 and cited below) with biotechnology as the main technology under investigation.

Lastly, the methods used for this study were a combination of extensive literature review on the commercialisation environment in Australia especially with respect to biotechnology, regional and sustainable development and barriers to these, depicting these using concept maps and then testing the models proposed. Some of the author's experiences in biotechnology research have been incorporated and hypotheses developed on the basis of documented international models and experiences, Australia-specific literature and local knowledge. These hypotheses were tested using the scientific method as described for business in the Howgrave-Graham et al. (2009) book chapter. Concept maps were used to depict the Australian innovation landscape to allow diagrammatical representation of how sustainable and regional development could occur (for easier evaluation during the subsequent hypothesis testing). These diagrams (as seen in subsequent chapters) and the accompanying explanations allow easier understanding of proposed models by the senior managers in Latrobe Valley, Gippsland and clearer responses which could be incorporated into subsequent models.

This thesis is a first example in which innovation is investigated simultaneously at national (government), regional and SME levels and dovetailed to depict a cross section of innovation permeation throughout Australia. The methods and innovation outputs measured were not identical, but rather tailored to suit to the topics and research subjects, such as use of a telephonic structured questionnaire to SME CEOs to investigate their sustainability practises and innovations, while CRCs were investigated using semi-structured e-mail questionnaires.

The studies conducted for this thesis were for the ultimate purpose of allowing informed policy formulation for sustainable and regional development and could thus be considered to fall within the ambit of science, technology and innovation policy research as discussed below. The knowledge depicted in this thesis will allow generation of the most complete innovation models for application in Australia for national, regional and sustainable development. The models developed and depicted in the early chapters reflect improvements on innovation models from the literature and were tested for their suitability in chapters 6[1] and 7[2]. A final new model for science and technology policy development, addressing stakeholder issues is depicted in chapter 7 at the end of the thesis. Each chapter thus identifies the gaps in the literature it addresses and has its own research questions. Finally, the research findings are tied together in the final chapters (6 and 7) to create the most comprehensive multi-level national study of innovation in Australia. The model derived in chapter 7 using this study as background is one that is aimed at directing regional policymakers to promote sustainable development. The stakeholders to be consulted are identified in the models to ensure that failure through overlooking a key one is avoided, as are their roles in generating the policies that will affect them and the other stakeholders. The benefits are also listed at the bottom of the models so that each stakeholder can identify his/her gain from the innovation process linked to model implementation.

1.2 Science, Technology and Innovation (STI) Policy Research

As mentioned in 2.1, the study used in this thesis should be considered one falling within the description of Science, Technology and Innovation (STI) policy research for reasons that are about to be explained. Morlacchi and Martin (2009, p.572) define STI policy research as "the application of social science (whether economics, sociology, political science, organisational science, business and management science, or psychology) to the study of policy for science, technology and innovation". At face value, this description appears too broad for the work done towards this thesis. However, further investigation reveals that these authors had also

[1] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[2] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

described it as being primarily a problem-oriented field that focuses on practical issues concerned with specific policies for science, technology and innovation rather than being theory- or paradigm driven and thus ties in with the primary purpose of this thesis which is to propose, develop and test innovation models suitable for practical application. Morlacchi and Martin (2009) also identified two other policy fields in which social scientists are involved in studying science, technology and innovation. These are “science and technology studies”, involving sociologist, philosophers and historians of science and technology, and “innovation management” which is primarily shaped by business and management studies with major contributions from economics and industrial organizations. The focus of the latter is on research, development and innovations within the individual firms and (to a lesser extent) collectively at the level of industries or sectors. Although this thesis has taken this approach in the Cleaner Production study on SMEs, it falls under the umbrella of STI policy research due to its preference for firm, industrial and national levels of analysis with government and policy-makers regulating or facilitating market-driven interactions and collective processes among businesses and other actors, as discussed by Morlacchi and Martin (2009). Another reason for saying that this thesis is closely linked with STI policy research is that it is also a problem oriented field focusing on practical issues to do with specific policies for science and technology, in this thesis it is the problem of harnessing science and technology for regional and sustainable development while maximising economies of scale. As reflected by Morlacchi and Martin (2009) it takes account of and investigates the central roles of firms in the evolution of technology and innovation. This study could equally be argued to overlap with other paradigms such as Science and Technology Studies or Technology and Innovation Management (Morlacchi and Martin, 2009) but the term STI policy research is preferred here due to the focus on policy and the additional opportunity to implement it for individual projects.

Ball (1995) described STI policy research as having four interacting components namely: STI policy science (seeking the most technically correct answer to political problems using the available scientific knowledge); STI policy engineering (using a set of procedures to determine the technically best action to implement a decision or achieve a goal); STI policy entrepreneurship (commitment to the application of certain technical solutions, organisations or contexts); and STI policy scholarship (less well defined, partly because its adherents often deny that there is one technically correct course of social interaction).

This study tends towards policy science and policy engineering due to the involvement of scientists in the relevant projects but, due to the controversial nature of some biotechnology research and development (such as the cultivation of genetically modified organisms), STI scholarship may apply due to the prevalence of divergent opinions and different outcomes, depending upon the regions and communities concerned. In STI policy engineering and policy entrepreneurship, "policy is both de-politicised and thoroughly technicised" (Ball, 1995, p.259). and called "problem-solving technicism" as it "rests upon uncritical acceptance of moral and political consensus", an impractical approach considering the diverse opinions among the subjects canvassed for this thesis with e.g. some non-government organizations interviewed being opposed to 'dirty' energy generation by other subjects, namely the industry burning the coal.

This study is aimed at bridging these four interactive components as models are proposed in which the author's experiences and the literature underpin their components and layout. Morlacchi and Martin (2009) used examples to demonstrate the need to address all four STI policy components adequately. The first example that they cite is the debate between MIT

(Massachusetts Institute of Technology) which published bestselling books on the limits to growth in the world, based upon world resources and pollution and SPRU (Sussex Policy Research Unit) that there was limited attention to political and social limits, such as the distribution of and desire for growth. This overlooking of policy scholarship could have dire policy consequences if these were related to the need for birth control to limit population growth for example. That is why this thesis takes this concern on board by increasing the pool of stakeholders from those identified in previous innovation models so that such concerns can be identified at the outset before a policy is implemented or controversial project pursued. This is especially important in light of the proposed Australian carbon dioxide emission tax and the effect that its introduction is anticipated to have on all aspects of life in Latrobe Valley which uses its abundant coal resources to generate power for the rest of Victoria.

Some previous STI policy research studies, as in the example cited above, have only addressed some of the four components of STI policy research but the models proposed in this thesis are intended to overcome this problem by identifying all stakeholders groups that should be consulted for policy development. A model (or potential framework) that advances upon previous innovation models is developed here in such a way that all four components of STI policy research have to be addressed in developing individual policies. An example of an application of the model is in making the controversial decision on whether genetically modified organism cultivation should be pursued in a particular region, a decision which will depend upon hard science as much as community opinion. The intention of this thesis is thus to create the first model that addresses the main issue in STI policy research as identified by Morlacchi and Martin (2009), the need for all four components of STI policy research to be addressed, while enhancing innovative and decision-making capability across a wide range of projects from the most to least controversial. The range of research projects that could be approached in such a way is wide as these authors cite cases by other authors on gender issues in science and technology, science policy during a transition from communism to capitalism, food safety governance, shortcomings of the National Innovation system framework in the United States among others. The work reported here, however, builds upon previous studies in regional development, sustainability and networking to achieve these. As such each paper is grounded in the relevant national, regional and SME literature and advances STI policy research beyond the theoretical level of STI studies cited by Morlacchi and Martin (2009) to one at which practical implementation becomes more realistic.

To facilitate the best outcome, the thesis first explores and describes the Australian background as derived using STI policy research (as it must have been conducted to develop the current policies), with biotechnology as the example. This background, together with innovation literature, allowed the proposal of innovation models published in subsequent chapters. Chapters 6 [1]and 7[2] then used questionnaires distributed to members of the stakeholder groups to test the propositions that 1) the policy environment described in Chapter 2[3] resulted in significant commercialisation, sustainability, and research productivity; and 2) that the models proposed at the beginning of the thesis are suitable for underpinning regional and national policymaking (shortcomings in the models, as identified by stakeholders, are to be rectified for chapter 7). There is thus a transition from the de-politicised and thoroughly technicised version depicted in the models to another version reflecting the collective or divergent realities of the respondents. The level of consensus on

[1] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[2] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131
[3] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59

the suitability of the models is thus determined allowing the development of a quantitative innovation model that would override the uncritical acceptance of its precursors.

Metcalf (1995) indicated that policy makers often adopted a systemic view in which interconnected institutions form a system to create, store and transfer knowledge, skills and artefacts related to technology and generate the policies to improve the "national system of innovation" (p.38) through industry-university collaboration. Mytelka and Smith (2002) indicated that the theory behind modern innovation theory has a combination of market and system failures, facilitating structure which may be ill developed or unhelpful for certain types of innovation. Nill and Kemp (2009), in discussing sustainable innovation policy in a Research Policy special edition on STI policy research, reflected that that a systemic-evolutionary view is behind actual innovation policies. These authors also indicated that a comparably specified evolutionary policy framework is still lacking and that three relatively well developed evolutionary sustainable innovation policy approaches were proposed in recent years that attempt to integrate insights gained in innovation policy practice. This is reiterated in their description of two approaches to innovation policy practice designed to overcome the earlier static 'one size fits all' approach. Nill and Kemp (2009) report that Hoogma et al. (2002) and Raven (2005) among others proposed "strategic niche management" (p. 672 in Nill and Kemp, 2009) which highlights the significance of "protected spaces" (occupied by promising technology that could inform private and public policies) and user involvement in early technology development. This approach is designed to alleviate the problem of unsustainable development and the generation of new paths to circumvent these through evolution. A relevant current example would be the generation of wind and solar power that would be seen as a business opportunity and a way to reduce environmental degradation in the form of air pollution. As touched upon earlier under the four components of STI policy research, the performance, effects, economic viability and social desirability would be discussed prior to policy generation. However, this approach does not consider desirability of the technology to proponents of competing technologies. This thesis tries to overcome this problem not identified in the literature and does so to a certain extent by investigating a region which does rely upon a competing technology for energy generation. It should be noted that the results of a STI policy research study could easily differ, depending upon who was canvassed prior to the policy generation. Renewable energy may be seen as a suitable alternative by national policy makers in Australia but coal would almost certainly be seen as the desirable energy source by a region with vast deposits of this commodity.

The second evolutionary policy framework approach, namely "Transition management" has a broad scope on systems changes and innovation relying upon evolving adaptive portfolios. This is a 'darwinistic' steering concept that occurs at both the national and local levels but is less concerned about specific outcomes than the mechanisms of change. Nill and Kemp (2009) summed up the key elements as long-term thinking (at least 25 years) for short term action; thinking in multiple domains such as energy and waste; a focus on learning and a special learning philosophy; and learning about a variety of options, as used by the Netherlands government for sustainable innovation. Some aspects of this approach are proposed by the current Australian government. By imposing a greenhouse emission tax, the government is seen to address global warming. However, many jobs are perceived to be at risk with such a proposal so funding is channeled to alleviate job losses in e.g. Latrobe Valley which must, over the next decades, shift to less greenhouse gas intensive industries. The models proposed later in this thesis are intended to allow alternative commercialisable projects to be identified while doing smaller scale problem-solving ones. The community and other stakeholders are to be incorporated in the decision- and policy-making at the regional level. However, the models will also be designed in such a way that national policy decisions can be made, which is why this is a “multi-level study”. This thesis is thus building upon the literature, by being one step ahead of it and with a practical outcome to address current environmental and regional development issues for more rigorous STI policy development. In so doing, it is filling a gap in the literature which clearly identifies that, for example “strategic niche management” occurs but does not describe a practical model that will facilitate it or other STI policy research approaches.

An even more resilient approach identified by Nill and Kemp (2009, p.673) would involve “time strategies” to focus on the political preparation and utilization of time windows of opportunity in unstable phases of technological competition. Nill and Kemp (2009) indicate some practical industry examples where these approaches have been utilized and, in these times of uncertainty with respect to global warming, other applications would be emerging in commodity driven economies such as Australia for power generation or water security. It is thus necessary for any model proposed to allow for this fluidity a difficult task since the events referred to are unforeseen. The best outcome would occur if mechanisms be built into the models in such a way that such events arise from opportunities created by adopting the models proposed. Revisiting the models when faced with such challenges would also be necessary to identify whether policies or strategies should be implemented to determine whether a new commercialisation opportunity should be pursued or abandoned.

The approaches so far discussed under STI policy research build upon the more static ones such as the triple helix model for university-industry-government cooperation as discussed by

Leydesdorff and Etzkowitz (1997) as they allow input from diverse sources such as NGO's and funding organizations as discussed in a later chapter. User involvement should, however, occur in early technology development to ensure that market pull rather than technology push strategies are adopted. Nill and Kemp (2009), in discussing evolutionary approaches for sustainable innovation also indicated that strategic niche management incorporates a "probe and learning approach" (p.672) to determine user acceptance, technical imperfections and complementary innovations *et cetera*. However, they reported that little was learned about how policy makers and other actors could be enrolled in the process. In this thesis, the intention is that models are proposed and evolve into ones in which the policy makers set up an initial policy that is flexible enough to allow for "probe and learning" approach to be driven by the knowledgeable actors in e.g. development and marketing. Any adjustments to the policy could be proposed to the policy makers by these 'on the ground' stakeholders who are drawn from the three major role players in the triple helix model as well as NGO's, community groups and other funding organisations.

Kern and Smith (2007) report on the development of a directorate in the Netherlands to foster collaboration between various departments for an energy transition. This was a typical case of where "transition management" (Nill and Kemp, 2009, p.672) has occurred with the input of stakeholders beyond the normal supplier-customer relationship. Such a directorate would have to develop the policies necessary to appease stakeholders, not an easy task in a country with plentiful supplies of non-renewable energy such as Australia. This task would, however, have been easier if a set of procedures built around the models to be proposed in this thesis were to be adhered to as current innovation models would be inadequate for this task, as will be demonstrated here.

The above paragraphs suggest that evolution should be incorporated in approaches for sustainable innovation policies as discussed by Nill and Kemp (2009). It would, however, be possible to build evolutionary approaches such as in "strategic niche management" and "time strategies" (Nill and Kemp, 2009, p.673) into a policy from the beginning. This can be seen in the models proposed later in the thesis as the policies proposed there build in a component for capitalizing on timely and learning opportunities. "Transition management" (p.672) on the other hand appears to be more a revolutionary than an evolutionary approach, but once installed each major transition can be followed by an evolution-driven approach.

1.2.1 STI policy research for growth

This section explores the applications of STI policy and research to enhance development, whether at a regional or national level, and for environmental sustainability. Aghion et al. (2009) pointed out that there is a widely shared perception that higher levels and rates of growth enjoyed by some national economies are due to those countries' greater success at exploiting emerging technological opportunities. The possibility that this is due to effective policy and programs stemming from a correct sequence of stimuli given to a suitable mix of exploratory and commercially oriented R&D as well as private sector investments in technology and training is suggested by Mohnen and Roller (2001) and Trajtenberg, (2002). Aghion et al. (2009) mentioned that information yielded by research can enlarge the stock of generic knowledge and technical capabilities upon which future research activities can draw but raised the issue of whether this information and knowledge generation should be optimised by public policy measures to yield desired long-run technological innovation and productivity growth. This thesis argues that it should, especially in light of controversial initiatives such as those to reduce greenhouse gas emissions or those that result in environmental degradation (such as harvesting of old-growth forests). However, the policy measures should be carefully derived in such a way that ethics as well as business and capacity issues be addressed. In this thesis, a mechanism for achieving this is through the innovation models proposed, which are intended for both policy development and for conducting individual projects that are not expected to have ethical concerns.

Aghion et al. (2009) go further in describing how “system research” and “systemic” embrace the holistic rather than reductionist approach to develop frameworks to study the dynamics of physical, technological, biological, social and cognitive systems. They refer (p.682) to how this approach can allow “science, technology, innovation and growth systems” (STIG) to be appropriate subjects for policy-oriented research as is the case in this thesis. They emphasized the complexity of certain models of the economy and, to overcome this problem, this thesis proposes a couple of models based upon the authors’ experiences and then tests these in terms of current regional and national development (growth) in Australia, and sustainable development. This approach, rather than proposing totally untested and potentially oversimplified models, or trying to ‘draw a picture using a committee’ (as would be the case if ideas were not initially proposed and depicted for debate, akin to using a blank canvas), meets in the middle with ideas and experience depicted for comment to generate a clearer picture despite the complexity. The purpose of such an approach is to overcome the danger of a little, or incoherent knowledge encouraging policy inaction as portrayed by Aghion et al. (2009). Such failures are reported in the literature in, for example, the application of the Triple Helix Model discussed below and this thesis attempts to overcome such problems, among others to be discussed in the relevant chapters. The final picture in this thesis (the result of system research) is revealed later and is aimed at allowing informed policymaking for growth through understanding the dynamics of the science, technology and innovation practices currently employed in Australia. This thesis takes a different approach from that of

Aghion et al. (2009) in that their study adopts an historical systems approach to technological change and innovation while this thesis concentrates on current systems in place to capitalize on technological change and innovation in Australia for growth. Hopefully the models proposed and tested later in this thesis are flexible enough to overcome the potential problem suggested by Aghion et al. (2009) that the results of some policy commitments, when implemented, may become impossible to reverse, such as lakes becoming too polluted to clean themselves or irreversible global warming. The models developed in this thesis have been designed to overcome these problems as the emphasis is on collaboration between experts and other stakeholders to constantly derive the best possible outcomes in terms of both sustainability and economic/regional growth and development.

1.3 Distinguishing between innovation, entrepreneurship and creativity

So far, the means of STI policy research has been explored in terms of evolutionary approaches as well as "growth" as an ultimate aim, while some challenges to STI policy research were also discussed. However, the terms "science" and "technology" have not been clarified, nor have ways that any of these can be measured been discussed. Innovation is going to be discussed briefly in this section and related to the terms "entrepreneurship" and "creativity" which are closely aligned because the models proposed in this thesis are directed at harnessing these in Australia, especially for biotechnology to allow the creation of suitable policies and strategies for national, regional and sustainable growth. Ways to measure these will be touched upon as these have been included as outcomes in the models proposed later in the thesis.

Leibenstein (1968, p.73) defines entrepreneurship as: “The activities necessary to create or carry on an enterprise where not all the markets are well established or clearly defined and/or in which the relevant parts of the production function are not completely known”. He continues by indicating that the entrepreneur has five roles related to arranging and co-ordinating the resources and stakeholders to produce and market a new product or service. These would be relevant in applying the models proposed in the following chapters but will not be listed here as this thesis is rather focused on the identity of the entrepreneur. Liebenstein’s (1968) definition above is suitable considering the lack of knowledge, established markets or production functions for the new products the entrepreneur must operate in. Opportunities are identified through serendipity or “lucky accidents” (Tidd, 2006, p.4) considered by the models proposed in this thesis. However, the product focus of entrepreneurship as highlighted in the literature is less suitable for this thesis as some of the subjects studied here, the CRCs, are focused on conservation rather than new products, but do identify entrepreneurs who run their projects. A preferred definition of an entrepreneur for the purposes of this thesis is thus one from the Oxford English Dictionary (1989), which defines an entrepreneur as “the person who organizes and directs the productive factors” (p.307) but goes on to indicate that this “person” may be a private businessman, a partnership, a joint stock company, a cooperative society, municipality or similar body. The extension of the definition to a cooperative society or municipality allows this gap between business literature definitions on entrepreneurship and entrepreneurial acts by NGOs (non government organizations), government departments and other concerned stakeholders to be closed as expected in some applications of the models proposed in this thesis.

McFadzean, O’Loughlin and Shaw (2005, p.352) continue by defining corporate entrepreneurship as “the effort of promoting innovation from an internal organizational perspective, through the assessment of potential new opportunities, alignment of resources, exploitation and commercialization of said opportunities". Extending the definition of an organisation to allow the grouping of industries, government organisations, universities and NGO's to form 'super-organisations' such as CRC's allows corporate entrepreneurship to be a prevailing theme of this thesis as chapters 4[1] and 5[2] propose models in which corporate entrepreneurs could be embedded within any of the member 'organisations', such as NGOs or municipalities, within the 'super-organisation', where they would be the primary innovators.

Tijssen (2006), in light of the widespread phenomenon of entrepreneurial universities world-wide, proposed a conceptual framework and stage model aimed at describing the science-based entrepreneurial orientation of universities, in which (for the purpose of this thesis) the university could be the organization which harbours the corporate entrepreneur within the 'super-organisation' as investigated in chapter 6[3] of this thesis. A narrower approach is taken in chapter 3[4] where the corporate entrepreneurs interviewed regarding their cleaner production initiatives were the CEO's (chief executive officers) of SME's (small to medium enterprises). They may thus be considered both corporate entrepreneurs and entrepreneurs while the market and production focus of Leibenstein's (1968) definition excludes the type of entrepreneur referred to in many of the organizations investigated in this thesis, including those employed by universities, as discussed by Tijssen (2006). McFadzean et al. (2005), by not expanding upon the term 'organisation' have opened up the use of the term "corporate entrepreneurship" (p.352) (or intrapreneurship) for use in this thesis as anyone who takes the

[1] Innovation and Development Model for Regional University Campuses, p.93
[2] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105
[3] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[4] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.95

initiative in pursuing an innovative project, irrespective of their affiliation or the size of the organization (or grouping of organisations).

McFadzean et al. (2005) proposed a model in which corporate entrepreneurs encourage innovation through their attitudes and actions while facing the challenges of bureaucracy and examining new opportunities, resources, implementation, exploitation and commercialisation. This model identifies the link between corporate entrepreneurship and innovation which these authors had identified as being missing in innovation models. The affiliation of the potential corporate entrepreneurs is suggested in chapters 5[1] and 6[2], while chapter 7 [3]of this thesis is aimed at identifying who these potential corporate entrepreneurs (in terms of their affiliation) are in the 'super-organisations' of CRC's and university-based centres in Australia, the findings to be correlated with the super-organisations' innovation productivity.

Various other types of entrepreneur have also been described such as: serial and portfolio entrepreneurs (Wickham, 2004); social entrepreneurs (enterprising individuals who seek to change society or address social issues through an organized initiative) (Pastakia, 1998); and ecopreneurs who Pastakia (1998) defines as eco-conscious change agents. Of these, ecopreneurs are relevant to this thesis as they would be the entrepreneurs who drive the sustainability and cleaner production initiatives described in chapters 3[4] and 5.

[1] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105
[2] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[3] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131
[4] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80

Naturally all the entrepreneurs, whether they are corporate entrepreneurs or ecopreneurs would have to engage in or foster creativity, defined in the Oxford English Dictionary (1989, p1134) as the ability to "produce where nothing was before" or "bring into being". Chang (2008) indicated that this creativity focuses on the generation of new ideas, regardless of how useful these new ideas may be in the long or short term. Entrepreneurs, in addition to creating these ideas, would need to carry out innovation, which Chang (2008) says centres on adding value to enterprises by implementing and marketing them. This creativity could come from a variety of workers, including scientists, architects, engineers, designers, educators, artists or musicians. This thesis is focused on how to harness the creativity of business people, university employees and/or government agents or NGO members to innovatively enhance regional and sustainable development in Australia, as well as biotechnology commercialization. To do so, the current status of these initiatives have to be investigated and, using cleaner production as an example SME entrepreneurs were interviewed in chapter 3[1] for their innovation. Based upon this information and other literature, the models in chapters 4 [2]and 5[3] suggest building upon McFadzean (1998)'s concept of creative problem solving to allow serendipity to generate the "lucky accidents" referred to by Tidd (2006, p.4) and the resultant economies of scale type innovations. Finally, Australia's innovation outputs by cooperative research centres in terms of commercialisable and other innovation outputs were quantified for this thesis as was the validity of these models for innovation by submitting semi structured questionnaires to senior government, industry, university and NGO's in a regional case study, followed by interviews where necessary. For this thesis entrepreneurs (business CEO's) were interviewed at the SME level and the identity of entrepreneurs (referred to as "champions/innovators" later in this thesis) was determined at the national level. It should be pointed out that, until now a broader scope has been identified

[1] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80
[2] Innovation and Development Model for Regional University Campuses, p.93
[3] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105

for the terms, innovation, entrepreneurship and creativity than traditionally allocated to these terms by the business community so that a wider catchment of innovators etc. can be canvassed for this thesis. It was argued that an entrepreneur and innovator need not be embedded in a business or company but could equally be from an NGO or municipality. This would allow more candidates to be eligible for the promotion and implementation of regional and sustainable development initiatives than identified in the business literature. As will be seen later, the same approach of relying upon broader definitions has been taken when describing biotechnology and commercialisation.

The potentially diverse identities of entrepreneurs and innovators pointed out above raises another issue that will be highlighted and expanded upon in the publications embedded in this thesis, which is knowledge and its transfer. Knowledge, which is necessary for innovators and entrepreneurs to succeed, has flamed extensive debate between philosophers in attempts to define it, without resolution for 2,500 years according to Brown and Duguid (2002). Davenport and Prusak (1998) reported that it often becomes embedded in documents, repositories, organizational routines, processes, practices and norms. It is a constructed rather than objective reality, created from experiences and their interpretation as a form of understanding. The harnessing of as much knowledge as possible is achieved by pooling knowledge within and between organisations, sometimes in the form of spillovers which Fritsch and Franke (2004) report may have an important impact on innovation processes and economic development. However, such knowledge transfer may need to be facilitated as suggested by Kirkels and Duysters (2010) for SME’s by intermediaries, which would be innovators and could well be entrepreneurs as well. Leydesdorff and Fritsch (2006) report that networks would provide the infrastructure for knowledge transfer. Cimoli and Constantino (2000) emphasised that interdependence between each economic actor creates conditions for the emergence of a system of networks to capture the benefits from knowledge exchange and the diffusion of innovation.

The following section explores previous attempts to describe the infrastructure and knowledge flows in which innovators and possibly entrepreneurs are involved while the remainder of the thesis builds upon this information to describe the infrastructure that exists in Australia and propose new infrastructure models aimed at enhancing sustainable economic growth.

1.4 Innovation models and innovation theory

In the section above, the terms innovation, entrepreneurship and creativity are compared but since this thesis is on innovation, it is necessary to further review innovation and how to measure it, and discuss innovation models. Chapters 4[1] and 5 [2]in this thesis propose improvements on previous models, while innovation measures had to be chosen to test these models for chapters 6 [3]and 7[4] and must therefore also be discussed. As most of the publications incorporated here (chapters 4 to 7) give consideration to the literature on these topics, the literature will be discussed in light of how it has affected the innovation models proposed in this thesis and how they were to be tested. In addition, the models proposed in this thesis will be aligned with the latest trends in innovation modeling.

As mentioned above, innovation is often described at a firm level especially since innovation was described by Sorensen et al. (2010) and others as being new products, services, production processes marketing procedures or organizational set-ups. Tidd (2006) reviewed

[1] Innovation and Development Model for Regional University Campuses, p.93
[2] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105
[3] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[4] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

the innovation models, allowing him to categorise them as first to fifth generation models, reflecting their evolution from first and second generation linear models based upon “need pull and technology push” (p.3) to the more recent fifth generation models (Figure 1 represents an example of one) with systems integration, extensive networking, flexible and customized response and continuous innovation within a firm. In between were the third generation models with greater interaction and feedback loops and the fourth generation models with greater integration in the firms and with upstream key suppliers and customers downstream, emphasizing linkages and alliances.

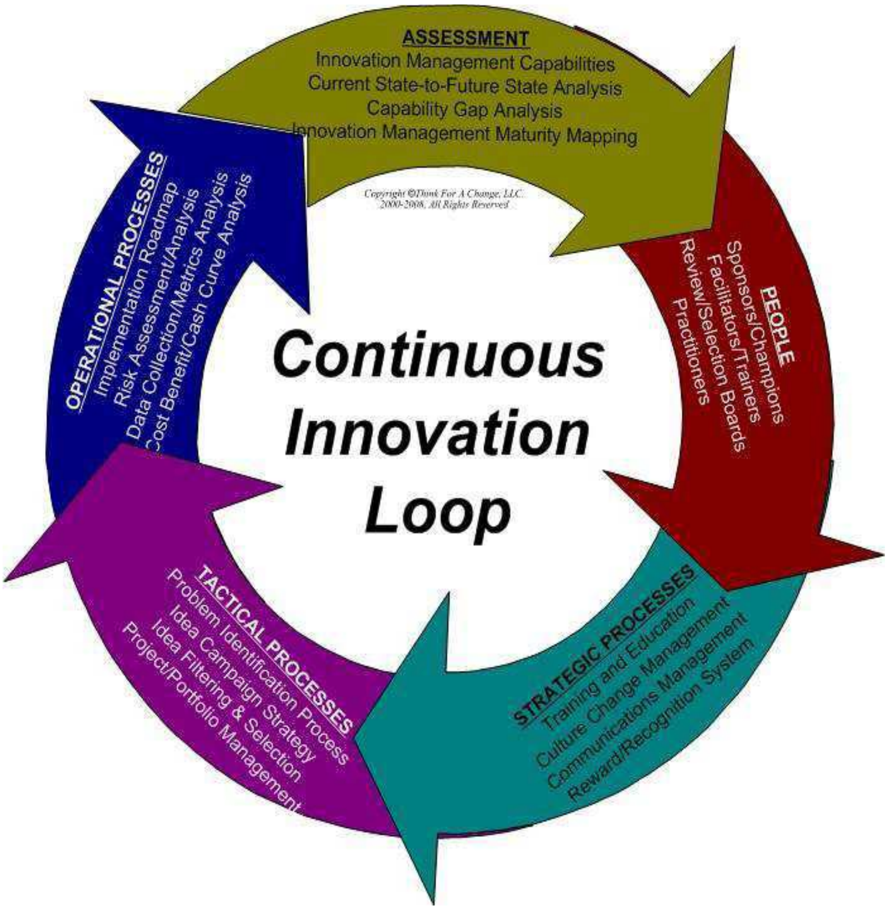

Figure 1. A fifth generation innovation model reflecting a continuous innovation loop (American Institute for Innnovation Excellence, 2009).

Earlier models of the 1950s and 1960s were firm based and, according to Evangelista et al. (1998), these linear models were characterised by a progression from basic scientific knowledge to technological knowledge to practical engineering. Mytelka and Smith (2002, p.1471), referred to these as "research to competitiveness-in-the-market" models. They indicated that by the 1970s, these models were found to be limiting in Europe and North America when a crisis occurred due to productivity increases becoming more difficult to achieve while growth of demand for products simultaneously faltered, due to unemployment and high inflation. According to Mytelka and Smith (2002) the next models of the innovation process to be developed were non-linear in that they involved feedback loops between research, the existing body of scientific and technological knowledge, the potential market, invention and various steps in the innovation process. These models emphasised the uncertainty and unpredictable nature of the innovation process, while stressing the dynamic impact of innovation clusters when compared to single innovations. The firm was then seen as a learning organisation embedded within a broader institutional context. The fourth generation innovation models described by Tidd (2006) built upon these third generation models by adding more formal integration within the firm and its upstream and downstream partners.

Taking focus away from the firm, Mytelka and Smith (2002) reported that organisations such as the OECD, the European Commission and the United Nations Conference on Trade and Development came to see innovation and technological change as central to welfare and growth problems and were identified as key instruments that could be applied at a policy level rather than for the creation of new technologies. The Triple Helix Model described by Leydesdorff and Etzkowitz (1997) was one in which greater collaboration between universities, government and industry could be used to formulate policy that should stimulate technological innovation. In a sense, ideas have been adopted from all five of the model generations described by Tidd (2006). Firstly, the industry sector, required to produce new products and services for survival would be dependent upon the academic sector to develop the technology and feedback would ensure that need pull and technology push and realistically intertwined. Government, through incentives and regulation, would play a key role in facilitating the integration and collaboration. Continuous innovation would ensure that the requirement for new products and services by industry is balanced by the universities' requirement to publish and the governments' requirement for solutions to problems, such as the ethical use of resources and the environmental sustainability of the practices. This aspect of continuous innovation has not been emphasized enough in the literature and is to be dealt with in detail in later chapters of this thesis, using examples.

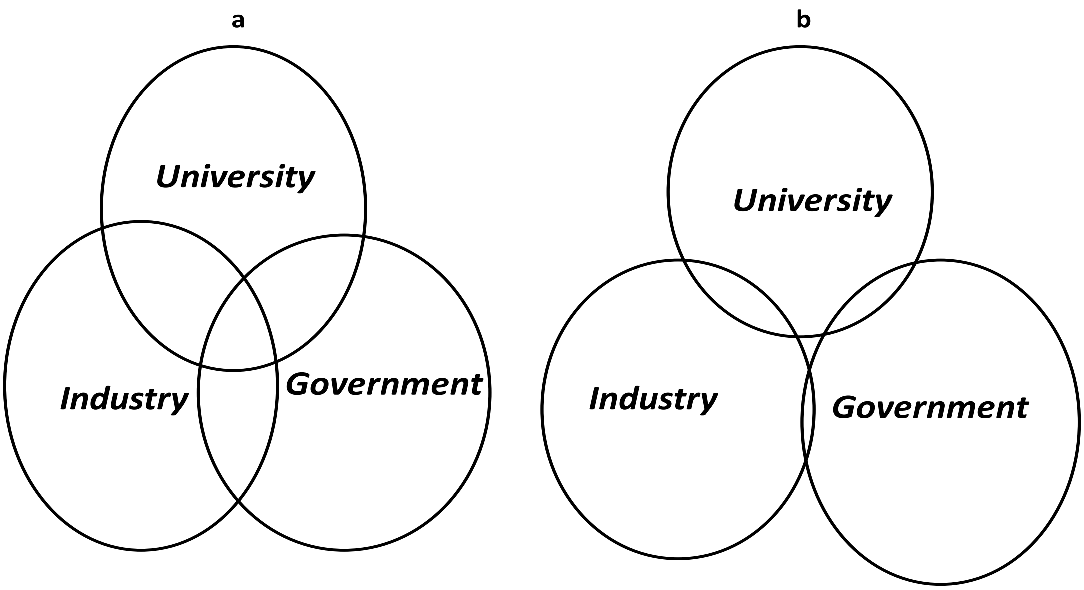

Figure 2. Triple helix configurations reflecting trilateral and bilateral integration (a) and bilateral integration only (b). Reproduced from Park and Leydesdorff (2010).

Etzkowitz (2002, p.2) described the triple helix model as "a spiral model of innovation that captures multiple reciprocal relationships at different points in the process of knowledge capitalization". It was said to have converging spheres of academia, industry and government as depicted in Figure 2a. He then indicated that it consists of three dimensions: internal transformation in each of the helices such as the development of lateral ties among companies; the influence of one helix upon another such as federal government instituting an industrial policy that could affect one or both of the other helices; and the creation of a new overlay of trilateral networks and organizations from interaction of the three helices to generate new ideas and innovations. Uptake of the model was seen to be highest in the USA where Etzkowitz (2002) reported that action is from the bottom up, sideways, criss-cross and top down, less so in Europe where intervention is primarily from the top down, although he reports that bi-lateral initiatives are starting to appear, especially in cross-border regions. He also reported that university-industry relations are gaining strength in regions where government-industry relations had previously predominated such as in Sienna. This cross border/boundary approach extends the National Systems of Innovation (NSI) approach which is especially well suited to bounded phenomena within nations or firms in which innovation, due to the lack of external input (akin to one of the helices acting independently) tends to favour incremental innovation. A further model is required to allow discontinuous innovation and the triple helix model is a step in the right direction. Another reason for considering the triple helix model is that innovations are sometimes not sufficiently market driven and then lacked a context to be put to use, for example when two public laboratories collaborate on a project without being tied to the market. A concern is, however, that privatization of companies will reduce the resources available for R&D. An innovative solution to this predicament is one which depends upon greater collaboration and open innovation. Such a solution is proposed in the models generated in this study. It also addresses other shortcomings of the triple helix model pointed out in the literature and mentioned below.

The triple helix model of innovation may occur in a top down manner as suggested by Etzkowitz (2002), encouraged by policy measures such as is predominant in Europe, or bottom up through the interaction of individuals and organizations as prevails in USA. He also admits that both regularly occur simultaneously and chapter 2[1] of this thesis indicates how the Australian government created the CRC program to stimulate innovation (top down) while expecting collaboration between industry and university to identify and drive specific innovation initiatives (bottom up). Figure 3 is a depiction of how the triple helix model is expected to work and has been drawn here in three dimensions to reflect that more than one project is undertaken at a time, involving different players in government, industry and academia, and requiring different interactions and connections depending upon the objectives of each project.

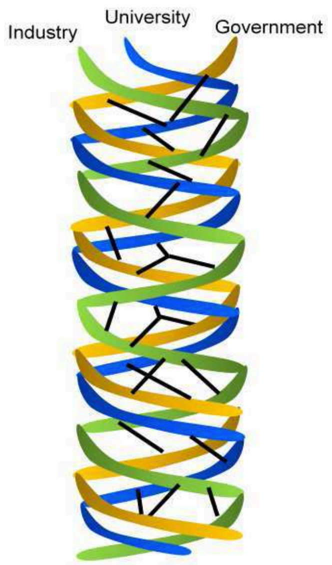

Figure 3. The Triple Helix Model for University, Industry and Government collaboration.

Prior to the triple helix models, other models described the policies as applied by various countries. Most of these had severe disadvantages, making them dysfunctional in some cases. Figure 2a is considered by Park and Leydesdorff (2010) to be desirable for competitive advantage as it demonstrates strong central integration related to university, government and

[1] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59

industry relations trilaterally. However, Figure 2b reflects complex dynamics that leaves self-organization of the system to mutual adjustments between partners without the need for a trilateral centre for coordination. These authors reflected that the South Korean government's BK21 program for promoting university research to generate publications as reflecting a breakdown in the trilateral coordination as the bilateral relations between university researchers and industries significantly decreased in activity. Here, a change in focus led to a breakdown in trilateral collaboration in South Korea.

Figure 3 was generated here to reflect, in three dimensions, the types of relationships reported in the literature that occur in both figure 2a and 2b (as reproduced from Park and Leydesdorff, 2010), as well as other interactions within each helix such as those between separate firms, or those between different universities or university departments in another helix, or separate government departments. These variations are not necessary detrimental as they are expected to occur, depending upon the projects but, in the case of the South Korean innovation model, exclusion of the third helix due to the change in academic focus was disadvantageous as it led to a breakdown in interactions that could have allowed economies of scale to generate both commercialisable and academic outputs. The innovation models proposed in this thesis are based upon the triple helix model but are improved to show how such complementarities can be achieved to the benefit of all, including those not listed in the triple helix, namely NGO's, funding agencies and community groups, each of which can also result in breakdown in innovation due to ethical concerns or a lack of funding as will be elaborated upon in the relevant chapters.

The above paragraph illustrated the breakdown of the triple helix model as applied to South Korea. However, other authors have mentioned how the model itself is innately flawed, an issue addressed in later models in this thesis and ultimately tested for in the research for chapters 6 [1]and 7[2]. The flaws listed below emerged as a result of other authors having applied the triple helix model under different circumstances and reporting upon the results. These flaws (which may be considered as unresolved issues) and ways that this thesis addresses them are:

- It does not focus enough on funding – research sponsors determine the nature and of the research (Benner and Sandstrom, 2000). This would depend upon the project as suggested above as government and industry funding would be included but not venture capital. To overcome this limitation any models, to be successful, must indicate awareness of all possible funding sources.
- Interactions between members of the triple helix model may not be effective due to a lack of vision and, especially in developing countries, ethics becomes secondary (Bunders et al., 1999). For this reason NGO's and community groups are to be incorporated in the models proposed in this thesis and the former interviewed for chapters 6[3] and 7[4].
- The entrepreneurs and potential innovators (scientists and researchers) are not treated as separate constructs in the model, feel excluded or avoid involvement with government actors (Brannback et al., 2008). These authors question the existing top-down triple helix model of innovation systems and propose a bottom-up double helix model. This issue will also be addressed in the thesis and is reflected in some of the

[1] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[2] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131
[3] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[4] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

interactions depicted (Benner & Sandstrom, 2000; Brannback, Carsrud, Krueger, & Elfving, 2008; Bunders, Broerse, & Zweekhorst, 1999) in figure 3 above, depending upon the project. This thesis addresses this issue further by extending research outputs to include the incentives important to academics and allowing economies of scale to make the triple helix a more inclusive model, preventing its failure as in the above South Korean case study.

Earlier, outdated models described by Etzkowitz (2002), leading to development of the triple helix model include those reproduced in figure 4.

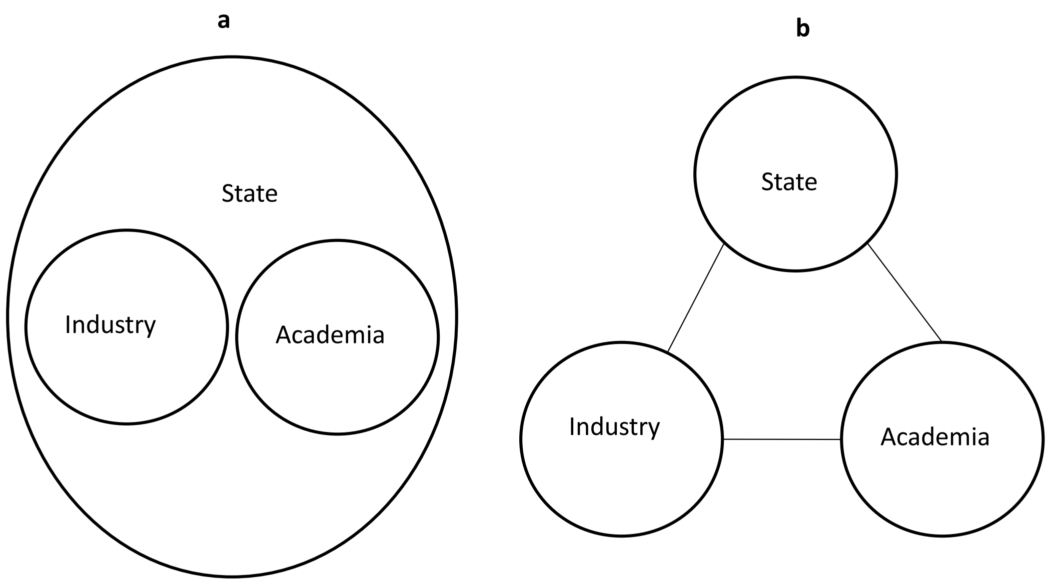

Figure 4. Models of Innovation leading to development of the triple helix model. Reproduced from Etzkowitz (2002).

Figure 4a represents a model in which the state incorporates industry and the university and, according to Etzkowitz (2002), represents the former Soviet Union and some Latin American countries in a previous era. Note that the spheres representing industry and academia do not collaborate with each other. On the other hand, figure 4b reflects the model of institutional spheres separate from each other, which Etzkowitz (2002) indicated is, in theory, how the USA is supposed to work. This reflects a lower level of collaboration and cooperation but the nature of some projects is such that institutional spheres overlap reflecting collaboration and cooperation with each other such as in the triple helix model. Chapter 2[1] of this thesis proposes a knowledge flow model describing interactions in Australia with CRCs as key components. These CRCs are shown to represent the central 'overlap' so the model depicted should be seen as one in which triple-helix-type collaborations is already assumed by grouping members from different sectors in each sphere.

One trend that is becoming apparent in the innovation models discussed so far is that they are becoming more open as they evolve, from the internalized linear models to feedback loops to integration, linkages and alliances within firms and between them and upstream and downstream suppliers and customers, to the addition of two more helices representing similarly integrated government and academia. International input to innovation and the capacity to draw from the multitude of resources outside of the three interwoven helices, while eliminating duplication of effort has not yet been discussed. Other drawbacks of the triple helix such as the role of NGOs and venture capital will be addressed in later chapters and corrections have been included in the models proposed. These shortcomings in the literature (discussed in later chapters where the new models are proposed) are addressed in the latest models of innovation, namely those involving "open innovation".

Open innovation is a more recent paradigm which was initially advanced as a tool for firms to modify their strategy to take advantage of innovations that may be peripheral to their main business but would be too costly or too impractical to pursue themselves. Chesbrough (2003,

[1] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59

p.XXIV) defines open innovation as "… a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as firms look to advance their technology". Chesbrough and Garman (2009) reflected upon open innovation at the firm level where traditional corporate boundaries are broken down to allow intellectual property, ideas, and people to flow freely into and out of an organization. These authors build upon previous work on outside-in open innovation in which outsiders' contribution enable an enterprise to create offerings beyond its internal capabilities. They suggest that, in lean times an inside-out approach, for which a business places some of its assets or projects outside its own walls, can be beneficial. Dahlander and Gann (2010) investigated both of these types of open innovation, calling them inbound and outbound approach, stating their characteristics as being "acquiring and sourcing" and "selling and revealing" respectively (p.702). They also related these term to pecuniary and non-pecuniary open innovation (particular relevant to this thesis due to its broad scope, encompassing both commercialisable and other outputs such as environmental conservation and publications) and did a detailed study of all publications on open innovation, a total of 102 starting from the year 2000 and classified them on the basis of the above characteristics. According to Chesbrough and Garman (2009) one of the ways to approach inside-out (or outbound) strategies would be to pursue a project as a customer or supplier, reducing costs and risks but still gaining a reduced benefit if a project is successful. An example of De Beers, the world's largest diamond supermaterial supplier created a new company to design, manufacture and market electrolytic devices for generating ozone, using De Beers supplied diamond wafer products. Both inside-out (outbound) and outside-in (inbound) innovations are depicted in figure 5.

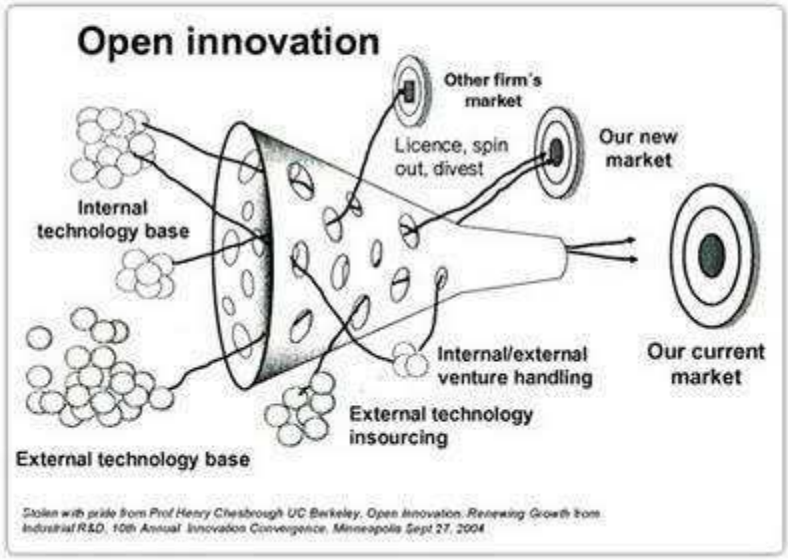

Figure 5. A representation of open innovation reflecting both outside-in (inbound) innovation from the left and bottom left of the figure and inside-out (outbound) innovation to the left and top left (Innovation Consulting, n.d.).

In explaining figure 5, http://www.business-strategy-innovation.com reflects that it sums up the open innovation but does not account for the increasing agile development and customer feedback incorporated by companies such as Apple, Google, which are characteristics of Tidd's (2006) earlier third generation models discussed earlier. According to http://www.business-strategy-innovation.com, customer feedback loops are becoming increasingly important as a part of the innovation cycle. As will be demonstrated later in this thesis, other feedback loops are also important such as between NGOs, industry and government, the absence of which has been identified by other authors as a shortcoming of the triple helix model. This issue will dealt with later in the thesis and the shortcomings addressed in the models proposed here.

Chesbrough and Garman (2009) mention other examples of inside-out innovation to demonstrate how business can get others to develop non-strategic initiatives to prevent the killing of projects that have not yet proven their potential, or that lie outside the core business and so doing missing opportunities for the firm's growth. Similarly, a firm's intellectual property that would otherwise sit on the shelf could be used for a new start-up company to exploit this opportunity, or a company could grow its 'ecosystem' such as Unilever, which has developed a series of ecosystem-related innovation process that could be further commercialized by an incubator created for the purpose. This gives more avenues for R&D staffers to see more paths for their markets to get to work. This thesis, for the first time, builds such avenues into models, extending this idea to incorporate 'lucky accidents' (as described by Tidd, 2006) or serendipity to emanate from collaboration between industries or other members of the triple helix model. These 'lucky accidents', once identified could easily result in spin-off products or improved processes.

In focusing on firms' innovation strategies in the Emilia Romagna life science industry, Belussi, Sammarra and Shaw (2010, p.710) describes an open innovation system called the "Open Regional Innovation System" in which open innovation extends beyond the boundaries of the firm but also of the region. Carlsson (2006) went further by concentrating on the literature related to the internationalisation of national innovation systems while Bathelt, Malmberg and Maskell (2004) covered knowledge creation and clusters for local-global connections. These publications were too late to be referred to in chapter 2[1] of this thesis, the published book chapter in which Australia CRC's are discussed, but the involvement of multinational corporations are briefly touched upon. It should be noted that internationally available tacit knowledge is expected to be already embedded in the diverse

[1] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59

experts collaborating for the innovation models proposed in this thesis and is already incorporated into the knowledge network depicted in chapter 4[1].

What has not been pointed out so far is that the models proposed in this thesis are not the first innovation ones developed in the Australian setting. Bernstein and Singh (2006) proposed one based upon practices in Australian biotechnology firms. Their model concentrates on the innovation processes such as control and communication in light of technology push and market pull factors. It is a firm level model and, like another innovation model by Potts (2010), does not identify the role players on a national or regional level. Potts' (2010) natural advantage model also focuses on the knowledge networks and activities such as education and regulation at the regional level in linking sustainability, innovation and regional development. Neither of these models go to the extent of detailing participants in the innovation process (as is the case in the triple helix model) and this oversight is addressed in this thesis as it is important to identify all stakeholders that are to contribute to it, and who is accountable before their roles can be identified.

To conclude this section on innovation models and innovation theory, it should be pointed out that the models proposed later in this thesis build upon the previous ones discussed above and are the first ones to incorporate all of the positive attributes of previous models while addressing subsequent authors' concerns about their practicality. In addition, the models proposed here were set in the Australian context as outlined in chapter 2 [2]at the macro scale using the Australian CRC system and biotechnology as the example; and on the micro scale

[1] Innovation and Development Model for Regional University Campuses, p.93
[2] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59

in chapter 3[1] on Australian SMEs, while relating the information to regional and sustainable development so that that the models could be used for regional or national policy generation.

As identified by Mytelka and Smith (2001) developments in the innovation literature are evolving too rapidly for there to be a unified theory that relates innovation to growth and distribution. These authors stated that “innovation theories emerged in a period of rapid change” (p.15). This thesis is an attempt to bring us closer to a suitable innovation theory by building upon the body of innovation knowledge at a time when these authors state that there is diminished policy credibility (often due to shortcomings already listed and referred to later in this thesis). Mytelka and Smith (2002, p.1479) stated that “much will depend upon the ability of innovation studies to remain an area of intellectual vitality and advance, something which will require a clear recognition of existing limits and weaknesses, and a clear willingness to seek to overcome those limits”. The recent emergence of open innovation seems to have reinvigorated the topic as is also the intention of this thesis and the publications embedded within. Another positive development is the emergence of new innovation systems such as Australia’s CRC policy, attesting to policymakers’ willingness to embrace recent findings and advances in innovation theory in a meaningful way.

1.5 The relevance of innovation to this thesis

Until now, the background and evolution of innovation, the entrepreneurs and creativity involved and innovation models have been dealt with and related to this thesis but the specific applications have only occasionally been touched upon. The relevant themes here are: biotechnology (chapter 2[2]), cleaner production and eco-efficiency (chapter 3[3]) and relating these to SME practices; regional development, knowledge networks and university

[1] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80
[2] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59
[3] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80

involvement (chapter 4[1]); sustainable development (chapter 5[2]); and tying these concepts together under the umbrella of STI policy research after testing the models proposed (chapters 6[3] and 7[4]). Each chapter is grounded independently in relevant literature which is used as its background (or introduction). The objectives/research questions are elucidated in each chapter, as is the contribution that each study makes to the body of innovation knowledge. A universal theme in these chapters is the need for collaboration and networking but what may vary is the identity of change agents/facilitators (entrepreneurs), especially in light of the research results generated for later chapters. Each of the chapters either describes the current state of innovation in Australia in terms of the relevant context, such as CRCs and clusters for chapter 2 and SMEs for chapter 3, or proposes or tests models that are designed to drive innovation and STI policy, such as in sustainable and regional development in later chapters. It can be seen from the literature that such models are necessary to drive sustainable and regional development and, to avoid the failures listed above, must be tested to prevent future dysfunction in policy development and innovation. This thesis is an attempt to do just that as it proposes models based upon earlier innovation models but modified to address their shortcomings previously listed, then tested through questionnaires before 'tweaking' to address stakeholder concerns. The true test would, however, be in its application at a national and/or regional level.

Most innovation publications, irrespective of the context or case study under investigation, emphasise the importance of collaboration and networking to improve the outcomes of the nation, firm or region. Some recent title examples drawn from just one journal are

[1] Innovation and Development Model for Regional University Campuses, p.93
[2] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105
[3] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[4] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

"Cooperation in innovation activities: The importance of partners" by de Faria, Lima and Santos (2010); "Investigating the factors that diminish the barriers to university-industry collaboration" by Bruneel, D'Ester and Salter (2010), "Organising links with science: Cooperate or contract?" by Cassiman, Di Guardo and Valentini (2010); "Working with distant researchers – Distance and content in university-industry interaction" by Brostrom (2010). Another earlier example related to biotechnology is "Knowledge networks of young innovators in the urban economy: biotechnology as a case study" by van Geenhuizen (2008). Although some of this literature has already been drawn upon above, a detailed literature review would dwarf the rest of this thesis and make it almost immediately out of date, so the approach here is that the most relevant examples will be cited in their respective chapters. An example of how extensive this literature review could be is described in Bryman and Bell (2007, p.100) in which these authors cite an example of a systematic review as being one by Pittaway (2004) on "networking and innovation". In this example, a review team limited the articles to a relevant list of 623 publications.

Other topics to be covered for this thesis will be discussed in the relevant chapters such as: a description of CRCs; Latrobe Valley as the subject of one innovation study; biotechnology; and Victorian government regional development policies to promote innovation. Due to its importance to this thesis, another topic that needs a brief introduction here is sustainable development as underpinned by the term "sustainability". Attempting to define "sustainability" is as fraught with difficulty as the word "knowledge", as suggested by the title of the journal in which two of the papers in this thesis were published, "The International Journal of Environmental, Cultural, Economic and Social Sustainability". This thesis is more focused on environmental and economic sustainability although the diversity of the stakeholders incorporated into the models proposed throughout could easily introduce one of the other sustainability paradigms as well. A narrower term will thus be defined that underpins much of the work that is to follow. This is "sustainable development" in which Parrish (2007) couples the long-term survival of humanity with qualitative improvement in the human experience of life on earth. Potts (2010, p.713) takes this a step further by defining sustainable development as "reducing the environmental impact from economic activity while promoting development that increases the quality of life".

1.6 Introduction to methods used

This thesis generally fits within the positivist paradigm as either quantitative data is used directly or qualitative responses from open-ended questions in the surveys are analysed to generate quantitative data. In addition, specific comments made in response to the open-ended questions are often reported in the relevant chapters to add richness. Each chapter reports on the methods used in more detail and will thus not be expanded upon in detail here. In addition, the questionnaires used for the telephone, postal and hand distributed surveys are included in the appendices to this thesis. A few comments should be made here to clarify how the methods had evolved to 'tighten up' the results, reflecting the learning process from chapter to chapter, to generate richer research results as the thesis progresses.

Chapter 2[1] draws from Bryman and Bell's (2007) systematic review as a systematic and scientific approach was used to review the literature and allow depiction of the role of CRCs and clusters in determining Australian biotechnology strategies. This is followed by a chapter (chapter 3[2]) in which structured telephone interviews of SME CEOs were used to determine SME sustainability practices in the form of cleaner production uptake. Transcripts were assessed by an expert panel of the authors, assessing quantitative data and converting

[1] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59
[2] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80

qualitative responses into quantitative scores. For this study, the purpose of the survey was not revealed until later in the interview to avoid "social desirability error", during which Bryman and Bell (2007, p.235) reports that respondents would state what they think the interviewer want to hear. This had the unfortunate consequence the questions being too vague and some respondents replying to a question such as "What innovations are you aware of that your company has implemented to improve operation efficiency and cut cost over the last three years?" with a list of innovations unrelated to cleaner production or eco-efficiency. This issue was addressed in later chapters by broadening the scope of questions in the e-mail survey to CRCs, asking for examples of what the CRC is doing in support of its responses on sustainability, and having follow-up interviews for the largely open-ended questions submitted to senior government, industry, university and NGO representatives consulted for the data reported in chapters 6[1] and 7[2]. To address the issue of the conversion of qualitative responses to quantitative data for chapter 3 of this thesis being fairly subjective, later questionnaires had an increased number of quantitative questions and qualitative questions were used as supporting material only and examples were used to support the objective quantitative data.

In both chapters 4 [3]and 5[4], the methods were more representative of "narrative theory" as described by Bryman and Bell (2007, p. 105) as the literature was reviewed in such a way that "theory is the outcome of the study, rather than the basis for it". The literature review on especially the triple helix model allowed evolution of the two models and the associated knowledge networks proposed for the first time in these two chapters. In addition, the models

[1] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[2] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131
[3] Innovation and Development Model for Regional University Campuses, p.93
[4] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105

proposed directed the research methods and questions for the following chapters. As mentioned above, the research methods for the chapters are described in more detail where relevant and copies of the questionnaires are included in this thesis as appendices. Although not mentioned in chapters 6[1] and 7[2], a pilot questionnaire was distributed to delegates at a symposium to test the questions for the final study and recruit volunteers to test the models proposed in chapters 4 and 5. Both NGO respondents (strategic office bearers of at least two NGOs per respondent) and one of the industry respondents were recruited for the relevant study in chapters 6 and 7 this way. Ethics approval was obtained for the studies and the reference number is quoted in the last chapters of this thesis. Note that memory sticks were promised and given to respondents from the Latrobe Valley region and CRCs as an incentive to increase response rates. In addition, follow-up messages and phone calls were used to remind people of the questionnaires they had been supplied with.

1.7 Chapter Summary

This chapter has given an overview of the terms used and literature relevant to the thesis with emphasis on issues needing further attention. Innovation and the relevant models were discussed and this discussion indicated that there is still no model suitable for practical application for policy development and that also allows economies of scale to maximize output from individual projects. A model needs to be developed that can be universally applied for STI policy research to drive regional and sustainable development. This thesis does so in two stages. Firstly models are proposed that address the shortcomings of previous ones as identified in the literature. To ensure that these models are properly grounded in the environments in which they are to be applied, an up-to-date literature review of this

[1] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[2] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

environment is introduced in Chapter 2[1] with Australian biotechnology cited as the example. The need for intervention by entrepreneurs/change agents drawn from outside business is investigated through a scoping exercise in Chapter 3 [2]on SME cleaner production, which also tests a new assessment method for cleaner production (another requirement for the quantification of sustainable development practices). On the basis of these 'scoping exercises', and literature on the topic (in which current innovation models are described in some cases and shown to be inadequate by subsequent authors) as well as other more recent models which do not indicate the relevant role players or stakeholders, nor how economies of scale and productivity can be enhanced through serendipity or 'lucky accidents', new models are proposed in chapters 4[3] and 5[4] in which shortcomings are addressed. In chapters 6[5] and 7[6], testing of this model and further information on the Australian government CRC programme is gleaned through questionnaires and interviews, culminating in a new (and currently best) practical model in chapter 7 [7]which is designed to develop policies that enhance regional and sustainable development beyond the levels currently possible with existing models. Such a model is long overdue and has significant ramifications for the introduction or advancement of controversial technologies and for identifying strategic directions for regions, especially those that are potential victims of national government policies, such as to achieve a reduction of greenhouse gas emissions by closing down coal-fired power generation as is threatened in Latrobe Valley, Gippsland. A model is required that can also be applied on a project-by-project basis and maximise output in disadvantaged regions, involving all potential stakeholders. The models proposed in chapters 4 and 5 and improved upon for chapter 7 are aimed at achieving such a framework.

[1] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59
[2] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80
[3] Innovation and Development Model for Regional University Campuses, p.93
[4] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105
[5] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[6] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131
[7] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

1.8 References

Aghion, P., David, P. A., & Foray, D. (2009). Science, technology and innovation for economic growth: Linking policy research and practise in "stig systems". *Research Policy, 38*(4), 681-693.

American Institute for Innovation Excellence. (2009). Continuous innovation. Retrieved 10 October, 2010, from http://thinkforachange.com/wordpress/wp-content/uploads/2009/11/Continuous-Innovation-Loop.jpg

Australian Commonwealth. (2008). Venturousaustralia: Building strength in innovation. from http://www.innovation.gov.au/innovationreview/Pages/home.aspx

Australian Institute for Commercialisation. (2006). *Inside commercialisation -> ideas ->opportunities -> outcomes: Annual review 2005/1006* (Annual Report). Brisbane: Australian Institute for Commercialisation.

Ball, S. (1995). Intellectuals or technicians? The urgent role of theory in educational studies. *British Journal of Educational Studies., 43*, 255-271.

Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. . *Progress in Human Geography, 28*, 31-56.

Bellini, N., & Piccaluga, A. (2000). The role of the university in constituency-building for industrial and territorial innovation: Reflections on an italian experience. In R. E. Lopez-Martinez & A. Piccaluga (Eds.), *Knowledge flows in national systems of innovation* (pp. 122-152). Cheltenham, UK: Edward Elgar.

Beluzzi, F., Sammarra, A., & Sedita, S. R. (2010). Learning at the boundaries in an "open regional innovation system": A focus on firms' innovation strategies in the emilia romagna life science industry. *Research Policy, 39*(2010), 710-721.

Benner, M., & Sandstrom, U. (2000). Institutionalizing the triple helix: Research funding and norms in the academic system. *Research Policy, 29*(2), 291-301.

Brannback, M., Carsrud, A., Krueger, N., & Elfving, J. (2008). Challenging the triple helix model of regional innovation systems: A venture-centric model. *International Journal of Technoentrepreneurship, 1*(3), 257-277.

Brostrom, A. (2010). Working with distant researchers - distance and content in university-industry interaction. *Research Policy, 39*, 1311-1320.

Brown, J. S., & Duguid, P. (2002). *The social life of information*. Boston: Harvard Business School Press.

Bruneel, J., D'Ester, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university-industry collaboration. *Research Policy, 39*, 858-868.

Bryman, A., & Bell, E. (2007). *Business research methods.* (2nd Edition ed.). Oxford: Oxford University Press.

Bunders, J. F. G., Broerse, J. E. W., & Zweekhorst, M. B. M. (1999). The triple helix enriched with the user perspective: A view from bangladesh. [Journal]. *Journal of Technology Transfer, 24*, 235-246.

Carlsson, B. (2006). Internationalisation of innovation systems: A survey of the literature. *Research Policy, 35*, 56-67.

Cassiman, B., Di Guardo, M. C., & Valentini, G. (2010). Organising links with science: Cooperate or contract? A project-level analysis. *Research Policy, 39*, 882-892.

Chang, C. M. (2008). Engaging the creative minds - the engage model. *International Journal of Innovation and Technology Management, 5*(1), 149-165.

Chesbrough, H. W. (2003). The logic of open innovation: Managing intellectual property. *California Management Review, 45*(3), 33.

Chesbrough, H. W., & Garman, A. R. (2009). How open innovation can help you cope in lean times. *Harvard Business Review, December*, 68-76.

Cimoli, M., & Constantino, R. (2000). Systems of innovation, knowledge and networks: Latin america and its capability to capture benefits. In R. E. Lopez-Martinez & A. Piccaluga (Eds.), *Knowledge flows in national systems of innovation* (pp. 56-81). Cheltenham, UK: Edward Elgar.

Dahlander, L., & Gann, D. M. (2010). How open is innovation? *Research Policy, 39*, 699-709.

Davenport, T. H., & Prusak, L. (1998). *Working knowledge: How organizations manage what they know*. Boston: Harvard Business School Press.

de Faria, P., Lima, F., & Santos, R. (2010). Cooperation in innovation activities: The importance of partners. *Research Policy, 39*, 1082-1092.

Dictionary, O. E. (Ed.) (1989) (2nd Edition ed.). Oxford: Clarendon Press.

Dooley, L., & O'Sullivan, D. (2001). Structuring innovation: A conceptual model and implementation methodology. *Enterprise and Innovation Management Studies., 2*(3), 177-194.

Etzkowitz, H. (2002). *The triple helix of university-industry-government implications for policy and evaluation*. Stockholm: Science Policy Unit.

Evangelista, R., Sandven, T., Sirilli, G., & Smith, K. (1998). Measuring innovation in european industry. *International Journal of the Economics of Business, 5*(3), 311-333.

Fritsch, M., & Franke, G. (2004). Innovation, regional knowledge spillovers and r&d cooperation. *Research Policy, 33*(2), 245-255.

Howgrave-Graham, A. R., Kirstine, W., & Larkins, J.-a. (2009). Benefits of the scientific method to business and how business and science can learn from each other. In J. E. Michaels & L. F. Piraro (Eds.), *Small business: Innovation, problems and strategy* (pp. 117-134). New York: Nova Science Publishers, Inc.

Innovation Consulting. (n.d.). Business strategy innovation. Retrieved 23 October, 2010, from http://www.business-strategy-innovation.com

Kern, F., & Smith, A. (2007). *Restructuring energy systems for sustainability? Energy transition policy in the netherlands. Sussex energy working paper, spru.* Brighton: University of Sussex.

Kirkels, Y., & Duysters, G. (2010). Brokerage in sme networks. *Research Policy, 39*, 375-385.

Knox, S. (2002). The boardroom agenda: Developing the innovative organisation. *Corporate Governance, 2*(1), 27-39.

Koontz, H., & Weirich, H. (1990). *Essentials of management*. Singapore: McGraw-Hill.

Leibenstein, H. (1968). Entrepeneurship and development. *American Economic Review, 38*(2), 72-83.

Leydesdorff, L., & Etzkowitz, H. (1997). A triple helix of university-industry-government relations. In H. L. Etzkowitz, L. (Ed.), *Universities and the global knowledge economy* (Vol. 1, pp. 155-162). London: Pinter.

McFadzean, E. S. (1998). The creativity continuum: Towards a classification of creative problem solving techniques. [journal]. *Creativity and Innovation Management, 7*(3), 131-139.

McFadzean, E. S., O'Loughlin, A. M., & Shaw, E. (2005). Corporate entrepreneurship and innovation part 1: The missing link. [Journal]. *European Journal of Innovation Management, 8*(3), 350-372.

Metcalf, J. S. (1995). Technology systems and technology policy in an evolutionary framework. *Cambridge Journal of Economics, 19S*, 25-46.

Mohnen, P., & Roller, L. H. (2001). *Complementarities in innovation policy, discussion paper 2712*. London: Centre for Economic Policy Research.

Morlacchi, P., & Martin, B. R. (2009). Emerging challenges for science, technology and innovation policy research: A reflexive overview. *Research Policy, 38*(4), 571-582.

Mytelka, L. K., & Smith, K. (2002). Policy learning and innovation theory: An interactive and co-evolving process. *Research Policy, 31*, 1467-1479.
Nill, J., & Kemp, R. (2009). Evolutionary approaches for sustainable innovation policies: From niche to paradigm? *Research Policy, 38*(4), 668-680.
Nonaka, I. (1994). A dynamic theory of organisational knowledge creation. *Organizational Science, 5*(1), 14-37.
Park, H. W., & Leydesdorff, L. (2010). Longitudinal trends in networks of university-industry-government relations in south korea: The role of programmatic incentives. *Research Policy, 39*, 640-649.
Parrish, B. D. (2007). Designing the sustainable enterprise. *Futures, 39*(7), 846-860.
Pastakia, A. (1998). Grassroots ecopreneurs: Change agents for a sustainable society. *Journal of Organisational Change Management, 11*(2), 157-173.
Peneder, M. (2010). Technological regimes and the variety of innovation behaviour: Creating integrated taxonomies of firms and sectors. *Research Policy, 39*, 323-334.
Potts, T. (2010). The natural advantage of regions: Linking sustainability, innovation, and regional development in australia. *Journal of Cleaner Production, 18*, 713-725.
Sorensen, F., Mattson, J., & Sundbo, J. (2010). Experimental methods in innovation research. *Research Policy, 39*, 313-322.
Tidd, J. (2006). *Innovation models* (No. 1). London: Tanaka Business School, Imperial College.
Tijssen, R. J. W. (2006). Universities and industrially relevant science: Towards measurement models and indicators of entrepreneurial orientation *Research Policy, 35*, 1569-1585.
Trajtenberg, M. (2002). Government support for commercial r&d: Lessons from the israeli experience. *Innovation Policy and the Economy., 2*, 79-134.
van Geenhuizen, M. (2008). Knowledge networks of young innovators in the urban economy: Biotechnology as a case study. *Entrepreneurship & Regional Development, March*, 161-183.
Wickham, P. A. (2004). *Strategic entrepreneurship* (3rd Edition ed.). Harlow, England: Pearson Education Limited.
Zahra, S. A. (1995). Corporate entrepreneurship and financial performance: The case of management leveraged buyouts. *Journal of Business Venturing., 10*(3), 225-247.

2. Cooperative Research Centres and Industrial Clusters: Implications for Australian Biotechnology Strategies

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Introduction

The success of various high technology industry clusters around the world has prompted governments at all levels to try and emulate this success through the introduction of technology policies that will develop many of the key aspects thought to be driving the success of these clusters. Rarely have governments been able to truly replicate the success of the best known clusters such as IT in Silicon Valley and the Route 128 region, and biotechnology in the South Bay area of greater San Francisco; however, these policies have often been instrumental in improving the competitiveness of a local high technology industry. This paper reviews the Australian Government's policies, especially that of utilizing a CRC (Cooperative Research Centre) model, as well as the strategies of individual Australian states. This review considers the appropriateness of the CRC model for the development of the Australian biotechnology industry and investigates how this model integrates with the development strategies used by various Australian states.

This paper will compare published state and national Australian strategies with each other and relate these to current infrastructure and practices by CRC's and industrial clusters to support them. The most crucial concepts to be investigated include Australia's productivity, alignment, complementarity and knowledge transfer mechanisms in biotechnology. Its current international standing and reasons for this position will be mentioned and the potential for it to be more significant globally will be discussed, together with the strategies it should pursue to be more successful.

What is Biotechnology?

For thousands of years, old (or traditional) biotechnologies have been used to generate a profit in the fermentation industries, for example in the making of cheese, wine, beer, yoghurt and other foodstuffs. Many of the processes would have been discovered by accident resulting from a lack of proper preservation methods. Inhibition of microbe induced deterioration by high concentrations of inhibitors such as salt or sugar would also have been observed while the treatment of infections using antibiotic-producing organisms was practiced by the ancient Egyptians. Thus while biotechnology in its traditional sense has been around for a considerable period of time, difficulties transporting biotechnology-based products limited the competitiveness of any one region to the extent that most regions engaged in basic biotechnology processes.

The emergence of new biotechnology applications, the advancement of supporting technologies, and globalization have created significant opportunities for the exploitation (in a commercial sense) of biotechnology. ‘Old’ and ‘new’ biotechnologies now run concurrently though where the boundaries lie definitionally are not entirely clear. Acharya (1999, p. 15) relies upon different definitions including ‘the industrial use of recombinant DNA, cell fusion and novel bioprocessing techniques’ and another as being ‘any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses’. Moses and Moses (1995, p. 1) take a slightly different approach, suggesting that biotechnology has two major attributes, namely that ‘it is a technology, a set of techniques for doing practical things, all of them with implications for the commercial and/or the public sectors’. These authors continue by saying that it involves ‘making products and providing services which can be sold for a price in the marketplace, or paid for from the public purse’. In the 2000 Australian National Biotechnology Strategy (http://www.botany.unimelb.edu.au/envisci/nick/prop-biotech_nat_strategy.pdf), a precise definition is not attempted but ‘modern biotechnology’, using recent more advanced nucleic acid-based techniques is distinguished from ‘traditional fermentation technologies’, representing the ‘older’ biotechnologies. The ***Biotechnology:*** *Strategic Development Plan for Victoria* (Department of State and Regional Development, 2001, p. 7) defines biotechnology as ‘the application of knowledge about living organisms and their components to make new products and to develop new industrial processes’. It is thus apparent that semantics is the first problem policy makers and strategists encounter when attempting to prioritize or fund ‘biotechnology’ initiatives. Not least of these is the dismissive attitude that ‘old biotechnologies’ or ‘traditional fermentation technologies’ are already established and have little room for improvement.

In this paper, the definition ‘the manipulation or modification of living organisms (or parts of organisms) for gain’ is being embraced to encompass both the ‘modern’ and the ‘old’ biotechnologies (across the fields of biomedicine, agriculture, environment, mining and bioinformatics), hence including more stakeholders and a wider range of networks and associations.

The Current State of Australian Biotechnology

The United States was the leader in this field in the early 1990s (Herbig and Miller, 1992), largely due to President Reagan’s 1982 policies including universities being permitted to take title to technologies developed using federal funding (Stewart, 1991). The United States’ current leadership is largely due to its high R&D expenditure by both government and industry (Mitchell, 1999), being approximately US$ 28 billion in 1999 (Department of State and Regional Development, 2001, p. 14). Europe was slow to follow the United State’s lead, largely due to policy issues creating a negative external environment for the exploitation of biotechnology (Senker, 1998). In Japan, the only other country (outside North America and Europe) Acharya (1999, p. 32) identified as being ‘industrialized’, the government has more recently made extensive efforts to build up biotechnology disciplines. Here, the lack of private finance and the strong actions of the state in funding major research agencies have led to the clustering of biotechnology and pharmaceutical firms around national laboratories (Wieandt and Amin, 1994). Government support in the above countries has contributed to the formation of high technology clusters, which have been associated with exceptionally high rates of technological innovation (Baptista and Swann, 1998).

In contrast, a lack of government support until recently has severely hampered Australia's biotechnology competitiveness and the economy has been branded in news reports as being 'commodity based' as recently as 2001, leading to a drive to emulate the success of the above industrialized countries. Ernst and Young (2001) paint a brighter picture of Australia emerging over the past decade during which government policy has provided opportunities to identify and add value to the fundamental research base. These authors identified that Australian biotechnology continues to grow but remains small in global terms with almost $1 billion in revenue in the 2000/2001 tax year with three sectors dominating namely: human health; equipment and services; and agriculture. This followed an expenditure of approximately $447 million on biotechnology R&D in the previous year.

The Role of Government in Developing Biotechnology

In light of a vast array of opportunities in biotechnology, many of which require expensive research before they can be considered 'market ready', external funding is often required for success in these ventures (Sherblom, 1991). Acharya (1999, p. 54) in describing biotechnology in industrialized nations indicated that success has been dependent upon the scientific base, activities of the private sector and the importance of government in developing a suitable environment for it to flourish.

According to Acharya (1999, p. 32) governments in developed countries encouraged the formation of biotechnology firms by providing finance in the form of loans or grants, or by developing links between research and production through the formation of networks. Methods to try and build networks were identified such as the creation of science or technology parks. The governments' regulatory role was also considered significant.

However, within developed countries such as the USA for example, Willoughby (1999) identified that New York was less competitive than other states, partly because of regulatory and economic constraints imposed by state government.

Australian Government Biotechnology Input

In order to foster the environment alluded to above, in which biotechnology could flourish, the Federal Government initiated a Cooperative Research Centre (CRC) Program more than ten years ago to boost the competitiveness of Australian industry. Both Federal and state governments also have additional funding available to support strategically important biotechnology initiatives, although historically this has been nowhere near as much as Australia's major competitors have invested in this field.

In addition, the federal and state governments have developed regulatory frameworks in which biotechnology research and commercialization can be conducted in an ethical manner. The greatest challenges in the development of new products are to ensure public health and safety and the preservation of Australia's unique environment. For example, the Commonwealth Gene Technology Act (2000) establishes a national scheme to regulate gene technology and provides a framework to achieve coordination across all levels of government. The regulatory framework for biotechnology is outlined in more detail in a document with the same name, produced by Victoria State Government's Department of Human Services (2002). A fine balance exists between under-regulation, which can have catastrophic consequences to the region concerned and its customers, and over-regulation that would stifle industry growth. It is still too early to determine the consequences, or even appropriateness of Australia's regulatory framework. Besides the public liability threats to biotechnology research, civil cases such as the Canadian one involving Monsanto's transgenic canola are set to test intellectual property rights in the courts.

More recently, the Commonwealth and most State Governments have formulated biotechnology strategy documents to outline the respective governments' vision and support for biotechnology. The national strategy and a few state examples are outlined and compared below and related to state-specific outcomes.

Australian Government Biotechnology Strategies

Australian organizations have been conducting biotechnology research for some time but the Commonwealth and State Governments, realizing the potential benefits of developing this technology for commercialization, recently started to take an active interest in this field, releasing a series of strategy documents during 2000 and 2001.

In 1999, the Biotechnology Consultative Group (BIOCOG) was formed to advise Biotechnology Australia and the Commonwealth Biotechnology Ministerial Council on the development of the recently released National Biotechnology Strategy. It is intended to provide a framework for Government and key stakeholders to capture the benefits of biotechnology development for Australia (Australian National Biotechnology Strategy, 2000).

In 2000 the Commonwealth Government published a biotechnology strategy document in which it outlined its national strategy. This concentrated on safeguarding human health and the environment through regulation; facilitation of community education and involvement in public policymaking; productive investment in biotechnology and biotechnology training; enhancing economic and community benefits of biotechnology by enhancing links between the research sector and industries as well as better management of intellectual property.

The states in turn have expressed visions or missions with Victoria's State Government expressing their desire to be recognized as one of the world's top five biotechnology locations by 2010 (Department of State and Regional Development, 2001, p. 2); South Australia aiming to accelerate its bioscience development, enabling the creation of 50 new bioscience companies by 2010 (**http://www.bioinnovationsa.com.au/template/php**); New South Wales initiated its BioFIRST strategy, enabling the state to create and respond to biotechnology opportunities through growth in its infrastructure, intellectual and capital wealth; while Queensland aims to be the Asia Pacific biotechnology hub (**http://www.treasury.qld.gov.au/budget/budget99/smartstate/biotech1.html**).

All of these strategy documents were developed since 1999 and list the competitive advantages, limitations and challenges particular to the nation and each state, as well as commitment to funding and actions to be taken to realize their objectives. The CSIRO was identified as a key player in Australian biotechnology and launched its own strategy in 2002 to ‘understand what we are doing and where we are going’ (Head, cited by Trudinger, 2002).

The strategies were generally prepared by individuals appointed or requested to do so and may thus be considered ‘top-down’. This is dangerous considering public opposition to many of the genetic engineering aspects of biotechnology. However, this problem was overcome by making each strategy broad enough to allow individual decisions to be made with stakeholder inputs and incorporating both regulatory and ethical considerations.

The States' current Biotechnology Activities

South Australia is one of Australia’s emerging states with respect to biotechnology innovation and Hollis (2002) cites the proximity between all the academic institutions and biotechnology firms as well as a high level of communication as major reasons. BioInnovations SA is the state government’s instrument for driving biotechnology innovation and has helped the state to develop expertise in genomics, clinical research and drug testing, diagnostics, oral and injectable pharmaceuticals and antivenin development, as well as contract research. Specific applications of these technologies include those in aquatics, pig and poultry production, crop improvement (such as salt tolerant varieties), crop disease diagnostics, cancer treatment. The state government has put $6.3 million into establishing a bionomics research facility in the Thebarton Biotechnology Precinct, which houses Bionomics and other biotechnology companies (Goldberg, 2002a). Bionomics attracted $3.3 million in Federal government funding and has already discovered 137 genes that could be useful in diagnostics or drug development. According to Trudinger (2002), a $1.5 million Biotechnology Fellowship Fund was recently launched by the BioInnovations SA, to be matched by three universities for bringing three eminent researchers to the state.

In Queensland, the biotechnology corridor is stretched between the Gold Coast and Brisbane with a thin band of technology parks and companies between them (Young, 2002a). State government has taken a different approach by not investing directly but being generous in supporting infrastructure, providing the right climate and a high level of encouragement for bioindustry efforts through the Department of Innovation and Information Economy. Despite being considered smaller than New South Wales and Victoria with respect to its biotechnology productivity (Young, 2002a), Queensland is very active in this field with significant Australian Research Council investment in its R&D. It has a range of unique ecologies, encouraging bioprospecting from its marine and other biota while its concentration on the treatment of cancer, vaccine development, disease diagnostic (such as for blood clots) and bioinsecticides are attracting attention, as is its ability to span genomics, structural biology, molecular design and medicinal chemistry (Young, 2002a). A growing number of biotechnology companies are establishing in Queensland, some of which could be considered ‘blue chip’, while a few recent start-ups have attracted Australian Research Council grants of up to $250,000. State government has also increased its R&D expenditure by more than 300 per cent to about $200 million since the beginning of 2000.

Victoria has a proud history of research and development and Victorian companies comprise 23 of the 62 listed biotech stocks and account for more than half of the $14.9 billion capitalization (Hollis and Trudinger, 2002). In addition, a Biotechnology Platform Technology Working Party has been established to determine and establish infrastructure needs and the state receives a significant proportion of NHMRC funding to complement state and City of Melbourne financial support. Victoria is, with significant state government funding, concentrating on the development of platform technologies such as the synchrotron as well as embryonic stem cell lines and gene targeted mice for supplying the pharmaceutical biotech and medical research industries. These facilities are (and will be) based at precincts such as Parkville and the Monash STRIP and can be used by industries and researchers from throughout Australia and the world. Victoria is also concentrating its efforts and funds on specializing in neurosciences, control of infectious diseases, stem cell research and tissue repair, plant biotechnology, proteomics as well as attracting world-class researchers (Hollis, 2002). Although it is considered to be the medical research capital of Australia, Victoria also hosts 16 research institutes, several CRC nodes and centres targeting agriculture such as the Plant Biotechnology Centre, The Victorian Institute of Dryland Agriculture, AgGenomics (offering plant genomic services) and the Victorian Institute of Animal Science. Its expertise in reproduction and development was identified in Hollis (2002) as being threatened by competition from Brisbane.

Unlike other states, Goldberg (2002b) pointed out that New South Wales (NSW) has not received a lot of infrastructure support from state government, nor had it needed it. Recently there has, however, been more pressure from the biotechnology sector for government to accelerate the growth of the industry through the development and support of relevant projects and strategies. The Hunter Valley project to link six major health and medical research institutions is one example of such a project. NSW is currently leading Australia in infrastructure support for hospital-based clinical research (Goldberg, 2002b). Efforts by state government to overcome the disadvantage of the Sydney sprawl by strengthening existing research relationships are now paying off. BioLink was recently created to link all the research efforts in NSW to make the state more competitive through cooperation (Goldberg, 2002b). Most of Australia's venture capital firms are based in Sydney and the government launched its BioFirst program at the end of 2000 involving several departments focusing on issues such as business outcomes, platform technologies and ethics. NSW is currently home to 40% of Australia’s biotechnology and pharmaceutical companies, generating $2.8 billion in annual sales. It intends to bring back expert expatriates to assist in developing key platform technologies for research into agriculture, medicine and the environment.

Australia’s other states and territories, although active in biotechnology, have not advanced as rapidly or as far as the above four states but have other geographical and resource advantages such as Tasmania’s proximity to the Antarctic and Western Australia’s wealth of mineral resources which have stimulated marine biotechnology and mineral leaching using bacteria respectively. Agricultural biotechnology is also a key activity for these states. Due to Australia’s size, the states differ with respect to the problems and opportunities that can be addressed using biotechnology, and these are usually investigated by the affected regions. However, there is also often overlap such as salinity which can be addressed across state boundaries through Cooperative Research Centres (CRC’s).

Cooperative Research Centres and Australian Biotechnology

As can be seen from the above synopsis of the most significant biotechnology activities in Australia, there is a bewildering array of participants scattered throughout the country creating the perception that competition between states would often supercede collaboration, potentially leading to considerable duplication of facilities. Such an image can be disastrous in attempts to attract overseas and local venture capital.

The Commonwealth Government introduced a system of Cooperative Research Centres (CRC’s) more than ten years ago to bring scientists from Universities, CSIRO, other government institutions, industry and private sector organizations together (Riedlinger, 2002). There are currently 65 centres in diverse fields and, according to Ernst and Young

(2001), of the 91 CRC's that were launched since the program's inception, 24 have had significant biotechnology components. Each CRC is funded by both Federal Government and industry, is national and brings research and industry together to work on specific R&D projects that will benefit from the critical mass of effort (**http://microtechnologycrc.com/aboutus.html**). Riedlinger (2002) mentioned that CRC's have an average annual budget of $7 million while Ernst and Young (2001) indicated that they are selected following a competitive process approximately every two years with funding typically provided for up to seven years. The CRC's practising biotechnology are in the categories of medical science and technology, the environment and agriculture (Riedlinger, 2002).

The CRC's are distributed across states and regions throughout Australia and meet on a fairly regular basis to discuss relevant issues. Some are struggling to meet revenue targets such as the CRC for Waste Management and Pollution Control (Goldberg, 2002b) while others, such as the Adelaide-based CRC for Tissue Growth and Repair are on the verge of transforming into independent companies once government funding expires. Many of the CRC's have commercial arms, such as the CRC for Vaccine Technology with its commercial arm, Vaccine Solutions, in Queensland (Young, 2002b).

Clustering in Biotechnology

The benefit of clustering firms, academic institutions, supporting infrastructure and sometimes even customers and suppliers in geographical proximity to enhance competitiveness has long been recognised with Silicon Valley cited as being the most prominent example in the USA. The formation of 'geographical clusters' defined by Baptista and Swann (1998) as 'strong collections of related companies and located in a geographical area, sometimes centred on a strong part of a country's science base' would be important in enhancing innovation (de la Rosa and Martin, 2000), one of the main objectives of such a strategy. The groupings have been referred to interchangeably as technology parks, precincts, hubs or clusters (Young, 2002b). Massey and Wield (1992) distinguished between clusters and science parks, indicating that the former have had considerable economic success while most science parks have been marginally successful at best.

Galvin and Davies (2002) reflected upon this discrepancy, highlighting the distinction between these two types of grouping. Clusters tended to be less formal networking between organizations in close proximity. Willoughby (1999) identified that successful clusters are characterized by strong 'biotechnology milieux' and are nurtured by rich networks for sharing knowledge both globally and locally. This departs from the 'industrial location factors' perspective described by Willoughby (1999), in which firms are attracted to relocate through reducing the cost of doing business locally. In the 'local technological milieux' perspective, interorganizational communication (locally and globally) is facilitated, primarily by government. This type of grouping is much more formal and many technology parks would fit this description (Galvin and Davies, 2002). Government artificially induces the grouping through incentives such as tax relief or more relaxed regulatory requirements. This is less sustainable in the long term and is sometimes referred to as the 'race to the bottom' as the major incentive is the reduced costs of doing business. The spontaneous generation of informal networks so crucial for knowledge exchange between like-minded organizations is usually absent.

The purpose of clustering, according to Young (2002b) is to achieve critical mass through shared resources (both infrastructure and intellectual) plus knowledge interchange across the boundaries of different disciplines and organizations. A biocluster was described by Bradley (cited by Young, 2002b) as being 'a geographical concentration of interconnected companies, specialized suppliers and service providers and associated academic and medical research institutions which compete but also cooperate'. They have all the components – service providers, incubators, large commercial companies that can contract research out to small companies, financiers and academic research institutes. This describes the basic structure of a cluster but one vital component for success has not been adequately researched and thus described, and that is techniques for micro-managing the flow of knowledge and information between the staff of the different cluster components.

Quoting from interviews with practitioners, Young (2002b) mentioned that setting up cross-organizational information channels is more an art than a science and the linkages within a cluster must be set up at different levels. A lot of interaction is random and spontaneous and, by clustering people in a fairly concentrated physical environment, the chances of it occurring increase.

In Australia, there are no substantial bioclusters that could be compared with those overseas such as in Boston or the South Bay area of greater San Francisco (USA). According to Young (2002b) there are plenty of tech parks, yet we may be ten to 15 years from having a substantial cluster (Monash Research Cluster for Biomedicine possibly being the most likely candidate in the near future). Many of the smaller bioclusters throughout Australia accommodate CRC nodes such as the CRC for Water Quality and Treatment, that has nodes in Western Australia, Queensland, Victoria, South Australia and New South Wales, mainly centred near universities.

Of the more successful Australian states facing the greatest challenges in making clusters work, New South Wales has had less proactive state government support than Victoria or Queensland (Young, 2002b) and the distances between discrete regions and organizations practicing biotechnology are high. South Australia, on the other hand, is pursuing the ‘local technological milieu’ model, with some duplication and less collaboration than desired including with respect to intellectual property.

The Importance of Networking for National Competitiveness

The underlying purpose of clusters, CRC's and technology parks is to develop and enhance innovation. As alluded to above, a factor significant for the building and retaining of innovation at a national level is the formation and maintenance of linkages and interactions between government support organizations, businesses and academia. Alcorta and Peres (1998) attribute the lack of competitiveness in technological specialization by the Caribbean and Latin American (except Mexico) countries to low investment in intangibles and human capital as well as the fragmentation of such linkages. India successfully founded Industrial Research Institutes (Katrak, 1998) for research and development collaboration and commercialization while Cuba's success in modern medical biotechnology follows largely from its regime's policy in medicine and health care, support by the Centre for Biological Research (Acharya, 1999, p. 58), and the Cuban Technology Innovation System (de la Rosa and Martin, 2000). Such institutions are important for the formulation and support of biotechnology policies and strategies as well as to support linkages between universities and the productive sectors to ensure the commercialization of research. Such networks, according to Coehen (1996) 'must produce some synergetic effects or additional benefits for its members or it must increase the efficiency of the activity on which the network is focused'. Cluster and CRC formation should enhance innovation and support such networks. Dense networks of contacts made possible through clusters improve innovative capacity and foster economic growth (Peters *et al.*, 1998) if fully exploited. It is just as important to identify the core competencies to be pursued by the cluster or CRC for enhanced competitiveness with inter- and intra-organizational knowledge generation and diffusion being critical to share ideas and eliminate repetition.

University-enterprise linkages were cited by Correa (2000), Fisher (1998) and Meyer-Kramer and Schmoch (1998) as being crucial although the difference in the knowledge developed by universities and that used by and developed in enterprises is cited by Correa

(2000) as being an inhibitory factor. The gap between these two types of knowledge is larger for the mature technologies such as food and textiles but less apparent in the high technology industries. For this reason technology transfer offices have been created in many universities to facilitate contractual relationships with enterprises and other potential clients. It can thus be concluded that the nature of the biotechnology (mature or high technology) embraced for competitive advantage by a country or state would determine the type and level of government investment to facilitate R&D and network creation. A scheme of existing and potential linkages in Australian biotechnology is represented in Figure 1.

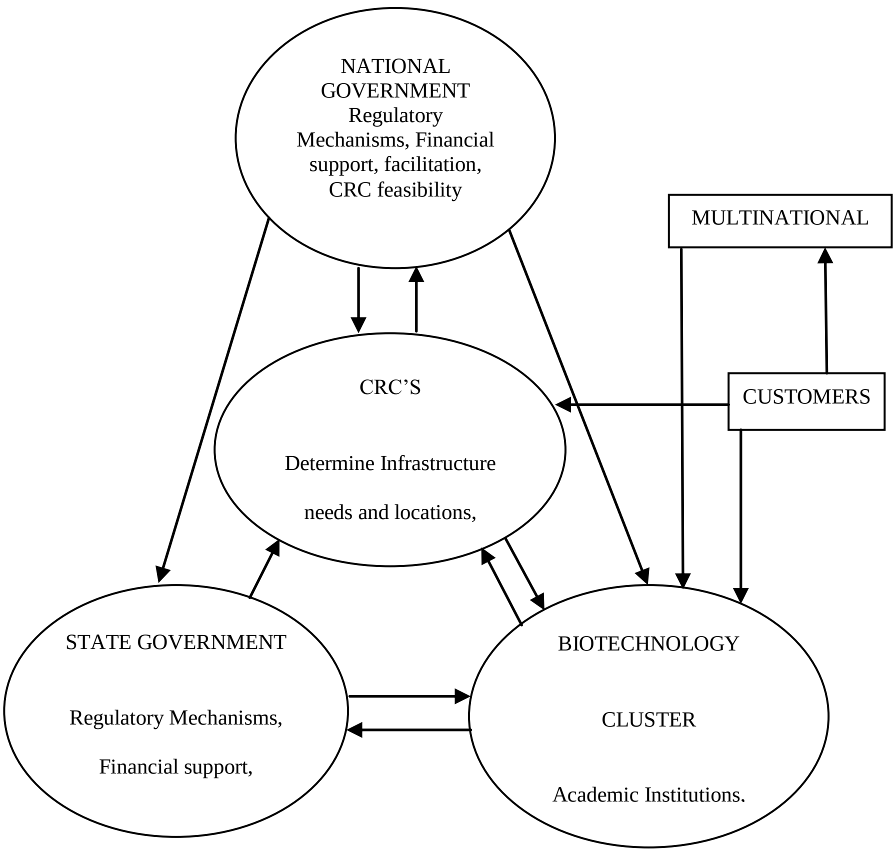

Figure 5.1 Knowledge flows to support Australian biotechnology

Emphasis is often on which of the 'grand strategies' listed by Pearce and Robinson (1997, p. 217), such as product development, innovation, integration or diversification, to pursue, rather than the cognitive aspects of change. Mezias *et al.* (2001) cite this as a major reason for strategic reorientations being difficult to achieve. Nonaka and Takeuchi (1995) criticize Porter for his under-emphasis on knowledge creation and diffusion. Most strategies rely on either top-down knowledge transfer that emphasizes explicit knowledge transfer, as in a bureaucracy, or a bottom-up approach that concentrates on tacit knowledge transfer through socialization. Nonaka and Takeuchi (1995) thus suggested a 'middle-up-down' approach to management dealing with both types of knowledge. Community and customer input is crucial for biotechnology strategy development due to the controversial nature of some products such as genetically modified foods, while biotechnology practitioners would have the technical knowledge to assess the feasibility of products being considered.

Tacit knowledge is socialized in Australia through informal meetings and relevant seminar presentations followed by opportunities to network within and between the organizations such as at the Westmead biomedical cluster in New South Wales (Young, 2002b). On-line discussion forums and e-mail allow the dissemination of previously subjective knowledge across the country, keeping close and distant members of CRC's informed. CRC meetings, due to the geographical distribution of members, cannot occur as regularly as those within clusters but these are still valuable in the transfer of knowledge between members. Publications such as Australian Biotechnology News and cluster or CRC newsletters are also valuable in keeping the biotechnology community informed on breakthroughs, relevant activities and potential linkages across the country and internationally.

How well is Australia positioned for Biotechnology Competitiveness?

So far, the infrastructure for biotechnology development and the strategies prepared to support this have been discussed. So, how successful is Australia, or will it be, in this field?

The historical disadvantages were mentioned and these are critical since biotechnology can have long lead times before commercialization. The lack of government funding and support has resulted in what is known as a 'brain drain' with much of Australia's innovative capacity being expatriated to the USA or Europe. There have been regulatory requirement hurdles such as in the import of biological materials that have made the research and innovation environment less favourable. Venture capitalists are perceived by some to be greedy, insisting upon a five-to tenfold increase in their investment within three to five years (mentioned at the Monash Research Cluster for Biomedicine Research Linkage Seminar 1, 2002). Venture capital, for many biotechnology innovations, would thus only be an option once all the risks had been taken and trials are nearing completion. In addition, the retention of intellectual capital, the perceived competition rather than collaboration between organizations and states and a lack of focus on commercialization has deterred investors. Furthermore, multinationals have been deterred by a lack of incentives (Binning, 2002) and would rather invest in Singapore, China or Japan where manufacturing infrastructure is better developed. Whether Australia should try to emulate the Asian countries to attract multinational manufacturing funding rather than capitalize on its innovativeness and research strengths is debatable, especially since the former require incentives that support the less sustainable 'local technological milieu' model described above.

Despite the limited government support in comparison with other developed countries advancing in the biotechnology field, Australia is an innovative country in comparison with its Asian neighbours, such as Singapore (Binning, 2002), which concentrate more on copying other innovations. However, Australia has little manufacturing infrastructure and labour costs are relatively high.

Australian innovation is in part due to the CRC system, which facilitates knowledge diffusion, and the more recent deliberate attempts to facilitate clustering and the associated socialization of tacit knowledge. Recent commitment by Federal and most state governments to support biotechnology development through the publishing of strategy documents as well as increasing financial and other support bodes well for the future. These inputs, together with Australia's wealth of natural resources, innovative capacity and high standard of living have the potential to make the country a world leader in biotechnology in the near future. Traditional biotechnology should be pursued concurrently with modern 'high tech' biotechnologies as the former are in a better position to yield short- to medium term profits through 'value adding' and could enhance development in 'less favoured regions', while the latter generally have much longer lead times and higher costs and would be based in the larger centres. Overlap between traditional and modern biotechnology, enhancing economies of scale through maximization of expensive capital equipment should be considered and coordination with Asian manufacturing capacity may be another feasible option.

To ensure that opportunities are not wasted, care must be taken to prevent the disbanding of CRC's that may have set unrealistic targets or have long lead times for their projects (impatience could result in a waste of all prior funding just before a breakthrough could potentially have been made). Each cluster's components must support the cluster's core business, while expensive infrastructure should be shared rather than duplicated. In addition to enhancing efficiency, this improves networking. Intellectual capital must be kept in the country by retaining key staff and 'extracting' their tacit knowledge in preparation for their eventual departure. For biotechnology to succeed in Australia, knowledge on desired products and processes, a bridging of the gap between research and commercialization paradigms, and a spirit of cooperation rather than competition should be enhanced. Hollis and Trudinger (2002) stated that, for Australia to make its mark in biotechnology, groups across the country need to cooperate more than they currently are. There is thus a requirement for better networking between governments, academic institutions, potential and existing manufacturers and support organizations (such as patent law and marketing firms) to enhance Australia's competitiveness.

Future biotechnology strategies should identify financially viable projects that can be accommodated by the complementary systems of CRC's and their industrial clusters. New CRC's are constantly emerging as opportunities emerge and this should be encouraged while states should strive to attract and support the infrastructure enabling them to efficiently undertake identified biotechnology projects or their components, as delegated by CRC's.

References

Acharya (1999), *The Emergence and Growth of Biotechnology*, Edward Elgar Publishing Ltd., Cheltenham, UK.

Alcorta, L. and Peres, W. (1998), 'Innovation systems and technological specialisation in Latin America and the Caribbean', *Research Policy*, Vol. 26, pp. 857-81.

Baptista, R. and Swann, P. (1998), 'Do firms in clusters innovate more?', *Research Policy*, Vol. 27, pp. 525-40.

Binnings, D. (2002), 'Money or nothing: Australia versus Singapore Inc.', *Australian Biotechnology News*, Vol. 1(24), pp. 16-21.

Coehen, R. (1996), 'Challenges of networking in technology assessment', *Technological Forecasting and Social Change*, Vol. 51, pp. 49-54.

Commonwealth Gene Technology Act (2000), Office of the Gene Technology Regulator (OGTR), Canberra.

Correa, C.M. (2000), 'University-enterprise linkages in the area of biotechnology', in R.E. Lopez-Martinez and A. Piccaluga, *Knowledge Flows in National Systems of Innovation*, Edward Elgar Publishers Ltd., Cheltenham, UK, pp. 155-67.

De la Rosa, L. and Martin, B.E. (2000), 'The role of the biotechnology and pharmaceutical scientific and productive clusters in the Cuban innovative activity', in R.E. Lopez-Martinez and A. Piccaluga, *Knowledge Flows in National Systems of Innovation*, Edward Elgar Publishers Ltd., Cheltenham, UK, pp. 168-83.

Department of State and Regional Development (2001), *Biotechnology: Strategic Development Plan for Victoria*, Department of State and Regional Development, Science and Technology Division, Melbourne.

Ernst and Young (2001), *Australian Biotechnology Report 2001*. Paragon Printers, Canberra.

Fisher, L.M. (1998), 'Technology transfer at Stanford University', *Harvard Business Review*, Vol. 13, Fourth Quarter, pp. 76-85.

Galvin, P. and Davies, J. (2002), 'Innovativeness in industrial clusters: a theoretical explanation of differences in innovation levels in industry clusters and science parks', *Conference paper presented at the Academy of Management Conference*, Denver, August 2002.

Goldberg, D. (2002a), 'Biotech in South Australia: dancing with the elephants', *Australian Biotechnology News*, Vol. 1(8), p. 28.

Goldberg, D. (2002b), 'Biotech in NSW: United they stand', *Australian Biotechnology News*, Vol 1(5), pp. 30-31.

Goldberg, D. (2002c), 'Waste CRC warns on revenue expectations', *Australian Biotechnology News*, Vol. 1(11), p. 19.

Herbig, P.A. and Miller, J.C. (1992), 'The United States versus the United Kingdom, Canada, and Australia', *Technological Forecasting and Social Change*, Vol. 41, pp. 423-34.

Hollis, T. (2002), 'Biotech in South Australia: how a 15-minute city bred a biohub', *Australian Biotechnology News*, Volume 1(8), pp. 24-7.
Hollis, T. and Trudinger, M. (2002), 'Biotech in Victoria: smaller players face big issues', *Australian Biotechnology News*, Vol. 1(6), p. 32.
http://www.bioinnovationsa.com.au/template/php
http://www.botany.unimelb.edu.au/envisci/nick/prop-biotech_nat_strategy.pdf
http://microtechnologycrc.com/aboutus.html
http://www.treasury.qld.gov.au/budget/budget99/smartstate/biotech1.html
Katrak, H. (1998), 'Economic analyses of industrial research institutes in developing countries: The Indian experience', *Research Policy*, Vol. 27, pp. 337-47.
Massey, D. and Wield, D. (1992), 'Science parks: a concept in science, society, and space (a realist tale)', *Environment and Planning*, Vol. 12, pp. 411-22.
Meyer-Kramer, F. and Schmoch, U. (1998), 'Science-based technologies: university-industry interactions in four fields', *Research Policy*, Vol. 27, pp. 835-51.
Mezias, J.M., Grinyer, P. *et al.* (2001), 'Changing collective cognition: A process model for strategic change', *Long Range Planning*, Vol. 34, pp. 71-95.
Mitchell, G.R. (1999), 'Global technology policies for global change', *Technological Forecasting and Social Change*, Vol. 60, pp. 205-14.
Moses, V. and Moses. S. (1995), *Exploiting Biotechnology*, Harwood Academic Publishers, Chur, Switzerland.
National Biotechnology Strategy (2000), Commonwealth Biotechnology Ministerial Council, Canberra.
Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, New York.
Pearce, J.A. and Robinson, R.B. (1997), *Formulation, Implementation, and Control of Competitive Strategy*, Irwin, Chicago.
Peters, L., Groenewegen, P. *et al.* (1998), 'A comparison of networks between industry and public sector research in materials technology and biotechnology', *Research Policy*, Vol. 27, pp. 255-71.
Riedlinger, M. (2002), 'Cooperative Research Centres going strong in the biosciences', *Today's Life Sciences*, Vol. 14(3), pp. 36-9.
Senker, J. (1998), 'Biotechnology: the external environment' in J. Senker, *Biotechnology and Competitive Advantage*, Edward Elgar Publishing Ltd., Cheltenham, UK, pp. 6-18.
Sherblom, J.P. (1991), 'Ours, theirs, or both? Strategic planning and deal making', in R.D. Ono, *The Business of Biotechnology: From the Bench to the Street*, Butterworth-Heinemann, Boston, pp. 213-24.
Stewart, J.M. (1991), 'Capitalising on new opportunities: Entrepreneurship in biotechnology'. in R.D. Ono, *The Business of Biotechnology: From the Bench to the Street*, Butterworth-Heinemann, Boston, pp. 23-38.
Trudinger, M. (2002), 'The other big Australian' *Australian Biotechnology News*, Vol. 1(25), p.18-20.
Wieandt, A. and Amin, N. (1994), 'Biotechnology: the emerging battlefield for US and Japanese pharmaceutical companies', *Technology Analysis and Strategic Management*, Vol. 6(4), pp. 423-35.
Willoughby, K.W. (1999), 'Strategies for the Local Development of Advanced Technology Industry: Clues from the Case of Biotechnology in New York State', Graduate School of Management, University of Western Australia, Perth.
Young, P. (2002a), 'Biotech in Queensland: beautiful one day, smart the next', *Australian Biotechnology News*, Vol. 1(4), pp. 24-8.
Young, P. (2002b), 'Bioclusters: get it together', *Australian Biotechnology News*, Vol. 1(31), pp. 26-8.

3. Assessment of Cleaner Production Uptake: Method Development and Trial with Small Businesses in Western Australia

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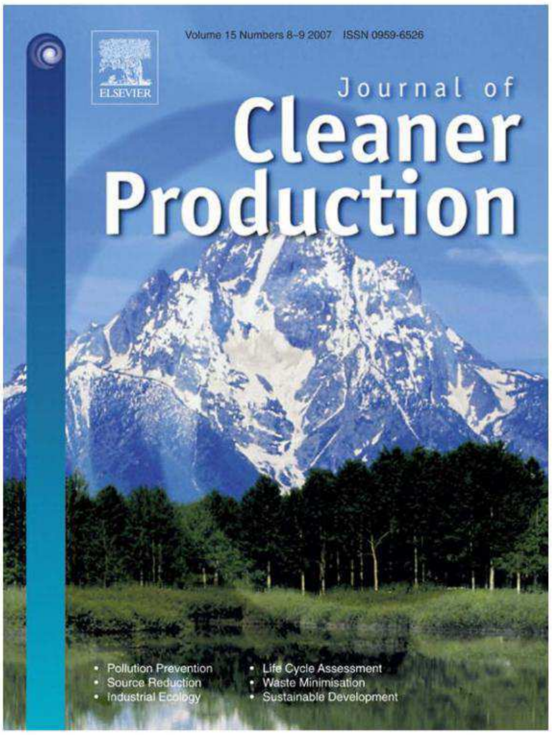
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Assessment of cleaner production uptake: method development and trial with small businesses in Western Australia

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Abstract

This paper reports on the development of an innovative semi-quantitative assessment method to estimate the level of uptake of cleaner production (CP) in small to medium-sized enterprises (SMEs) on the basis of three component ratings: awareness of CP ideas and benefits; presence of management features and/or system components conducive to CP; and CP content of recent innovations and operational improvements. The assessment method was designed for application through a telephone survey and was deliberately structured to minimise intentional socially preferable responses. It was trialled on 140 SMEs in four sectors, mostly from Western Australia: printing and book making; dry-cleaning; food processing and metal products. The trial showed that the assessment tool can judge the business' capacity to implement CP. The levels of CP uptake found in the trial reflect well on the experience of CP practitioners, albeit much lower than reported from previous mail surveys. In the trial the drycleaners performed significantly better than the other businesses, with food processing, metal processing and printing businesses being ranked second, third, and fourth respectively. The higher uptake by drycleaners was expected given that a sector specific CP program was conducted in that sector. Overall, the results suggest that generic (*non-industry specific*) semi-quantitative proxy indicators can be used for estimating the level of CP uptake in SMEs. Although further verification with quantitative environmental and economic performance data would in principle be desirable, this would be impractical due to the general lack of monitoring and recordkeeping of environmental data in many SMEs, and would also face the common conceptual, methodological and fundamental challenges for CP quantification. The tool may therefore be more useful to target CP promotion efforts, and measure their effectiveness.

Keywords: Cleaner Production; Eco-efficiency; Australia, SMEs

1. Introduction

Cleaner production (CP) and eco-efficiency (EE) are often used interchangeably, even though they differ significantly in their strategic intent [1,2]. CP is most commonly understood as positive economic benefits arising from efficient use of materials and energy. EE is concerned with positive environmental benefits from economic efficiency. The United Nations Environment Programme (UNEP) defined CP as "the continuous application of an integrated preventative environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment" [3]. Vickers et al. [4] favoured Jackson's [5] definition of CP: "an operational approach to the development of the system of production and consumption, which incorporates a preventative approach to environmental protection". EE is best characterised as "creating more value with less impact" [6,7]. The World Business Council for Sustainable Development (WBCSD) defined EE as the "delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity throughout the lifecycle to a level at least in line with the earth's estimated carrying capacity" [6,7]. A number of highly comparable other terms are

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commonly used in other jurisdictions and industry sectors, including: pollution prevention, toxics use reduction, design for environment, and industrial ecology [1,8].

CP and EE overlap and could very well have the same outcome when applied in a given business process or context despite perspectives differing according to whether the business objective is to cut costs, through EE, or to minimise environmental impacts, through CP. This is further illustrated by the fact that CP is most commonly further described in terms of a set of operational practices (*the means*) while EE is further described in terms of EE elements (*the objectives*). The most commonly used CP prevention practices are: good housekeeping; technology modification; input substitution; on site recovery, reuse and recycling; and product modification [1,3,8–10]. EE includes: reduction of material intensity of products and services; reduction of energy intensity of products and services; reduction of the dispersion of toxic materials; enhancement of material recyclability; extension of product lifetime; use of sustainably sourced renewable resources; and increase of the service intensity of products [1,7].

There has been a consistent growth in the number of publicly documented case studies of CP implementation in a wide range of industry sectors and business sizes, both in Australia [1,11] and internationally [12–15], since the early 1990s. These practical examples suggests that CP is widely applicable [16] and generally delivers both environmental and competitive advantage [2,6], even though the theoretical debate whether being green can be competitive is far from resolved [17–19]. Meanwhile however there remains great uncertainty about the actual level of implementation of CP in businesses, in particular among small to medium sized enterprises (SMEs) (e.g. [20,21]).

The research reported here aimed to develop and trial an innovative, generic assessment method for estimating the level of consideration and implementation of CP, with particular applicability in SMEs. Section 2 summarises key considerations in measuring CP, both quantitatively as well as qualitatively. Section 3 reviews Australian environmental management surveys. Next the design of the assessment tool is described in detail (in Section 4). The trial findings are summarised in Section 5, while Section 6 draws conclusions both with regard to the trial and possible applications of the assessment tool.

2. Measuring cleaner production

Despite a growing international interest in CP measurement over the last decade [15,22] there remains a great deal of uncertainty on how to measure CP/EE results properly. Measurement of the actual environmental and economic performance improvements would be preferred, but such is not straightforward at the firm level, as:

- *Conceptually*, measuring CP results is faced with the fact that *what needs to be measured no longer exists* (i.e. the avoided waste stream or resource consumption). It is therefore most common to compare the company's environmental and economic performance before and after implementation of a CP project. However, even though the CP project might reduce or nearly eliminate a specific waste stream, this does not necessarily show up in the company's overall environmental performance, if for example the reduced waste stream was a small contributor to the total waste stream of the company, or if product mix and/or output change. Tracking trends in the company's environmental performance over time however remains the most desirable CP quantification.
- *Methodologically*, environmental performance trend data need to be normalised against a meaningful indicator of business activity. This would typically lead to the use of (pollution) *intensity* indicators, expressed as net environmental impact (e.g. tonnes of waste, water use) per unit of production or sales (operational environmental performance indicators as in ISO 14031 [23]). Alternatively, *efficiency* ratios can be measured, i.e. the economic value created (in production units or financial turn over or profit) per net unit of environmental impact caused (e.g. total energy and water consumption [24]). Even though pollution intensity or eco-efficiency ratios can be regarded as best practice CP measurements, they cannot capture trade-offs, i.e. where one environmental impact category (e.g. waste water) improves at the expense of another environmental impact category (e.g. energy use), or where chemicals with different environmental impacts are being substituted (e.g. ecosystem toxicity versus human toxicity). While life cycle impact assessment tools can in principle be used to assess such trade-offs, there is only very limited experience in doing so [25].
- *Fundamentally*, CP is an environmental business improvement strategy, and the absolute or relative level of CP result, that is the level of environmental business improvement, does not consider the absolute performance levels before or after CP implementation [26]. An equal level of CP *achievement*, for example a 20% decrease in water pollution load, would be far more significant for a company already operating near or at industry best practice compared to a company that is catching up from being well below industry best practice. De facto, this approach penalises the industry leaders, as it is more challenging for them to achieve further substantial improvements then for the industry laggards.

In addition to these conceptual, methodological and fundamental considerations, the reliability of quantitative assessment of CP results ultimately depends on the comprehensiveness, reliability and integrity of the monitoring of environmental records at the company level. While larger businesses have generally moved to adopt best environmental performance monitoring systems [27], such systems are generally defunct or not existent in SMEs (e.g. [20,21,28]).

To bypass data problems, many studies and program evaluations have focused on the number of CP measures considered or implemented (e.g. [12,15,29,30]). Doing so is however also not very satisfactory as the number of options neither reflects upon the complexity of implementation nor upon the size of environmental and financial impacts of the implemented options. A simple housekeeping measure, for example fixing a tap, counts equally to a complex process change, for example inclusion of a process-integrated reuse/recycling system [16,31].

Qualitative, or semi-quantitative, measurement schemes can also be linked to the CP technology diffusion process or to the impact of the CP uptake on the business.

- CP uptake can be viewed as a specific example of *technology transfer*, broadly understood as technical innovation through transfer of ideas, knowledge, devices and artefacts from leading edge companies, R&D organisations and academic research to more general and effective implementation in industry and commerce [32]. A generic four activity descriptive framework can be used for such inward technology transfer [32]:
  1. *Awareness:* the processes by which an organisation scans for and discovers what information on technology is available;
  2. *Association:* the processes by which an organisation recognises the value of this technology or ideas for the organisation;
  3. *Assimilation:* the processes by which an organisation communicates these ideas within the organisation and creates generic business opportunities; and,
  4. *Application:* the processes by which an organisation applies this technology for competitive advantage.
- The *effectiveness and depth* of CP uptake can also be rated on the basis of the impact of the CP project on the company. For example, the greater savings, the better alignment with business priorities and/or the greater staff involvement in the CP project, the more likely the company develops a CP ethos, as a basis for further CP achievements in the future. Van Berkel [16] proposed an evaluation scheme that has since been used in several post-implementation reviews of CP programs [33–35]. It rates effectiveness in three areas:
  1. *Practical value*: the economic and environmental effectiveness, and operational feasibility of the CP opportunities identified;
  2. *Technical impact*: the innovativeness of the CP opportunities identified, which enhance the likelihood that their implementation will have a lasting impact on the technology selection, operation and maintenance of the company;
  3. *Systemic impact*: the degree to which the CP uptake has contributed to changes in management and information systems, organisation structure and corporate culture of the organisation, which enhances the likelihood that CP uptake will have a lasting impact on the day-to-day management of the company.

3. Environmental management surveys

Several studies were conducted in Australia to determine industry's current environmental performance. Kestigian [36] found that matters dealing with the environment were considered, by most companies, to be *backburner* issues, consuming valuable resources better spent elsewhere. Frost and Wilmshurst [37] surveyed chief financial officers of the top 500 Australian companies to determine the level of adoption of environmental accounting practices. Only 43% of respondents believed that environmental information was important to the users of annual reports.

Holmes and Girardi [38] surveyed corporate environmental practices and environmental strategy adoption in manufacturing companies with a written questionnaire and follow-up interviews of selected firms. Of the 153 respondents (response rate of 16%), 85% claimed to have implemented Waste Minimisation in the past, 45% CP and 5% EE. However, few respondents explicitly merged productivity and environmental issues—the essence of effective implementation of CP—as only few companies reported that environmental management issues had a significant influence on their production strategies. The adoption of preventive environmental management practices was found to lag behind the general advance of the environmental management function. They found that little information existed to assess the extent of linkages between environmental improvement, productivity initiatives and competitive strategy, while such information is essential to develop appropriate government policies, incentive systems and educational strategies.

Greene [39] interviewed 53 businesses that were identified by their industry and government peers as sector leaders to determine the existing structures, operations and planning within manufacturing organisations to support CP implementation. The results showed that 85% of the respondents claimed to be aware of CP. The responses however also indicated that companies that have employed CP methods have not moved from use on one project to comprehensive use in all operations.

Andrews et al. [40] investigated the awareness and adoption of CP in SMEs in the Geelong region using a mail survey, distributed to 500 businesses. The 145 respondents (response rate 29%) demonstrated a low familiarity with CP (only 28% of respondents were aware of CP). Nevertheless, there was a fairly high awareness of the environmental and economic advantages of CP-like measures. It was also found that the majority of CP practices are of a good housekeeping nature, reflecting the embryonic nature of the CP approach in these businesses.

Zutchi et al. [41,42] researched the experiences of Australasian organisations with the implementation of environmental management systems (EMS). They obtained 132 completed surveys from the 286 certified organisations approached (response rate of 46.2%). Only 14 respondents had 19 or fewer employees. The reported highest-ranking benefits of EMS adoption were: *protection from prosecution, fines and legal fees, reduction in organisational risks (health, safety and environment)* and *compliance with regulation* [41]. Remarkably it turned out that *establishing and monitoring CP and EE targets* was the only benefit for which the expectations were higher then the actual achievements [42]. Moreover it was found that employees were the most important stakeholders in EMS adoption, with only few organisations working directly with suppliers [42]. It was also found that the cost benefit analysis for EMS implementation was troubled by the difficulty to put a dollar value on the intangible benefits like *improvement of corporate image*. An opportunity was found for streamlining EMS adoption through integration with other management systems, for example for quality management [42].

The Australian Chamber of Commerce and Industry conducted a mail EE survey in late 2002 [43], to which 330 of its member businesses responded. The survey focused on environmental activities and outcomes, and the interplay of barriers and motivators. In terms of activities, *waste recycling and reuse* turned out to be the only environmental activity widespread among businesses of all size (at least 2/3 of companies in each size category engage in waste recycling). Uptake of any of the other environmental activities, including CP-focused activities like *design for environment*, *environmental purchasing* and *life cycle assessment*, was well below 20% of small businesses. Uptake by medium and large businesses was higher, in particular for *environmental audits* (50% of large and 37% of medium businesses) and *nature conservation* (33% of large and 19% of medium businesses) and *environmental purchasing policy* (32% of large and 21% of medium sized businesses). In terms of environmental outcomes, the most frequently reported environmental outcomes are *waste reduction*, *energy conservation* and *materials conservation* (each reported by at least half of the respondents of each business size). Overall, environmental outcomes occur more frequently in medium and large businesses than in small businesses. The differences between medium and large businesses appear to be marginal, if present at all. The three most frequently mentioned barriers were: *cost of implementing improved operations* (35% (small) to 55% (large businesses)); *lack of time* (35% (large) to 46% (medium businesses)); and *lack of commercial benefit from improved operations* (33% (small) to 43% (large businesses)). A remarkable finding was that all barriers are more frequently reported by medium businesses than by small businesses (with the exception of virtually equal occurrence of *lack of knowledge on alternative ways of operations*). With regard to motivators, three stand out as the most common motivators: *increased environmental awareness* (52% (small) to 68% (large businesses)); *cost savings* (39% (small) to 56% (large businesses)) and *compliance with regulations* (25% (small) to 50% (medium and large businesses)). Motivators are less frequently experienced and reported by small companies than by their medium and large business peers. An overall energy intensity indicator was calculated across all respondents: 3.7 MJ/AUD$ turnover.

The Swan-Canning Industry Survey [44] is the most significant effort in Western Australian. It determined potential threats to the Swan River by site inspections and assessment of more than 520 light industrial premises. The uptake of CP was however not investigated with any great depth.

4. Assessment method

This research aimed to develop an assessment method that could provide a proxy-indicator for the level of consideration and implementation of CP. During initial scoping it was found that indirect questioning on the implementation of CP through mail surveys a number of compounding errors occurs, particularly: low and selective response (only those who take the environment seriously will commit to return environment related surveys) and biased responses for socially-preferred, environmentally sound business activity. Moreover the nature of SMEs (in particular their often informal structure, high turn over of staff and businesses, etc.) does not lend itself to a vigorously quantitative assessment on the basis of documented and measured emissions, waste generation, and water, energy and materials consumption.

The method merged elements of the technology transfer process with the evaluation of the impact of the CP uptake on the business. It was structured to elicit one score for:

1. *Awareness:* indicator for the level of awareness of CP, with particular reference to the underlying ideas and practices, and awareness of the potential for environmental and economic benefit;
2. *Management:* indicator for the presence of key environmental and resource management features and tools within the business, reflecting the level of incentives created within the business's day-to-day operations to identify and pursue CP opportunities;
3. *Implementation:* indicator for the actual implementation of CP, or similar opportunities within the business over the preceding three years.

The awareness and implementation score relate to the awareness and application stages in technology transfer [32], while the association and assimilation stages are captured in the management indicator. While the implementation and management scores represent the operational value and systemic impact of the CP project [16], it was found impractical to properly assess technical impact in this assessment method. For each of these components a compounded 100-point score was developed, reflecting the authors' broad understanding of key drivers and shapers for effective preventive environmental management in businesses (as supported by in particular [6,13,16,31,45,46]). The scoring system is detailed in Table 1.

This rating scheme was expanded into an interview protocol for a 10–15 minute telephone interview with the senior manager (the CEO, unless unavailable). The choice for a telephone-based instrument was made to minimise response bias, which occurs when respondents answer in a certain direction, i.e. they "consciously or unconsciously misrepresent the truth" [47]. It was anticipated that this response bias would be far more marked in a written survey in which respondents can identify the purpose of the survey and respond to the awareness questions according to what they believe the researcher wants to hear. Moreover, the telephone survey was specifically designed to prevent the respondent from knowing upfront the detailed purpose of the survey and was short enough to make CEOs more amenable to contribute. It started with the implementation questions (which did not refer to environmental issues directly), and then moved into the

Table 1
Scoring system for assessing CP Uptake in SMEs

Component	Criteria	Score
Awareness score: awareness of CP ideas and familiarity with their key benefits		
Understanding of CP (30 points)	Company to provide three features of CP	10 points for each listed feature rated as appropriate by researchers
Understanding of EE (30 points)	Company to provide three features of EE	10 points for each listed feature rated as appropriate by researchers
Appreciation of possible benefits (40 points)	Company to judge four statements on nature of CP/EE	10 points for each appropriate judgement
Maximum *awareness* score		100
Management score: presence of management incentives conducive to consideration and implementation of CP		
Environmental management responsibilities (30 points)	Staff with principal environmental management responsibility	Maximum of 20 points, awarded as follows: 8 points for CEO/senior manager, and 3 points for any of engineering/technical manager, environmental manager, EHS officer and other staff
	Consideration of environment and energy in staff appraisals	5 points for inclusion of environmental issues, and 5 points for inclusion of energy issues
Environmental management plan (30 points)	Presence of a current environmental management plan (regardless of level of formalisation)	20 points but only awarded if respondent could provide reasonable detail of the plan (e.g. priorities for action and achievements to date)
	Staff involvement in development of the environmental management plan	Maximum of 10 points. 4 points for each of senior manager, environmental manager and engineering manager. 1 point was awarded for each other staff member
Awareness and management of environmental costs (40 points)	Maintenance of separate records for costs of gas, fuels, power, water and waste management	For each item for which costs were tracked, 2 points were awarded, and an additional 3 points if the responding manager was able to provide the respective costs
Maximum *management* score		100
Implementation score: inclusion of CP or EE elements in innovations implemented by the company in the preceding three years		
Recent innovations (50 points)	Five projects listed by the company that have been implemented to improve operation's efficiency	Each project considered to have a CP or EE element was given 10 points
Recent resource use reductions (50 points)	Projects listed in regard to reduction of reduction of water use, reduction of energy use, reduction of liquid waste, reduction of solid waste and reduction of air emissions	Each project with a genuine environmental benefit (over and beyond cost reduction costs) was given 10 points
Maximum *implementation* score		100
Integrated CP uptake score		[(Awareness score) + (management score) + (implementation score)]/3
Maximum		100

management questions (which dealt with environmental management, but not specifically with CP). The specific questions on awareness of the ideas and benefits of CP were only touched upon once a picture had emerged of the company's efficiency and resource management practices and achievements. Another type of error that may have occurred in the telephone interview was a limited response, due to the CEO being in a hurry or busy when contacting the business. This would skew the results as awareness, implementation or management incentives may be underestimated for that respondent.

5. Trial of assessment method

5.1. Trial design

The trial took place in October and November 2001 and involved: drycleaners; food processors; metal fabricators (including engineering workshops); and printers (including book making). These are dominated by SMEs, and have diverse environmental impacts (energy use, water use and emissions, air emissions and toxic materials). Through the inclusion of drycleaners, a deliberate bias was introduced to create a positive control as the Centre of Excellence in Cleaner Production had worked extensively with this sector to promote CP through performance and process benchmarking [28]. The awareness, management and implementation scores for the drycleaning sector were thus expected to be higher than for the other sectors. The pilot was focused on businesses in the greater Perth region (WA). Half of the respondents for the printing sector were from outside WA (25% Queensland and 25% South Australia) to gain some insight into possible regional differences.

The businesses were randomly sampled from stratified business populations, to ascertain pre-set response levels within each sector and region, respectively: 20 drycleaners; 40 metal fabricators; 40 food processors (all in Perth) and 40 printers (20 in Perth), 10 in Queensland, and 10 in South Australia). Using Yellow Pages® lists were compiled of all businesses within the sector and region, and these were organised alphabetic by business name. Next the necessary level of response was ascertained by dividing the target response by the number of businesses. This led the team to define which businesses would be included (in case of food industry for example 40 businesses from a total population of 412, meant every 10th business was selected). In case of non-response (unwillingness to participate) the next one on the list was contacted until a response was obtained.

All participants needed to have between 3 and 250 employees. These numbers were decided upon to prevent exclusion of the micro-operators that could still have a significant impact on the environment. A couple of respondents, however, had only two staff, in addition to the owner/operator working in the business. These were included all the same. One organisation employed over 250 staff but was considered highly innovative and a suitable candidate as a food industry case study.

5.2. Response rates

Of the 334 metal products manufactures in Perth listed in the Yellow Pages®, 149 were contacted and of these, 41 completed the assessment (response rates 27.5%). This was lower than planned probably due to insistence to interview the CEO and because ship/boat builders were particularly busy due to the approaching crayfish season. In the food-related industries, 125 of the 412 listed organisations were contacted, of which 40 CEOs or their representatives were interviewed (32% response rate). Of 106 drycleaners 51 were contacted to obtain the 19 responses (37% response rate). Of these, six had been involved in the sector CP program. Of the over 660 printers and bookbinders in the Perth region, Queensland and South Australia, 40 responses were obtained from contacting 103 companies (39% response, specifically 52% in WA, 29% in QLD and 43% in SA).

The total response rate was 32.7% (428 organisations contacted to obtain response from 140 CEOs, managing directors, owners or equivalents). This was better than the response rate for Holmes and Girardi (16%) [38], for Andrews et al. (29%) [40], but lower than for Zutshi et al. (46%) [41], all mail surveys, in the case of Zutshi only to organisations with high environmental awareness (as they had a certified EMS). Greene [39] and Water and Rivers Commission [44] did not record response rates.

5.3. Cleaner production uptake

Table 2 contains the sector-averaged component and integrated scores. The *implementation* score is the lowest component score and the *management* score the highest component score. The average integrated CP score for all businesses surveyed was 27, out of a possible 100. In detail:

- The mean *awareness* score for all responses is 22. This is consistent with the low level of CP awareness in the Geelong survey (27% of businesses aware of CP) [40]. This trial confirms their finding that much needs to be done to raise awareness levels and convince businesses of the potential benefits of CP.
- The *management* score was generally the highest of the three component scores investigated. This determined whether the company had an environmental policy or plan, the nature of these, the CEOs awareness of the company's utility accounts, whether environment or energy conservation were considered in staff evaluation, as well as who is responsible for the environmental affairs of the company. The word *responsible* created some confusion with most respondents taking it to mean *accountable*, in which case they may have accrued fewer points if general staff were also considered *responsible* through their implementation practises. Sixty of 140 businesses indicated that they had environmental policies and/or plans which varied from being an unwritten undertaking to reduce waste, through a written but confidential policy distributed by franchisors or an EPA license, to an extensive plan developed specifically for and by the respondent company. Points were allocated according to the nature of the plan/policy and who devised it. All but one of the organisations kept separate utility accounts and 74 of the respondents (53%) could quote most or all of these from memory or by immediate access through a computer at their desk.
- The lowest scores throughout were for *implementation*, suggesting that very little innovation is being devised or implemented for conserving resources or reducing waste. Fifty-five respondents (39%) listed at least one innovation that could be ranked as CP. Meanwhile 14 respondents (10%) indicated that they had implemented no innovations during the last three years. Some other innovations listed included retrenching staff and working longer hours, while a few industries indicated that no innovations were

Table 2
Sector averaged scores in trial

Sector (number of responses)	Sector averaged score (scale 1–100)			
	Component scores			Integrated CP score
	Awareness	Management	Implementation	
Food processing (40)	22	43	20	28
Metal products (41)	23	41	14	26
Printing and print finishing (40)	18	39	13	23
Drycleaning (19)	32	52	27	37
All sectors (140)	22	43	17	27

necessary. Respondents were not aware of the environmental and CP focus of the interview until after the implementation questions were asked, allowing the level of their focus on these issues to emerge spontaneously. Overall, this trial derived the score for CP *implementation* from actual changes made in the companies' operations, and therefore appears to have found much lower levels of CP implementation than indicated in previous surveys that directly asked companies whether or not they had implemented CP. The trial findings are more consistent with the day-to-day practical experience of CP promoters in Australia, which in turn adds to the argument that previous surveys might indeed have been significantly biased by socially desired rather than factual responses.

In order to analyse the variability of the scores between businesses in the same industry sector, the businesses have been grouped according to their individual scores, in five categories, respectively (similar categories were used before for ranking on environmental reporting [48]):

- *Bottom crawlers:* businesses achieving a score between 0 and 20;
- *Not so hot:* businesses achieving a score between 21 and 40;
- *Pressing hard:* businesses achieving a score between 41 and 60;
- *State of the art:* businesses achieving a score between 61 and 80;
- *Trailblazers:* businesses achieving a score between 81 and 100.

Figs. 1–4 show the frequency distributions for these categories for the component and integrated scores. Although there is a degree of difference between the graphs, it is apparent that overall the share of businesses in the lowest category (*bottom crawlers*) is remarkably high for the *awareness* score (54%), the *implementation* score (70%), and total CP uptake (37%). The exception is for the *management* score, where 46% of the businesses made it at least to the *not so hot* category. The conclusion from these frequency distributions is best captured in Fig. 4. This shows that most businesses were *bottom crawlers* (37%) or *not so hot* (45%). In other words, 82% of the respondents, achieve an overall score lower than 40 (out of a possible 100) for their level of consideration and implementation of CP. The drycleaners perform better (the two lowest categories contain only 52%). The printing and metal products sectors perform worse than average of the four sectors (in both sectors the two lowest categories account for 90% of businesses).

5.4. Variations by region, sector and business size

The trial was not explicitly structured for an in-depth study of sectoral and regional variations in CP uptake. A statistically significant comparative study would have to include greater numbers of businesses in each of the sectors and regions, and should also investigate whether the regional and sectoral variations are significant variables to be correlated with, for example: size of business; type of operations; and level of environmental legislation, that could have influenced the levels of CP uptake.

The forty companies in the printing and bookbinding sector were from Perth (20 businesses), Queensland (10 businesses in Brisbane, Townsville and Cairns), and South Australia (10 businesses in Adelaide). As there are over 200 companies for each state, the sample size was relatively small but large enough to give an initial indication of possible differences in

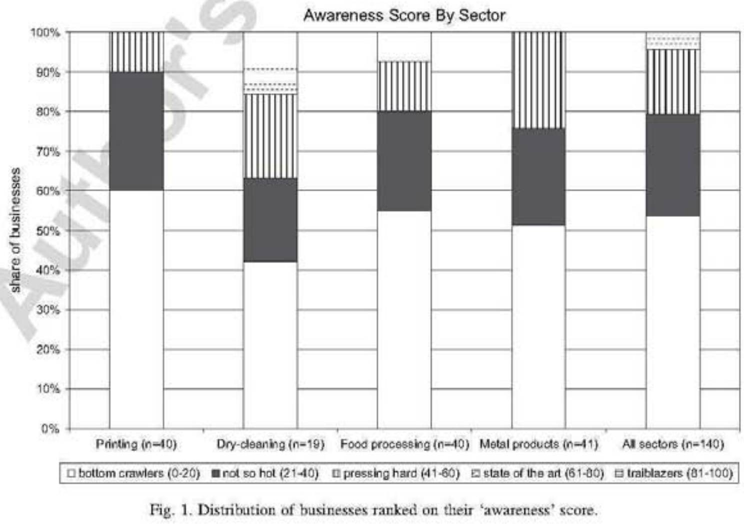

Fig. 1. Distribution of businesses ranked on their 'awareness' score.

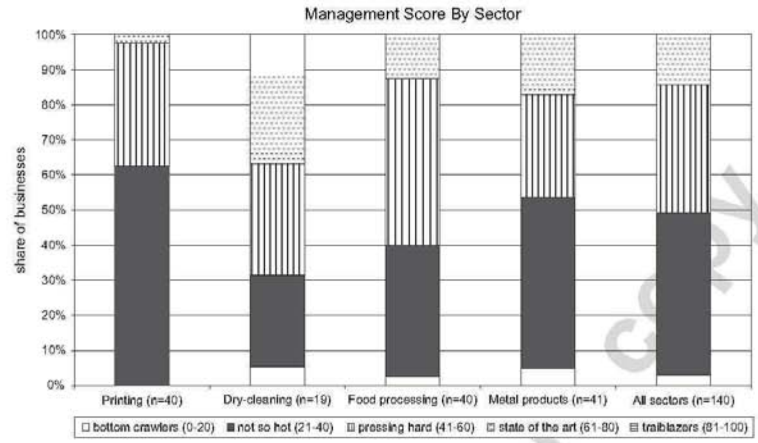

Fig. 2. Distribution of businesses ranked on their 'management' score.

the levels of consideration and implementation of CP. Table 3 includes the mean values for the component and integrated scores for each of these states.

Table 3 shows that WA printers and book binders appear to outperform their SA and QLD peers, in particular for *implementation*, and to a far lesser degree also for *management*, *awareness* and *CP uptake*. A rigorous statistical analysis to confirm this apparent trend was not performed, given the great uncertainty with regard to compounding variables that are potentially quite different between the states (e.g. levels of environmental regulation and waste management costs, business size and structure).

Table 2 shows the sectoral differences. These are statistically insignificant between food processing, metal products and printing industries. The uptake of CP by drycleaners is, however, remarkably higher. The difference of 10 points in the total score between the drycleaners and the average of all sectors is statistically significant. This was expected, given the concerted effort in the preceding 18 months to promote CP to drycleaners. The printers from WA, SA and QLD scored lowest in all three categories. Overall, there is much room for improvement as even the highest scoring sector, drycleaners, achieved only an average of 37 out of a maximum of 100, while the averaged value for all businesses surveyed was 27.

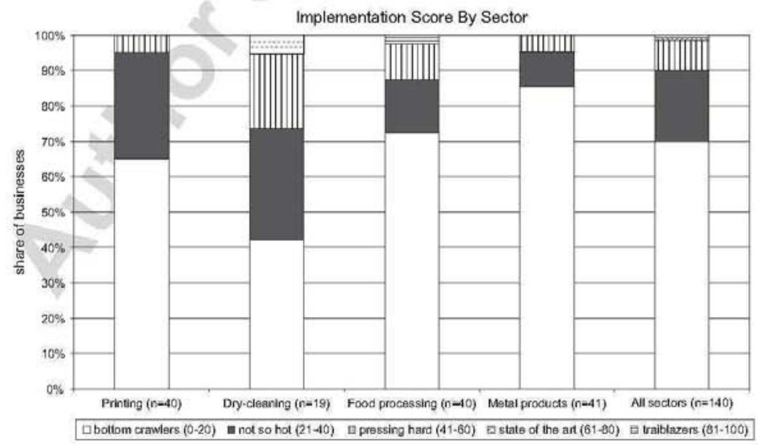

Fig. 3. Distribution of businesses ranked on their 'implementation' score.

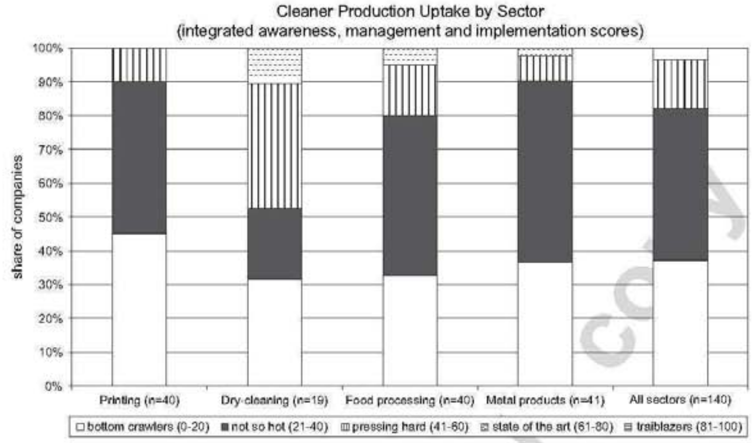

Fig. 4. Distribution of businesses ranked on their score for CP uptake.

The 19 drycleaners in this trial included 6 businesses that participated in the sectoral CP/EE program (the researcher undertaking this trial was not aware of which drycleaners had participated). A series of Bonferroni tests were performed to assess the statistical significance of the sectoral differences, and among the drycleaners between participants and non-participants in the CP/EE program. The statistically significant findings are summarised in Table 4. In summary there is a statistically significant difference between drycleaners who participated in the CP/EE program and those that did not participate. The program participants had on average a total score 31 points higher than the non-program participants. Likewise, there is a statistically significant difference between drycleaners who participated in the CP/EE program and all businesses in the other sectors. These participants had on average a total score of 32 points higher than the average of businesses in the other sectors. The analysis also showed that the difference between drycleaners who did not participate in the CP/EE program and businesses in other sectors was not significant. The limited exposure to CP that non-participating drycleaners might have had to CP appears to have had little effect on their CP uptake.

A similar analysis was contemplated for the impact of business size, as illustrated by the distribution of CP uptake scores in Fig. 5. This illustrates in a qualitative way that the larger SMEs outperform the micro SMEs in terms of their environmental performance and consideration and implementation of CP. Using Bonferroni and *t*-tests, it was apparent that there was no significant difference between large (over 75 employees), medium-sized (16–75 employees), and small (6–15 employees) businesses. Larger companies did, however, outperform micro-enterprises (less than 6 employees) with respect to *CP uptake*. Given the low numbers of businesses in the larger business size categories, this trial did not provide the proper statistical underpinning for this intuitively justifiable trend.

6. Concluding remarks

Given the inherent conceptual, methodological and fundamental complexities of measuring CP accurately in physical and/or monetary units, the study reported here set out to develop a simplified method to arrive at a proxy indicator for the level of consideration and implementation of CP in particular among SMEs. A review of strengths and weaknesses of different measurement approaches as well as the results of previous environmental management surveys among Australian businesses informed and guided the method development. Merging ideas from technology diffusion and CP impact studies, the proposed semi-quantitative method is based on the

Table 3
State averaged scores in trial for the printing and book making industry

State (number of responses)	Sector averaged score (scale 1–100)			
	Component scores			Integrated CP score
	Awareness	Management	Implementation	
Western Australia (20)	20	41	25	29
South Australia (10)	13	36	0	16
Queensland (10)	19	38	0	19
All states (40)	18	39	13	23

Table 4
Bonferroni test results (multiple comparisons, dependent variable = SCORE)

(I) Group	(J) Group	Mean difference (I − J)	Standard error	Significant	99% Confidence interval	
					Lower bound	Upper bound
DC in CP program	DC not in CP program	30.99	6.67	Yes	11.07	50.91
	Other industry sectors	32.46	5.65	Yes	15.58	49.34
Other industry sectors	DC not in CP program	−1.47	3.94	No	−13.25	10.31

The mean difference is significant at the 0.01 level. DC, dry cleaning; CP, cleaner production. Based on CP uptake score, with maximum of 100 points.

notion that successful CP uptake should be demonstrable at the levels of *implementation* (record of achievement in CP type innovations), *management incentives* (demonstrable elements of the management and information systems that create a CP-conducive business environment) and *awareness* (understanding of CP ideas and practices). The indicator was therefore structured in three equally weighted component scores for *awareness*, *management* and *implementation*.

The tool was trialled with 140 businesses from dry-cleaning, printing and book making, food processing and metal fabrication sectors, and took between 5 and 10 minutes to complete for each business. The response rate of 33% compared favourably with response rates from written surveys. The majority of businesses demonstrated low levels of consideration and implementation of CP, as reflected in the averaged CP uptake score of only 27 (out of a potential 100). This is also visible from the distribution of companies between laggards and leaders, which demonstrated that across the four industry sectors, as few as 18% of the businesses achieved an overall CP uptake score of 40 or more (out of a potential 100). These key trial findings align well with the general observations of CP practitioners regarding current levels of CP uptake in SMEs.

The method does still rely upon a certain amount of subjectivity, and therefore lacks precision in assessing the rigour and depth of CP implementation and environmental and economic benefits achieved thereby. The CP uptake score is therefore at best a proxy for the experience and capacity of the business to implement CP. The results achieved by the use of the tool, as in the trial reported here, therefore need to be interpreted with care. They only provide a once-off snap shot of CP implementation across an industry sector. The trial results suggest that the method results in a more realistic picture of the actual industry practice then achieved from written surveys which accuracy and reliability is severely constrained by self-selection, socially-biased answers and low response rates. Although further quantitative verification would be desirable, it is unlikely that the necessary performance data are adequately monitored by SMEs.

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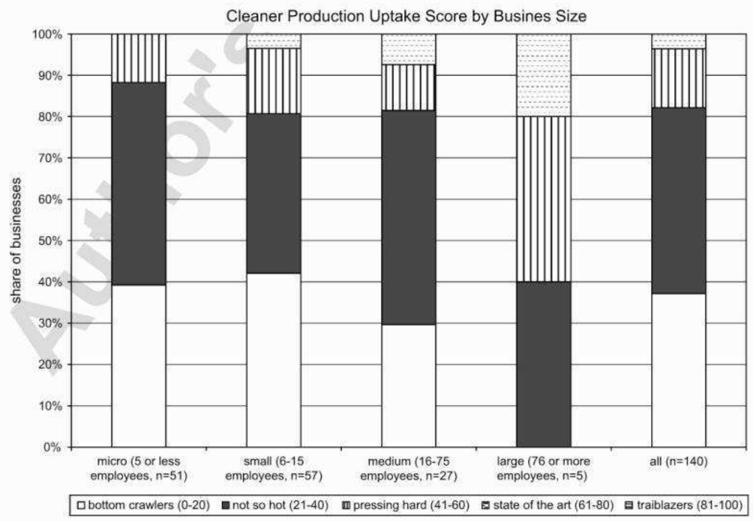

Fig. 5. Distribution of businesses by size ranked on their score for CP uptake.

and Resources (printing and book making sector) and from the WA Waste Management and Recycling Fund for the operation of the Centre of Excellence in Cleaner Production. Professor van Berkel held the position of Chair of Cleaner Production, which is proudly sponsored by CSBP Limited.

References

[1] van Berkel R. Cleaner production in Australia: revolutionary strategy or incremental tool? Australian Journal of Environmental Management 2000;7(3):132–46.
[2] WBCSD/UNEP. Eco-efficiency and cleaner production: charting the course to sustainability. Geneva: World Business Council for Sustainable Development and United Nations Environment Programme; 1996.
[3] UNEP. Government strategies and policies for cleaner production. Paris, France: United Nations Environment Programme; 1994.
[4] Vickers I, Cordey-Hayes M. Cleaner production and organizational learning. Technology Analysis & Strategic Management 1999;11(1):75–94.
[5] Jackson T. Principles of cleaner production: an operational approach to the preventative paradigm. In: Jackson T, editor. Developing preventative environmental management in the industrial economy. Boca Raton: Lewis Publishers; 1993. p. 143–64.
[6] DeSimione L, Popoff F, editors. Eco-efficiency: the business link to sustainable development. 1st ed. Cambridge, MA: The MIT Press; 1997.
[7] WBCSD. Eco-efficiency: creating more value with less impact. Geneva, Switzerland: World Business Council for Sustainable Development; 2000.
[8] van Berkel R, Willems E, Lafleur M. The relationship between cleaner production and industrial ecology. Journal of Industrial Ecology 1997;1(1):51–66.
[9] USEPA. Waste minimisation opportunity assessment manual. Cincinnati (OH): United States Environmental Protection Agency; 1988.
[10] de Hoo S, Brezet H, Crul M, Dieleman H. Manual for the prevention of waste and emissions. In: Crul M, editor. PREPARE: manual and experiences. The Hague, The Netherlands: Ministry of Economic Affairs; 1991.
[11] DEH. Eco-efficiency and cleaner production case studies. Canberra, Australia: Department of Environment and Heritage; 2004.
[12] Dieleman H, van Berkel R, Reijenga F, de Hoo S, Brezet H, Cramer J, et al. Choosing for prevention is winning. In: Crul M, Brezet H, de Hoo S, editors. PREPARE: manual and experiences. The Hague, The Netherlands: Ministry of Economic Affairs; 1991.
[13] Dorfman M, Muir W, Miller C. Environmental dividends: cutting more chemical waste. New York, USA: Inform; 1992.
[14] UNEP. Cleaner production worldwide. Paris, France: United Nations Environment Programme; 1993.
[15] USEPA. Pollution prevention 1997: a national progress report. Washington DC, USA: United States Environmental Protection Agency; 1997.
[16] van Berkel C. Cleaner production in practice: methodology development for environmental improvement of industrial production and evaluation of practical experiences. Amsterdam: University of Amsterdam; 1996.
[17] Porter M, van der Linde C. Green and competitive: ending the stalemate. Harvard Business Review 1995;September–October;120–34.
[18] Landis-Gabel H, Sinclair-Desgagne B. The firm, its routines and the environment. In: Tietenberg T, Folmer H, editors. The international yearbook of environmental and resource economics 1998–1999: a survey of current issues 1998.
[19] Reinhardt F. Bringing the environment down to earth. Harvard Business Review 1999 July–August;149–57.
[20] Hillary R. Environmental management systems and the smaller enterprise. Journal of Cleaner Production 2004;12(6):561–9.
[21] Cote R, Booth A, Louis B. Eco-efficiency and SMEs in Nova Scotia, Canada. Journal of Cleaner Production 2006;14(6–7):542–50.
[22] Huppes G, Ishikawa M. A framework for quantified eco-efficiency analysis. Journal of Industrial Ecology 2005;9(4):25–42.
[23] ISO. AS/NZS ISO 14031:2000 Environmental management — environmental performance evaluation — guidelines. Sydney, Australia: Standards Australia; 2000.
[24] WBCSD. Measuring eco-efficiency: a guide to reporting company performance. Geneva, Switzerland: World Business Council for Sustainable Development; 2000.
[25] Rundenauer I, Gensch C, Griesshammer R, Bunke D. Integrated environmental and economic assessment of products and processes: a method for eco-efficiency analysis. Journal of Industrial Ecology 2005;9(4):105–16.
[26] van Berkel R. Cleaner production perspectives: cleaner production and industrial development. Industry and Environment Review 2001; 24(1–2):28–32.
[27] Bit E. A measure of progress: guidelines on measuring environmental performance. Longon, UK: Business in the Environment and Ernst and Young; 2001.
[28] Altham J. Benchmarking to trigger and sustain the implementation of cleaner production in small to medium sized enterprises. In: Centre of excellence in cleaner production. Perth, Australia: Curtin University of Technology; 2004.
[29] De Bruijn T. Pollution prevention projects in The Netherlands. Journal of Cleaner Production 1996;4(1):41–53.
[30] van Berkel R, Chandak S, Sethi P, Luken R. From waste to profits: towards financial and environmental dividends from waste minimization in small scale industries in India. Vienna, Austria: United Nations Industrial Development Organisation; 1995.
[31] De Bruijn T, Hoffman P. Pollution preventon and industrial transformation: evoking structural changes within companies. Journal of Cleaner Production 2000;6:215–23.
[32] Trott P, Cordey Hayes M, Seaton R. Inward technology transfer as an interactive process. Technovation 1995;15(1):25–43.
[33] van Berkel R. Assessment of the impact of the DESIRE project on the uptake of waste minimisation in small scale industries in India. Journal of Cleaner Production 1993–1997;2004(12):269–81.
[34] Sarmiento F. Assessment of the impact of E2P3 project on the uptake of pollution prevention in Ecuador. Journal of Cleaner Production 2004; 12:283–96.
[35] Stevenson R. Impact of the ASEAN Environmental Improvement Project on the adoption of waste minimisation practices in the Philippines. Journal of Cleaner Production 2004;12:297–303.
[36] Kestigian M. The greening of accountancy. Australian Accountant 1991; 61(8):20–7.
[37] Frost G, Wilmshurst T. Going green … but not yet. Australian Accountant 1996;66(8):36–9.
[38] Holmes D, Girardi G. Survey of productivity and environmental strategies and practises in Australian manufacturing companies. Melbourne (Vic), Australia: Australian Industry Group; 1999.
[39] Greene D. Carrots, sticks and useful tools: a study of measures to encourage cleaner production in Australia. Sydney, Australia: University of New South Wales; 1999.
[40] Andrews S, Stearne J, Orbell J. Awareness and adoption of cleaner production in small to medium-sized businesses in the Geelong Region, Victoria, Australia. Journal of Cleaner Production 2002;10:373–80.
[41] Zutshi A, Zohal A. Environmental management systems adoption by Australasian organisations: Part 1: reasons, benefits and impediments. Technovation 2004;24:335–57.
[42] Zutshi A, Zohal A. A study of the environmental management system adoption process within Australasian organisations: Part 2: role of stakeholders. Technovation 2004;24:371–86.
[43] ACCI. Eco-efficiency survey 2002–2003. Canberra, Australia: Australian Chamber of Commerce and Industry; 2003. p. 24.
[44] SRT. Swan Canning Industry Survey: pilot survey findings. Perth, Australia: Swan River Trust; 1999.
[45] USEPA. An organisational guide to pollution prevention. Cincinnati (OH), USA: United States Environmental Protection Agency; 2001.
[46] NwMexEPA. The nothing to waste manual: incorporating pollution prevention into small businesses. New Mexico Environmental Protection Agency; 2001.
[47] Zikmund W. Business research methods. 6th ed. Orlando (Fl), USA: The Dryden Press; 2000.
[48] Jeyaretnam T, Tunney J, Hughes T. Public environmental reporting: where does Australia stand? Melbourne, Australia: SMEC; 1999.

4. An Innovation and Development Model for Regional University Campuses

Alan R. Howgrave-Graham

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An Innovation and Development Model for Regional University Campuses

Alan Roderick Howgrave-Graham, Monash University, Victoria, Australia

Abstract: This paper builds a practical model that highlights how university developed innovations may be both generated and commercialized. Building on existing innovation models, the paper outlines the role of other actors in the system that are instrumental within the innovation process. Knowledge flows that can maximize technology transfer and allow serendipity to enhance productivity are indicated. The focus of the model is on regional universities that suffer from lower levels of funding, more junior researchers and a general lack of resources to facilitate the commercialization process relative to their major city counterparts. It reveals how the simultaneous generation of commercializable outcomes such as new products and spin-off companies, as well those of more importance to the universities, such as publications and degree completions can emerge from a process of creative problem solving, funded mainly by industry opportunities and facilitated from within the university campus. The role of NGO's and community groups in ensuring that local community concerns are addressed is also built into the model. Regional Victoria within Australia is the basis for much of the discussion and practical application of the model.

Keywords: Innovation Models, Creative Problem Solving, Regional Campuses, Commercialization, Research Outputs, Australia

Introduction

THE COMMERCIALIZATION OF university intellectual property is a widely debated issue, both in terms of its desirability at the potential 'cost' to teaching and basic research through the perceived shift in culture, and in terms of how it can best be achieved. This is especially relevant considering the increased competition for funding of university activities and the push to increase tangible university productivity. One initiative that is rapidly gaining momentum is the transfer of university technology to industry for commercial benefit to both parties. Such an initiative will require alternative approaches to innovation than existing single-focus strategies and be capable of overcoming a number of barriers to effective technology transfer.

A study by Decter, Bennet and Leseur (2007) identified several perceived barriers in the transfer of technology from universities to business in the USA and UK, and suggested approaches which may overcome these, especially in the UK. The main barriers to UK technology transfer were found to be: a "publish not patent" tendency; the skepticism of university technology by industry; replacement of lost company R&D, outsourcing this activity to universities (for which they are not as well equipped); diverse UK university technology transfer policies; and technology being difficult to access. These authors suggest government funding of the university-industry interface and enhancement of the current university technology transfer offices.

Additional barriers to entrepreneurship by universities were listed by Kirby (2006) and include the requirement for control, the many levels of approval embedded in their hierarchical structures, and university's conservatism and impersonal nature. Entrepreneurship was also mentioned as being hampered by among other things, the need for immediate results, lack of entrepreneurial talent and inappropriate compensation methods.

The above problems can be exacerbated in regional campuses of large universities because of their remoteness from their main city-based campuses. Several theoretical models have been proposed for the enhancement of innovation and the commercialization of university intellectual property, and some of these have been evaluated on a case-by case basis. However, little information is available on how the models can be practically applied, especially in regional areas. This paper gives a brief background on innovation and some models that are considered applicable for the commercialization of university intellectual property. A new practical model is then proposed which incorporates complementary university-specific deliverables such as publications and degree completions. Its application would overcome many of the disadvantages of regional campuses by, for example, encouraging participation by a greater range of staff who would otherwise have been marginalized, especially less established researchers. It would enhance economies of scale by addressing innovation both as a process and a product. Although

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the main setting is a regional campus in Victoria (Australia), other examples from the author's prior experience will be used to illustrate some points.

The need for Australia to become more innovative is clearly illustrated by Tijssen (2006) as it is considered to be at the lower end of the OECD countries in terms of public-private knowledge creation and knowledge spillover processes between universities and industries. The model suggested below is a practical way in which all universities and their campuses in Australia (and other countries), irrespective of size and reputation, can become more entrepreneurial in the commercial exploitation of their research-based knowledge assets.

Literature Review

Many of the innovation models that have been described reflect innovation as a process incorporating the phases of idea generation, research design and development, prototype production, manufacturing, marketing and sales (Knox, 2002; Poolton and Ismail, 2000). Tidd, Bessant and Pavitt (2001) suggest that consideration must also be given to the product so that organizations can evaluate their success at innovation. According to Heany (1983), the least novel and risky form of innovation is to incrementally change the style of a product, with a predictable and slight effect on the market, i.e incremental innovation. Major or radical innovations, however, can create new markets and new industries but can be risky and uncertain (Brown, 1992). Teece (1986) illustrates the challenges associated with benefiting from innovation (with his implicit emphasis being on major or paradigmatic product innovations), whilst Kim and Mauborgne (1999) demonstrate that those few major innovations that make it all the way through commercialization have a massive effect on the bottom-line, with the 14 percent of innovations considered to be major contributing 61 percent of the new revenue.

The inherent suggestion of these research efforts is that innovation is a product-focused process that adds value to an organization. In line with this, McFadzean, O'Loughlin and Shaw (2005, p.353) defined innovation as "a process that provides added value and a degree of novelty to the organization and its suppliers and customers through the development of new procedures, solutions, products, and services as well as new methods of commercialization". Such a definition is suitable for application within an organization but the processes are equally applicable to regional development with more role players involved in the process and the potential for more innovations to occur through greater collaboration.

Etzkowitz (1998) reported on the lack of definition of the role of universities in light of their growing participation in business activities and a more holistic model, called the triple helix model was proposed by Leydesdorff and Etzkowitz (1996) to reflect how university could play a lead role in technological innovation in increasingly knowledge-based societies. The model is described as a spiral process emerging from reflexive university-industry-government interactions to stimulate technological innovation. Bunders, Broerse and Zweekhorst (1999) indicated that, in applying this model to Bangladesh, stimulating interactions between the members of the triple helix was not effective because a vision on how to guide the innovation process was lacking. This guidance eventually came from NGO's with a strong user perspective who involved the triple helix members in the process. Marques, Caraca and Diz (2006) report on success of a triple helix model driven by the University of Coimbra (Portugal) in terms of, among other things, the creation of a Business Incubator, enhanced R&D and the transfer of knowledge/technology. These authors also report on the emergence and importance of not-for-profit institutions in the process.

Another criticism of the triple helix model was by Benner and Sandstrom (2000) who indicated that it does not focus enough on funding. Research sponsors determine the nature and strategies of research, they can redirect the orientation and actions of researchers, reproduce existing routines and halt or hinder institutional transformation. These authors argue that the institutionalization of a triple helix model is critically dependent upon new forms of research funding. However, where the sponsors are not government or industry bodies, and there is no conflict of interest, this does not negate the triple helix model for knowledge production.

Benner and Sandstrom (2000) describe three models for academic research, namely: an interventionalist model driven by a mission-oriented agency aimed at adjusting academic research to industry's knowledge interests; the autonomy model oriented towards basic research by councils; and the transinstitutional model, combining the previous two models and more closely related to the triple helix. According to these authors, countries adopting the transinstitutional model include Britain, USA and Australia. A catalytic, rather than regulating role, of the funding agency is apparent in this model and the situation in Australia is described in more detail in Howgrave-Graham and Galvin (2005) as pertaining to the biotechnology industry.

Consistency and successful application of each model appears particularly elusive as evidenced by the discrepancies between the University of Coimbra (Marques et al. 2006) and the Bangladeshi experience (Bunders et al. 1999) in the application of the triple helix model and discrepancies between USA and Britain in applying the transinstitutional model

(Decter et al. 2007). In the Bangladesh experience (which reflects similar situations in Latin America), Bunders et al. (1999) reported that the demand for innovations was insufficiently specified or the supply of knowledge was too fragmented to raise industry's interest. Technology push, rather than market pull strategies seem to have been applied there.

McFadzean et al. (2005) tabulated a comparison between the other key innovation process models and every one had potential weaknesses such as failure to recognize collaboration, networking, commercialization or marketing features, the variety of variables making up the innovation stages, innovation processes or functions, or opportunities for commercialization. The models described thus seem to be more theoretical and a practical model is thus required which would allow all opportunities for innovation to be realized, which can be applied in a wide range of circumstances.

From the Theoretical to the Practical: Victoria as an Example

It seems, from the points made above, that it is difficult to devise a model that applies to every situation. The problem is exacerbated within countries because of the different configurations of resource, infrastructure, university and state government regulatory environments in each area. For example, although Queensland in Australia has similar mining resource to some of the rest of Australia, it has a different political climate and, due it's sub-tropical nature, different agriculture to much of the rest of the country. The discrepancies do not end there. Even within universities there can be differences in corporate culture and opportunities. For example, Monash University, Australia's biggest in terms of student numbers has seven campuses across three countries (http://www.monash.edu.au), with four campuses in the city of Melbourne and two in regional Victoria. The opportunities vary considerably from campus to campus, as do the on-site facilities. In science, the Clayton Campus is well equipped for medical research while the Gippsland Campus, which hosts the Australian Sustainable Industry Research Centre (ASIRC) is well equipped and situated to address regional opportunities such as clean coal technology and water treatment due to the abundant coal resources and power stations in the area, as well as a recently announced $174 million 'water factory' being built nearby.

The Victorian Government has, through the establishment of its Science, Technology and Innovation (STI) initiative in 1999/2000 (Smith and Pech, 2006) further changed the commercialization environment in which universities such as Monash University operate, through the allocation of $310 million over five years (and another $310 million for its "Second Generation" announced in 2003/2004 for infrastructure initiatives) to facilitate strategic collaboration between research organizations and industry to pursue commercial opportunities. Smith and Pech (2006) describe a model whereby potential "winners" are picked up and supported as opposed to propping up "losers". The STI initiative is fairly rigid in its requirements as, among other criteria that need to be fulfilled for funding eligibility, dollar-for-dollar external support is required and a business plan according to set criteria must be developed with "pathways to market" clearly identified. STI also favours projects with relatively rigid governance structures as it noted that unincorporated joint ventures generally suffered from reduced commercial effectiveness and were less likely to be sustainable over time.

The above STI initiative requirements tend to favor innovation and new product development in the cities where there is close proximity between collaborators, leaving regional campuses to fend for themselves with respect to commercialization. However, the Victorian Government has created another initiative, the "make it happen in Provincial Victoria" campaign (http//:www.provincialvictoria.vic.gov.au) in which councils and a government department, Regional Development Victoria, collaborate to enhance growth in regional Victoria. This regional specific program is required because academics in the regional campuses are often restricted due to small class sizes requiring more teaching contact hours in diverse subjects to 'pay their way' and thus have less time for research. For regional innovation and entrepreneurship to occur, a more suitable model must be more flexible to allow even small, less time consuming opportunities such as industrial consultancies to be capitalized upon as well as those programs from e.g. regional governments or NGO's set up to support entrepreneurial initiatives.

Constant vigilance is required to identify further opportunities for commercialization that may unfold during a consultancy project so that maximum benefit can be gained from each advancement, irrespective of how small it is. An important consideration is that, although regional campuses in Australia seldom have the economies of scale of the city campuses, they have access to centralized university facilities such as commercialization offices and capital equipment. Staff at regional campuses is less likely to succeed at attracting the large competitive grants such as STI initiative funding because of the significant hurdles mentioned above and their possible poorer research track records. Ways to overcome such disadvantages include teaming up with prolific researchers at other campuses for such grants and a new more flexible commercialization model which will incorporate a broader definition of commercialization to allow a greater flexibility in identifying and capitalizing upon opportunities. Such a model, like the STI model discussed by Smith and Pech (2006) should also be a version of the triple helix or traninstitutional models but with commercialization being seen as more than marketable products with the regional campus, rather than government being seen as the main driver. Small increments in commercialization could give time for a "loser" to become a "winner" while generating income, as will be discussed in the model proposed in this paper.

Several authors have restricted their definition of commercialization to include various combinations of patents, licenses, or start-up company formation as deliverables. These definitions are thus restricted to some economic benefits only and the one proposed by the Australian Institute for Commercialization (2006) is better suited to the model proposed in this paper: "Commercialization is the transformation of ideas into economic outcomes. They could be in the form of a product, a service, a process or something of value to the community". This differs from McFadzean et al. (2005, p.353)'s definition of innovation in that the commercialization definition does not require novelty, nor does it need to add value to a specific organization but can be altruistic or the application of familiar technology for creative problem solving. Even more loosely, commercialization in the above definition can include benefits to the university involved such as publications and degree completions or kudos but the model suggested in this paper proposes that these outcomes be considered separately (partially because they are not incorporated into the innovation models previously described) although they would be a spin-off of the economies of scale suggested.

The Model

Figure 1 depicts the proposed model, based upon the triple helix model but adapted to include the role of stakeholders such as NGO's, and alternative funding sources, both previously discussed as shortcomings of the triple helix model by Bunders et al. (1999) and Benner and Sandstrom (2000) respectively. It is designed for practical application, potentially driven by university technology transfer offices and specialist centres, or even staff groupings. It emphasizes networking and how problems with the theoretical models described in the above literature review can be overcome in practice, and incorporates additional components to consider a wider group of stakeholders than the key innovation models described in the literature.

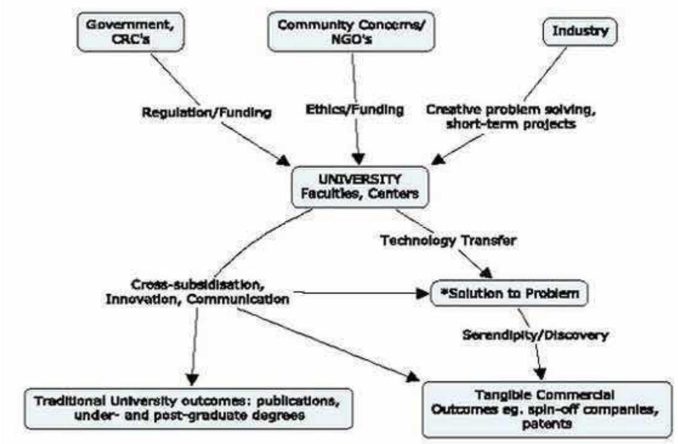

Figure 1: An Opportunity-driven model Illustrating Networks and funding sources Established by University- or Campus-based Facilitators to Maximize Economic and Academic Outcomes and Spin-offs from Creative Problem Solving

This model would be a fifth generation innovation model described by McFadzean et al. (2006) and Tidd (2006) as ones in which there is systems integration and extensive networking, flexible and customized responses and continuous innovation. It is especially suited to address all the limitations listed by Tidd (2006) in his table listing the problems that occur if the perception of innovation is limited to e.g. only breakthrough changes, thus neglecting incremental innovation; only strategically targeted objectives, thus missing out on "lucky 'accidents"; or only associated with key individuals, thus failing to utilize the creativity of other employees. As in Tidd's (2006) regional cluster or "best practice" clubs the innovation networking in this model is heterogeneous.

This model considers commercialization as being beyond new product development and spin-off company formation to include more mundane activities such as industrial consultancy. Although it also resembles the fifth generation innovation models in that it includes stakeholder co-development and collaborative research and marketing, it is more holistic in its approach, allowing cross-industry innovation (due to facilitation by the neutral third party such as a university). An example is in improving lighting efficiency as part of a cleaner production program. The installation of high bay lighting with motion sensors can save considerable power and can be adopted by a wide range of industries once a case for its use has been established by one early adopter. Its benefits would then be promoted by the central organization, depicted in this model as being universities, faculties or centers. The use of such intermediaries is not new and Howells (2006) cites several authors who identified the role of "middlemen" in the agriculture, wool and textile industries of the 16th, 17th and 18th centuries. Howells (2006) identifies several roles for modern day "change agents" to increase the speed of technology diffusion and new product uptake. However, these agents are usually industry specific whereas the model proposed here requires a broad knowledge base by the intermediary to allow technology transfer across industries and a wider perspective to allow serendipity or discovery to occur that would lead to new products, the "lucky accidents" mentioned by Tidd (2006). Regional university campuses are ideally positioned to drive such inter-industry innovation and Monash University, Gippsland is a good example as it houses ASIRC in the centre of a region rich in coal power, timber, dairy, wineries and other industries.

Another way that the model described here differs from the key innovation models described by McFadzean et al. (2006) is that it builds economies of scale into its predicted outcomes. It does not focus on innovation in new product or process development alone but includes the university-specific requirements for post-graduate student completions and publications. Funding obtained from industry or other organizations can be channeled into post-graduate scholarships and non-confidential outcomes can be published. Academics can create small slush funds using leftovers from contract research/consultancies to subsidize basic research or new product development from ideas generated while creatively solving industry problems. This would allow the advancement of a potential new product to the 'proof of concept' stage, where venture capitalists would start to show an interest in further development, possibly resulting in spin-off companies and patents. For example, while commissioned to investigate ways to decay of wooden poles, plastic barriers were investigated by an academic to separate the wood from soil containing wood-rot fungi. These barriers were further tested and improved and have now been patented and are being marketed on four continents as field liners (see http://www.biotrans-uk.com).

The third way that this model differs from previous innovation models is to address the shortcoming of the triple helix model highlighted by Bunders et al. (1999), namely that guidance of the innovation process is lacking. Although these authors suggested the use of NGO's in Bangladesh, the model here clearly identifies an impartial intermediary with a much broader perspective to take in a wider range of stakeholders than customers, suppliers, manufacturers and R&D such as in the models described by McFadzean et al. (2006). In the author's experiences at a regional campus, stakeholders were found to include organic and other commercial farmers as well as concerned community members when the potential introduction of genetically modified crops was considered. This model thus incorporates community concerns and NGO's. As in both the triple helix model of Leydesdorff and Etzkowitz (1996), and the traninstitutional model described by Benner and Sandstrom (2000) government is included in the model. Government plays a major role by describing and enforcing the regulatory framework as well as in development such as the "make it happen in Provincial Victoria" campaign (http//:www.provincial-victoria.vic.gov.au) discussed above. The regulatory framework, as well as ethical considerations and funding would thus add more stakeholders to those listed in previous innovation models, as would the education and research interests of the university.

Universities or closely affiliated generalist centers would be ideal intermediaries because of their very broad requirements for degree completions and publications, almost irrespective of the topic. This allows them to take a more holistic view of commercialisation. Senker, Faulkner and Velho (1998) highlight that most knowledge that flows from academia into industry does so via informal rather than formal linkages. They refer to earlier work in which academia is said to take a "dating agency" rather than "marriage broker" approach (Faulkner and Senker 1995). Regional campuses can be expected to have such informal linkages due to the smaller communities and can quickly make these linkages formal through contractual agreements. An advantage to these campuses is that less established researchers can innovatively access less competitive funding from local industries and increase commercial outputs with academic productivity increasing as a spin-off. Staff with lower eligibility for large government grants due to being early in their research careers or hampered by higher teaching loads can thus participate in the commercialization process. They would thus have the opportunities to build their reputations to make them more eligible for larger government grants. The above example of field liners (http://www.biotrans-uk.com) also illustrates how industry funding could generate publications as well as patents and other commercial outcomes.

Applying the Model

Figure 2 indicates how the above model could be put into practice. In a team-based approach, ideas will emerge both for addressing the government, industry or NGO issues or problem through creative problem solving, as well as identifying potential applied or basic post-graduate projects and potential new products. The triple helix and transinstitutional models both identify that the university has a crucial role in facilitation of such interactions and in the model proposed here, this task can be delegated to a research/technology transfer office or dedicated centre affiliated to the university. The role of staff in these offices is to make the relevant codified base knowledge available through publications, then the tacit knowledge held by some staff explicit to others, and identify opportunities based upon skills available at the university (technology push) and requirement for specific commercialization outputs (market pull).

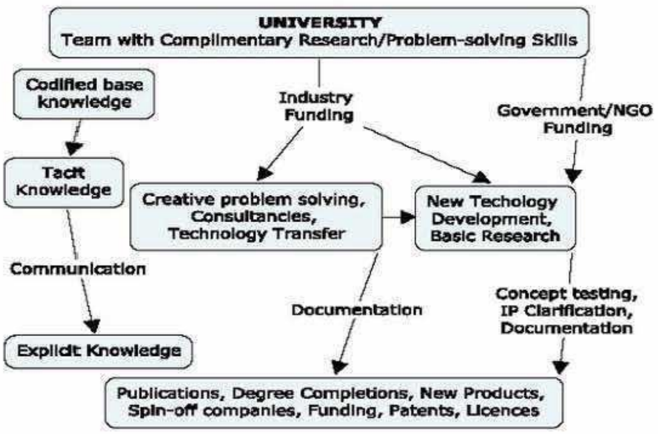

Figure 2: The Knowledge, Ideas and Funding Flows associated with the Opportunity-driven Model of Figure 1

The above model adds to the innovation models described so far through the incorporation of other, more traditional university outcomes such as degree completions, publications and prestige for the regional campuses. Funding targeting innovation could, through economies of scale, support post-graduate student scholarships and lead to achievement of these outcomes, together with a solution to the industry problem through creative problem solving (McFadzean, 1998). Here, creative solutions to scientific problems can have both financial and educational benefits. Taking the benefits of applying this model even further, serendipity could play a large role towards further commercialization because of the chance of the "lucky accidents" referred to by Tidd (2006). In Figure 2, this would be the flow-on effect depicted as the transition from "creative problem solving consultancies to "New Technology Development", such as a consultancy to prevent wood rot resulting in the patenting of field liners. The team with complimentary research/problem solving skills would have to include a material scientist (for determining the most suitable plastic to use as a sheath); a mycologist to quantify fungal rot and understand its prevention; and a wood scientist. Towards the bottom of Figure 2, beyond the proof of concept and creative problem solving stages, the patent attorneys, economists and marketers would determine the commercialization potential of the new product. Even if it never gets to market, the creative problem solving step attracted industry funding, allowing the funding of post graduate students and publications or even the cross subsidization of other basic research. This is thus a win-win situation with the only variable being how much is won. Due to skills in regional areas being more widely distributed, all academics in practical fields, irrespective of prior performance, should be able to source local funding in such a way and enhance their track records.

In more advanced or tightly regulated product development fields such as biomedical research, funding can be obtained from federal or state governments, and/or the university in the early stages, with venture capitalists investing at a later stage. Some cross-subsidization from the consultancy driven projects can further support early research with the understanding that the costs can be recouped once and if products developed reach the marketing stage. This strategy is less risky since all the work conducted was supported by outside funding and a worst-case scenario is that the funding organization would have benefited through a completed investigation which would hopefully have solved a problem using the scientific expertise embedded in the university campus or centre. The university also stands to benefit through the academic output indicated in the model.

Knowledge capture and transfer is a key component of this model and communication can be facilitated through a commercialization/technology transfer office and specialist centers can focus on specific objectives, such as cleaner production in industry or sustainable development, to achieve the same goals. Howgrave-Graham and van Berkel (2007) identified how, by bringing dry cleaners together through the Centre for Excellence in Cleaner Production (CECP) at Curtin University workshops, knowledge was transferred between the participants that, according to Altham (2006) resulted in a significant reduction in costs and environmental impacts. This centre overcame the problem mentioned by Woolgar, Vaux, Gomes, Ezingeard and Grieve (1998) that technology transfer between universities and SME's is particularly difficult since their communication channels generally do not extend beyond suppliers, customers and other related businesses. The potential for the CECP to extend its cleaner production promotion activities to SME's to other industry sectors was identified by Howgrave-Graham and van Berkel (2007) while ASIRC at Monash University Gippsland Campus is ideally situated to carry out similar activities in regional Victoria.

A spin-off of the applied projects is often basic research because of the requirement for post-graduate students to apply greater rigor to their projects than required by the funding organization. An example is in the field of anaerobic digestion for the purification of industrial wastewaters. All industry requires is that its 'dirty' water is converted to clean water. This can be achieved by altering parameters such as feed rate, temperature and pH. However, success on these alone is unlikely to result in a degree completion. Further investigation is required and this is the basic research component which industry is usually not averse to supporting as a 'by product'. Incidentally, both the applied and basic research can lead to the development of a new product through serendipity. An example is the invention of the up-flow anaerobic sludge bed (UASB) reactor which is currently used world wide to treat industrial effluents. Engineers initially believed that mixing was important for anaerobic digestion. However, stirrers in one digester broke down and were not repaired. Unexpectedly, a self-mixing system developed requiring less energy and giving better results. Further development resulted in the patenting and marketing of the UASB. Several PhD theses and publications have been generated from studies on this innovation and its underlying microbiology.

Technology transfer or commercialization offices should try to identify such opportunities and get the team together to facilitate all the investigative and legal aspects, unless a centre is created for this purpose. Communication with human resources and other university departments should also facilitate recruitment of new academics with the innovative capacity to identify and harness each opportunity as it arises, whether in basic or applied research, in innovative methods of attracting funding or in the attraction of gifted students who would be able to contribute significantly to the team's commercializable and traditional university outputs.

This all proposes that universities employ 'super academics' who are excellent teachers, team-workers and negotiators, have the curiosity to conduct basic research and can hunt down practical problems that they are potentially capable of solving. They must have the scientific know-how to investigate solutions and the intuition to identify other potential commercializable outputs, while being prolific writers of grant proposals, publications and legal documents when required. This all requires a high degree of lateral thinking, well grounded in relevant scientific knowledge. Needless to say their administrative capability must also be excellent. These people do exist and the correct incentives must be in place for universities to attract them. However, teams of researchers can work together, ensuring that the skills listed are all present for one or more relevant projects. Such a team would also allow new researchers to increase their output and access more competitive grants.

Besides this model's advantages as discussed above, it also addresses a lesson identified after 16 year of application of the Cooperative Research Centers (CRC) program in Australia. Insight Economics (2006) determined that CRC's focused on fostering the development of "new" industries or companies face a greater challenge to deliver benefits than do those that focused on promoting incremental performance improvement in large sectors or companies. This model allows incremental improvement to generate new innovations that can facilitate the emergence of "new" industries with significantly less risk. Not only is funding for applied research obtained from the beginning but the risk of funding organizations losing their entire investment without any practical gain is significantly reduced. This is particularly pertinent in light of the observation by Gosch (2007) that fifteen of Australia's CRC's are in danger of folding "if federal funding is not increased this year". This highlights the need to find other alternative funding sources such as industry to support research. Two examples of Australian universities which use their embedded expertise to attract industrial funding are Curtin University of Technology in Perth with its Centre of Excellence in Cleaner Production and Monash University's affiliation with the Australian Sustainable Industry Research Center (ASIRC) in Gippsland. Both centers have relatively broad mandates to solve industrial problems and, in doing so, there is a chance of a potential new product emerging at a much reduced risk than if the primary mission was to develop a new product at the outset.

This model is aimed at adding another strategy for maximizing university output in all of its functions, including generating knowledge. So much time is wasted by academics in writing unsuccessful applications for large grants. The success rate of obtaining a government Australian Research Council (ARC) grant has consistently been less than 25% since 2000. The time spent on writing the remaining 75% of unsuccessful grant applications would have been better used to aquire funding in a market with a more realistic chance of success, by those academics not yet in a position to compete for the higher stakes. The model allows the outcomes of commercialization according to the broader definition given above to be achieved through creative problem-solving, planned product development, basic research and/or serendipity. This would be funded by a combination of large government grants, smaller consultancies and NGO's within a fluid framework of cross-subsidization which can be negotiated on a case-by-case basis. It allows those with high teaching loads to keep occupied and productive in the 'mini-bites' of time they have to do so. The problem-solving aspect could be aimed at new process development (in cleaner production, this is aimed at cost and environmental benefits) and could lead to new product development, both of these being positive commercial outputs. Economies of scale will be achieved by linking these activities to the generation of publications, basic research and degree completions which would enhance the reputation of the university campuses involved.

Conclusion

Most existing models of innovation have shortcomings that limit their usefulness for practical and/or universal application, such as the limited number of stakeholders or funding sources incorporated. These are described in greater depth in several publications evaluating their application or suitability in different settings. All innovation models focus on fairly narrow definitions of innovation and commercialization to reflect mainly economic benefits. In addition, a strong research base and supporting infrastructure for commercialization is prescribed, yet the situation surrounding regional university campuses seldom reflects such R&D intensity especially in Australia. However, the opportunities exist for piecemeal commercialization where this term is considered to generate benefits including but also beyond economic ones, such as the conservation of biodiversity or the generation of publications and degree completions by universities.

To achieve these outcomes, regional universities and their campuses should be especially vigilant for opportunities, irrespective of how small, to facilitate the economies of scale that can simultaneously drive regional development and more traditional university outcomes. Small grants for creative problem solving gives busy academics the opportunity to increase their research and consultancy. These projects allow 'lucky accidents' to happen in which greater economic benefits can be derived from patenting and commercializing new innovations designed to solve the industry 'problem'. This is a win-win-win situation with academic productivity increasing, industry problems being investigated and hopefully solved, and regional development derived from the economic commercialization of new technology.

The above processes cannot happen spontaneously and require proactive and dynamic intermediaries such as impartial employees of the university or affiliated centers. They should focus on identifying government opportunities such as the 'make it happen in Provincial Victoria program' as well as industry and NGO opportunities through networking and either pursue these, or perform a 'marriage broker' role by bringing those who need work done together with those who can do the work, keeping an eye open for other commercializable opportunities.

The model proposed here indicates how all these outcomes can be achieved and indicates how cross subsidization can facilitate basic research by academics who choose to do it, for example through a levy on creative problem solving projects. The model is by no means confined to regional campuses but the economies of scale it advocates is a sensible approach for increasing productivity by harnessing a much higher proportion of a university's intellectual capital through better time management.

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References

(Heany 1983; Brown 1992; Leydesdorff and Etzkowitz 1997; Etzkowitz 1998; McFadzean 1998; Senker, Faulkner et al. 1998; Woolgar, Vaux et al. 1998; Bunders, Broerse et al. 1999; Benner and Sandstrom 2000; Poolton and Ismail 2000; Tidd, Bessant et al. 2001; Knox 2002; Howgrave-Graham and Galvin 2005; McFadzean, O'Loughlin et al. 2005; Altham 2006; Economics 2006; Kirby 2006; Marques, Caraca et al. 2006; Smith and Pech 2006; Tidd 2006; Tijssen 2006; Decter, Bennet et al. 2007; Gosch 2007; Howgrave-Graham and van Berkel 2007)

Altham, W. (2006). "Benchmarking to trigger cleaner production in small businesses: Drycleaning case study." *Journal of Cleaner Production* 15: 798-813.

Benner, M. and U. Sandstrom (2000). "Institutionalizing the triple helix: research funding and norms in the academic system." *Research Policy* 29(2): 291-301.

Brown, R. (1992). "Managing the 'S' curves of innovation." *Journal of Business and Industrial Marketing* 7(3): 41-52.

Bunders, J. F. G., J. E. W. Broerse and M.B.M. Zweekhorst (1999). "The triple helix enriched with the user perspective: A view from Bangladesh." *Journal of Technology Transfer* 24: 235-246.

Decter, M., D. Bennet and M. Leseure (2007). "University to business technology transfer - UK and USA comparisons." *Technovation* 27(3): 145-155.

Etzkowitz, H. (1998). "The norms of entrepreneurial science: Cognitive effects of the new university-industry linkages." *Research Policy* 27(8): 823-833.

Gosch, E. (2007). CRCs' future in the balance. *The Australian.* 30 June: 30.

Heany, D. F. (1983). "Degrees of product innovation." *Journal of Business Strategy* 3(4): 3-14.

Howgrave-Graham, A. R. and P. Galvin (2005). Cooperative research centres and industrial clusters: Implications for Australian biotechnology strategies. *New regionalism in Australia.* A. G. Rainnie, M. Aldershot, England, Ashgate Publishing Limited. 1: 87-102.

Howgrave-Graham, A. R. and R. van Berkel (2007). "Assessment of cleaner production uptake: Method development and trial with small businesses in Western Australia." *Journal of Cleaner Production* 15: 787-797.

Insight Economics, (2006). Economic Impact Study of the CRC Programme. Australian, Government, Department of Education, Science and Training, Insight Economics Pty Ltd: 1-68.

Kim, W. C. and R. Mauborgne (1999). "Creating new market space", *Harvard Business Review* 77(1): 83-93.

Kirby, D. A. (2006). "Creating entrepreneurial universities in the UK: Applying entrepreneurship theory to practise." *Journal of Technology Transfer* 31: 599-603.

Knox, S. (2002). "The boardroom agenda: Developing the innovative organisation." *Corporate Governance* 2(1): 27-39.

Leydesdorff, L. and H. Etzkowitz (1997). A Triple Helix of university-industry-government relations. *Universities and the global knowledge economy.* H. L. Etzkowitz, L. London, Pinter. 1: 155-162.

Marques, J. P. C., J. M. G. Caraca and H. Diz (2006). "How can university-industry-government interactions change the innovation scenario in Portugal? - the case of the University of Coimbra." *Technovation* 26(4): 534-542.

McFadzean, E. S. (1998). "The creativity continuum: Towards a classification of creative problem solving techniques." *Creativity and Innovation Management* 7(3): 131-139.

McFadzean, E. S., A. M. O'Loughlin and E. Shaw (2005). "Corporate entrepreneurship and innovation Part 1: The missing link." *European Journal of Innovation Management* 8(3): 350-372.

Poolton, J. and H. Ismail (2000). "New developments in innovation." *Journal of Managerial Psychology* 15(8): 795-811.

Senker, J., W. Faulkner and L. Velho (1998). Science and technology knowledge flows between industrial and academic research: A comparative study. *Capitalizing Knowledge: New intersections of industry and academia.* H. Etzkowitz, A. Webster and P. Healy. Albany, NY, State University of New York Press: 111-132.

Smith, S. and R. J. Pech (2006). "A template for commercialising science and facilitating innovation: A case study of Victoria, Australia." *European Journal of Innovation Management* 9(3): 279-299.

Teece, D. J. (1986). 'Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy'. *Research Policy,* 15: 285-305.

Tidd, J. (2006). Innovation models. London, Tanaka Business School, Imperial College: 1-15.

Tidd, J., J. Bessant and K. Pavitt (2001). *Managing Innovation: Integrating technological market and organizational change.* Chichester, England, John Wiley & Sons.

Tijssen, R. J. W. (2006). "Universities and industrially relevant science: Towards measurement models and indicators of entrepreneurial orientation *Research Policy* 35: 1569-1585.

Woolgar, S., J. Vaux, P. Gomes, J-N. Ezingeard and R. Grieve (1998). "Abilities and competencies required, particularly by small firms, to identify and acquire new technology." *Technovation* 18(8/9): 575-584.

5. An Interdisciplinary Knowledge Transfer Approach to Facilitate Sustainable Development: Australia as an Example

Alan R. Howgrave-Graham

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An Interdisciplinary Knowledge Transfer Approach to Facilitate Sustainable Development: Australia as an Example

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Abstract: Historically, sustainability has seldom been a prime consideration during development. This is due to commercialization of intellectual property being considered in purely economic terms in most innovation models. The description of commercialization has generally been limited to a few outcomes with economic growth and profit as the only considerations. This paper motivates for the description to be extended to incorporate other benefits such as environmental impact of the products and processes developed. Ways in which sustainability can be practically built into commercialization is described here as a three-pronged approach namely: the development of new sustainability products; building sustainability into the development of other products; and promoting sustainable practices in industry through creative problem solving. A model is proposed which looks at how Australia's research and development environment of cooperative research centres and industrial clusters could include knowledge from professionals with a 'triple bottom line' focus. These scientists, engineers and marketers would drive the three prongs above by facilitating cleaner production and eco-efficiency while being alert for new sustainability product opportunities. This paper discusses a few examples of opportunities and projects a country can, by using universities or centres as mediators, use to become incrementally more environmentally sustainable while gaining economic and other benefits.

Keywords: Sustainable Development, Cleaner Production, Innovation Models, Commercialization, Australia

Introduction

THE DESIRE TO improve our standard of living through development is a human trait and this has too often been at the expense of the environment. Only recently have concerns been raised about out 'ecological footprint' and the earth's 'carrying capacity'. This has resulted in the emergence of the concept of 'sustainable development' in which development can continue, taking these requirements into consideration. Malaska (2001) suggested a post-modern vision of progress in which sustainable development represents both a vision of the future worthy of human aspiration and a continuous process of adapting human activities to achieve this, making sustainable development both a goal and a process.

Moran *et al.* (2007) reports that a necessary condition for sustainability is that society metabolizes resources into waste no faster than the biosphere can convert this waste back into resources. Unfortunately, these authors cite the Millenium Ecosystem Assessment (2005) as reporting that human use is degrading 60% of the planet's ecosystem services. Ceballos *et al.* (2005) and Monfreda *et al.* (2004) refer to the Ecological Footprint as the amount of biologically productive land and water area that is required to support a given population at its current level of consumption and resource efficiency. This paragraph reflects the requirement that we improve our practices so that we do not overtax the environment in which we and future generations must live. The tendency is, however, to continue development using non-renewable resources so that we may improve our lifestyles. Current and new commercializable products are seen as the 'trappings' of an affluent society and, in many cases, little regard has been given for the drain on irreplaceable resources that have been used for their development and production.

Australia is fortunate in having reached a relatively high level of development but the quest for new products to further drive development has not abated. An example of an initiative set up to drive development is the Cooperative Research Centre (CRC) programme set up by the Commowealth Government more than ten years ago, focusing on development in a wide range of fields (Riedlinger, 2002). Each CRC is a country-wide initiative with seed funding from government and industry to bring together scientists from Universities, the CSIRO, other government institutions, industry and private organizations together to work on specific R&D projects that will benefit from the critical mass of effort. It can thus be seen as one instrument to drive the Triple Helix Model for commercialization, as proposed by Leydesdorff and Etzkowitz (1996).

The triple helix model was proposed by Leydesdorff and Etzkowitz (1997) to reflect how university could play a lead role in technological innovation in increasingly knowledge-based societies. The model is described as a spiral process emerging from reflexive university-industry-government interactions to

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stimulate technological innovation. In this, and other innovation models, little emphasis has been placed upon environmental sustainability during the innovative processes of R&D and commercialization, although this would be an obvious spin-off when the innovation is in renewable energy or environmental biotechnology projects.

This paper proposes a model which goes beyond the triple helix model to build sustainability into the development of new products and facilitation of commercialization. It is designed for practical application in Australia but can easily be adapted for application in other countries as well. It identifies a wider range of stakeholders and roles than in previous innovation models, such as NGO's and CRC's. Another problem it overcomes is that several authors have restricted their definition of commercialization to include various combinations of patents, licenses, or start-up company formation as deliverables. These definitions are thus restricted to some economic benefits only and the one proposed by the Australian Institute for Commercialization (2006) is better suited to the model proposed in this paper: "Commercialization is the transformation of ideas into economic outcomes. They could be in the form of a product, a service, a process or something of value to the community".

Commercialization will thus, for the purpose of this paper also include innovative cost saving measures for industry which, through the use of less materials and resources or use of less toxic ones, would also improve environmental sustainability. Sustainable development will thus follow a three pronged approach to commercialization, namely: the commercialization of products and processes aimed at improving, or reducing the demand, on the environment; incorporating environmental impact considerations into the development and marketing of new products and processes; and improvement of existing products or processes to limit the impact their use and application will have on the environment. The model proposed here is set in the Australian business climate as dictated by the current system of CRC's and clusters as described by Howgrave-Graham and Galvin (2005) and is particularly suited to being driven by universities.

Sustainable commercialization will be seen as commercialization in sustainability as well as the development of products that will, while enhancing the standard of living, be developed and produced with environmental sustainability in mind.

Driving Sustainability through Commercialization of Environmental Technology

Chertow (2000) identified ways to accelerate the commercialization of environmental technology to increase USA global competitiveness, diversify the nation's industrial base and improve environmental quality. She emphasized the importance of the smooth flow of environmental technology from idea to market for sustainable development to occur and identified that there is a gap between government's involvement in the R&D stages and investment in the early-stage ideas by risk averse private 'actors'. The model proposed below overcomes this hurdle because it allows ideas and cross-subsidization to emerge from creative problem solving as described by McFadzean (1998). In practice, the targeting of an environmental problem may result in the emergence of a new marketable product or process that is a solution to the problem. An example would be development of the activated sludge process to facilitate biological phosphate removal from sewage and thus prevent algal blooms. The blooms were seen as the problem, the phosphate in sewage as the cause and the specific patented activated sludge process such as the Bardenpho process seen as the solution. Other products, such as infrastructure to capture solar or wind power are funded from the outset without being instigated by a specific problem except to minimize our global 'footprint'. This is, however, a competitive field with limited chances of success at producing new products or processes, and failure being costly to the funding organizations.

The risk-averse "private actors" mentioned above often have a point because products developed using government funding may not necessarily be addressing a market niche, reducing the chances of commercialization because all potential players/stakeholders were not collaborating from the outset. For new product or process development, the players would have to come from diverse backgrounds with marketers, engineers, economists and scientists all involved in the decision making and design. CRC's are ideal instruments for facilitating such collaboration nation-wide between funding organizations, the inventors and potential customers, all usually from the above professions. For more localized applications or processes, regional university campuses could drive the collaboration.

Value theory (Brown, 1984) is a crucial consideration in the development of an environmental technology product. This theory states that the value of an object is relational to the subject doing the valuing ie. the usefulness of the object to the valuer. For this reason, marketers are important contributors to the development process. An example in the experience of this author was the installation and testing of a small rural biogas digester in KwaZulu-Natal, South Africa. Although the digester worked and generated an alternative energy source in the form of biogas, the community made it clear that it would not, for cultural reasons, use biogas generated from faeces for cooking or heating. The urge by researchers to develop their ideas into commercializable products should be tempered by input from marketers on whether their products would address a particular need and if so, where.

Incorporating Environmental Considerations into Developing New Products

Internationally recognized system such as ISO14001 and ISO9004 have been developed to be used by industry as a means of reporting on their environmental credentials and new European Union policies and directives are increasing the legal, financial and market-related pressures on manufacturing industries to develop more sustainable products (Maxwell and van der Vorst, 2003). Jorgensen (2007) lists ways in which management of organizations can improve sustainability through life cycle management and integration. This author lists a wide range of tools that can be incorporated into an organization's operations and some of these should be considered during the design phase of a new product, such as cleaner production guidelines, green accounts, life-cycle assessments, eco-design, life cycle cost analysis and eco-labelling. Using such tools would determine both the environmental and economic viability of a new product. Incorporation of specialist skills into the product development team, either from experience, short courses or an engineering background would assist in making the new products more sustainable from an environmental perspective. However, a conscious effort has to be made to focus on e.g. the recycleability of components and materials used by the developers.

Existing Product or Process Improvement to Limit Environmental Impact

Another opportunity in sustainable development is to improve things we are currently doing by taking environmental aspects into consideration. Cleaner production is such a tool and Howgrave-Graham and van Berkel (2007) identified that there was a large scope for SME's in Australia to incorporate practices which have both environmental and financial benefits. Duarte *et al.* (2007) identified that the SMEs' main obstacles for the implementation of sustainable development strategies into their businesses are their small investment capacity in research and innovation and because they are mainly focused on their daily activities, a short term perspective.

Various centers in Australia such as the Centre of Excellence in Cleaner Production at Curtin University in Perth and the Australian Sustainable Industry Research Center at Monash University in Victoria are ideally positioned to take up opportunities to improve the economies of scale for SME's (see Altham, 2006 for how this has benefited dry-cleaners), and enhance the profit of larger companies through consultancies. Such short-term contracts and education initiatives have the added advantage that exposure to the processes and the subsequent knowledge transfer allows new opportunities for products to be identified through serendipity. Again, the advancement of the new products from the idea stage should be carried out by the multidisciplinary team to determine whether there is a potential market for the product, that the new product is economically feasible, and is developed to be as efficient as possible.

One of the major hurdles to knowledge transfer is the need for businesses to maintain a competitive advantage. For this reason, knowledge in a business often remains tacit. In the interest of global sustainability, efforts should be made to disseminate knowledge on ways to minimize material useage and generate less waste. This role could be played by an impartial third party such as a CRC, university or government department. Figure 1 indicates how such input can draw on every opportunity to enhance productivity through communication and cross subsidization in Australia while maintaining good social and environmental ethics.

An Opportunity-Driven Model to Drive the Three Prongs of Sustainable Development

The model proposed in this paper (Figure 1) is designed to deliver on all three prongs for sustainable development discussed so far. It is a practical model with all stakeholders incorporated as participants to, through knowledge transfer, maximize output in terms of financial and environmental gains, as well as traditional university outputs.

The top tier in Figure 1 represents the environment in which Australian business operates. This determines the external drivers or hurdles for sustainable development in the form of: regulatory constraints or support from government; industry's desire or receptiveness to develop particular products or processes or solve particular problems; and communities and NGO's acting as collective consciences. All three groups are also capable of funding projects of interest. Universities and their faculties or centers, or in some cases CRC's (for larger projects) are central to Figure 1, because they, sometimes through commercialization offices, are the drivers or mediators of development and would take responsibility for creating teams to incorporate sustainability as well as marketing strategies. An opportunistic approach is advocated in which industrial problems such as in cleaner production are addressed through consultancy, while keen observation for opportunities allows new product or spin-off company ideas to emerge and be further pursued.

An Insight Economics (2006) study quantitatively evaluated the the economic impact of the Australian CRC programme in terms of benefits derived from the cooperative networks created. This study determined, as a "best estimate", that the CRC programme resulted in Australia's gross domestic product (GDP) being $1.16 higher per dollar of GDP than if it were left with taxpayers, at the time of writing. This equates to a GDP of $2,554 million higher than in the absence of the CRC programme since its inception in 1990. It was further estimated that by 2010, the CRC programme would have increased the GDP by $2,877 million above that expected if the funds were left with taxpayers, and investment would also be $436 million higher. This is strong evidence for installing collaborative centres to enhance national productivity and reflects the central role that CRC's would play in the model depicted in Figure 1. However, CRC's target specific projects/industries, such as the 'Australian sheep industry CRC' and there is still a need for more generalized centres to address projects too small or diffuse to warrant new CRC creation. It is encouraging to note that, of the 30 CRC's highlighted in the Insight Economics (2006) report, nine have sustainability included or implied in their titles, suggesting that economic growth may not necessarily be at the expense of other sustainability targets such as the environment.

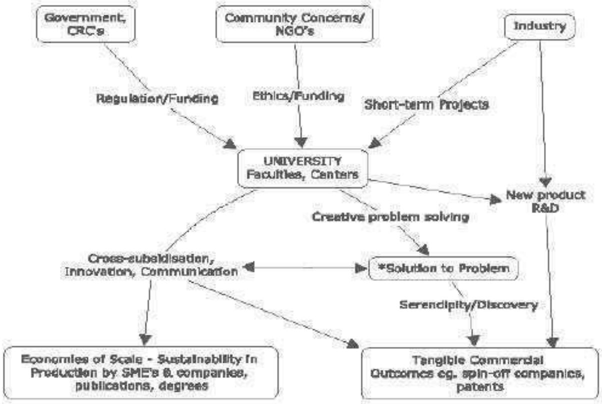

Figure 1: An Opportunity-Driven Model to Drive Sustainable Development

The above model requires collaboration between all of the stakeholders, including as many industry representatives as possible to allow the diffusion of tacit knowledge, in the form of ideas that do and those that do not work, between stakeholders (e.g. practitioners in the dry cleaning industry had to critically evaluate the practicality of suggested cleaner production measures). Such knowledge could also play a crucial role in the design and for determining the desirability of new products. Other success stories include those of recycling waste, such as the conversion of worn car tyres to athletics track surfaces and the use of coal mine fly ash for making bricks. These commercialisable products emerged as solutions to address excess waste generation problems. Sponsors of such work could have the dual benefit of having their problems solved as well as the rights to new revenue-generating technology. Many of these initiatives would not come to fruition if it were not for the input of specialist scientists such as soil scientists, chemists (specializing in material science), engineers, marketers and economists (to determine the cost effectiveness of products or processes). The right hand side of Figure 1 illustrates the first tier of sustainable development as described in this paper, namely targeting of funds to develop products to enhance sustainability. Note how the figure also allows, through serendipity, the development of new products as a result of funded creative problem-solving.

The framework in Figure 1 also allows for the cross subsidization of teams working on product development from creative problem-solving work through a tariff for e.g. using university facilities to solve the industry problems such as corrosion, or saving costs by implementing cleaner production measures. This author's experience is that the creative problem solving (McFadzean, 1998) approach has the greater chance of success because only a few products progress from the idea to an economically viable commercial product stage. The close cooperation of marketers, economists and designers would improve the chance of success in product development and specialists in cleaner production and/or material science would ensure the most environmentally friendly design. Universities applying this model would have the additional benefit of generating student post-graduate completions, publications and a less competitive entry level for funding of early career researchers than many government grants.

The model is ideally applied in a developed country such as Australia where a stable, educated and motivated workforce can channel adequate infrastructure and funding into sustainable development. In such a country, social and environmental ethics are driven by government legislation and community groups. However, developing countries tend to have lower education levels and cheaper labour, as well as greater emphasis on survival than environmental concerns or product or process innovation. As a result, these countries become technology followers, such as for light engineering firms in Zimbabwe as discussed by Chipika and Wilson (2006). Although this can be accommodated in the above model with entrepreneurial employees looking for further opportunities, a far greater threat to its successful application in developing countries is the lack of infrastructure or its maintainance, such as the lack of maintenance of the sophisticated laboratories supplied to Bangladesh by Japan and the Food and Agriculture Organization (FAO); and the brain drain of scientists studying abroad on scholarships from e.g. the World Bank (Bunders *et al.,* 1999). These authors reported that scholarship holders often leave their home country such as Bangladesh to e.g. the USA or Australia. This exacerbates a technology and expertise gap, potentially restricting effectiveness of the above model in all but the subsistence/low technology fields in the developing country. Potential donors could learn from these experiences and include maintenance contracts for donated infrastructure while making scholarships conditional upon the return of successful applicants to their home country for a stipulated period. Bunders *et al.* (1999) also report that, in Bangladesh, interactions between the members of the triple helix model were not effective due to a lack of vision, which could be supplied to some extent by a donor agency that may be required to drive the sustainable development initiatives. NGO's and community concerns have been incorporated into the above model (Figure 1) to address this issue because ethics, including towards the environment, are too often secondary to economic development.

In conclusion, this paper proposes a model that addresses shortcomings of the triple helix model to make it more applicable in developing countries by allowing NGO's to be proactive in sustainable development. Community concerns are allowed to play a role in decision making and/or as drivers in both developed and developing countries. Stakeholder inclusion is further increased by allowing less recognized scientists to participate through cross-subsidisation and smaller creative problem-solving opportunities. It allows for radical (such as new product development) as well as incremental (such as cleaner production) innovations. This model requires that a broader view be taken of commercialization to consider benefits beyond economic ones, making the resultant development sustainable. Three approaches have been discussed to achieve this namely: the commercialization of environmental technology; incorporating environmental considerations while developing new products; and improving existing products or processes to limit environmental impact. Drivers of such initiatives in Australia include specialist centres such as CRC's, created in affiliation with universities and which have been shown to enhance development through commercialization. Although sustainability is often not integral to the development process, it is encouraging to note that it has been incorporated into or implied in the title of some of the Australian CRC's. It is often overlooked that sustainability can lead to economic benefits through the use of less material (cutting costs) and the opportunities from consultancies can lead, through knowledge transfer, to the development of new sustainable products or processes. The involvement of, and communication between marketers and experts in sustainability or cleaner production should reduce the failure rate of new product commercialization while enhancing both sustainability and economic benefits to stakeholders. The model is a proposal that draws upon the experience of the author and addresses the shortcomings of existing innovation models to incorporate sustainability and greater stakeholder involvement. It also allows economies of scale to maximize the output of each project in terms of commercial as well as research and education productivity. An interesting and useful study would be to further relate this model to current practises in both the developing and developed worlds. It could be usefully applied as a framework for driving sustainable development using selected universities/NGO's/Centres. Performance should then be measured in terms of new projects implemented and how sustainability has been achieved during or through this 'development'.

References

Altham, W. (2006). "Benchmarking to trigger cleaner production in small businesses: Drycleaning case study." *Journal of Cleaner Production* 15: 798-813.

Australian Institute for Commercialisation (2006). Inside commercialisation -> ideas ->opportunities -> outcomes: Annual Review 2005/1006. Brisbane, Australian Institute for Commercialisation: 1-23.

Brown, T. C. (1984). "The concept of value in resource allocation." *Land Economics* 60: 231-246.

Bunders, J. F. G.; Broerse, J.E.W.; Zweekhorst, M.B.M. (1999). "The triple helix enriched with the user perspective: A view from Bangladesh." *Journal of Technology Transfer* 24: 235-246.

Ceballos, G. C. P.; Erlich, J.; Soberon, I.; Salazar, I.; Fay, J.P. (2005). "Global mammal conservation: what must we manage?" *Science* 309: 603-607.

Chertow, M. R. (2000). Accelerating commercialization of environmental technology in the United States: Theory and case studies. Connecticut, Yale University: 343.

Chipika, S.; Wilson, G. (2006). "Enabling technological learning among light engineering SMEs in Zimbabwe through networking." *Technovation* **26**(8): 969-979.

Duarte, A. P.; Martins, P.; Alexandre, J. (2007). "Pro-active behaviour induction by integration of sustainability in business strategic management: INOVE project case study." *Journal of Cleaner Production* In Press: 1-15.

Howgrave-Graham, A. R.; Galvin, P. (2005). Cooperative research centres and industrial clusters: Implications for Australian biotechnology strategies. *New regionalism in Australia*. A. G. Rainnie, M. Aldershot, England, Ashgate Publishing Limited. 1: 87-102.

Howgrave-Graham, A. R.; van Berkel, R. (2007). "Assessment of cleaner production uptake: Method development and trial with small businesses in Western Australia." *Journal of Cleaner Production* 15: 787-797.

Insight Economics (2006). "Economic Impact Study of the CRC Programme." Australian, Government, Department of Education and Training. Insight Economics Pty Ltd: 1-68.

Jorgensen, T. H. (2007). "Towards more sustainable management systems: through life cycle management and integration." *Journal of Cleaner Production* In Press: 1-22.

Leydesdorff, L.; Etzkowitz, H. (1997). "A triple Helix of university-industry-government relations." *Universities and the global knowledge economy*. H. L. Etzkowitz, L. London, Pinter. 1: 155-162.

Malaska, P. (2001). "A futures research outline of a post-modern idea of progress." *Futures* 33: 225-243.

Maxwell, D.; van der Vorst, R. (2003). "Developing sustainable products and services." *Journal of Cleaner Production* 11: 883-895.

McFadzean, E. S. (1998). "The creativity continuum: Towards a classification of creative problem solving techniques." *Creativity and Innovation Management* 7(3): 131-139.

Monfreda, C.; Wackernagel, M.; Deumling, D. (2004). "Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessments." *Land Use Policy* 21: 231-246.

Moran, D. D.; Wakernagel, M.; Kitzes, J.A.; Goldfinger, S.H.; Boutaud, A. (2007). "Measuring sustainable development - Nation by nation." *Ecological Economics* in Press: 1-13.

Riedlinger, M. (2002). "Cooperative Research Centres going strong in the biosciences." *Today's Life Sciences* 14(3): 36-39.

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Alan Howgrave-Graham, Monash University (School of Applied Sciences and Engineering), Australia. He spent four years working in hydrological research then pollution control in the Department of Water Affairs in South Africa, before spending twelve years teaching microbiology and doing environmental biotechnology research, mostly at the University of Natal where he completed his PhD. He migrated to Australia in 1999 and started a Doctorate in Business Administration specializing in commercialization of University intellectual property. In 2001 he worked at Curtin University at the Centre of Excellence in Cleaner Production before taking up his current position as microbiology lecturer at Monash University. He has published 17 scientific journal articles on anaerobic and aerobic treatment of wastewaters and the detection of protozoan pathogens in water. More recently he published a book chapter on the implications on biotechnology strategies of the Australian system of cooperative research centres and industrial clusters, as well as a journal article on opportunities for cleaner production in West Australian SME's. His research interests are in all the above topics as well as in methods for teaching to large classes and in multicultural settings.

6. The Composition and Productivity of Australian Cooperative Research Centres, with Emphasis on their Participation in Biotechnology, Regional and Sustainable Development

Alan R. Howgrave-Graham

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The Composition and Productivity of Australian Cooperative Research Centres, with Emphasis on their Participation in Biotechnology, Regional and Sustainable Development

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Abstract: More than a decade ago, the Australian Commonwealth Government introduced and funded a system of Cooperative Research Centres (CRC's) to bring scientists from universities, CSIRO, other government institutions, industry and private sector organizations from throughout Australia together. These CRC's were to work on specific research and development projects that would benefit from the critical mass of effort. In 2002 there were 65 CRC's in diverse fields but by 2009 there were 49 listed on their dedicated web page, each with its specific R&D focus. For this paper, each of these CRC's (and each of two university-based centres with a sustainability focus) was contacted to determine: its participants; its basic and applied research output; whether it is involved in biotechnology projects; whether clustering is used to enhance knowledge transfer through geographical proximity; and whether it is involved in regional and/or sustainable development. The response rate was 37% and the aggregated results are discussed. An additional questionnaire with open-ended questions was distributed to senior members of local industries, NGO's, government officials, and a local university in Gippsland, Victoria to further investigate collaboration for regional and sustainable development on a local basis. This questionnaire served the additional purpose of testing two previously published models on knowledge flows between such organizations for basic and applied research in Australia. The responses to both of these questionnaires are collated in this paper to depict the drivers and level of innovation in Australia as a whole and one regional area as an example.

Keywords: Australian Cooperative Research Centres, Sustainable Development, Regional Development, Biotechnology

Introduction

SEVERAL MODELS HAVE been proposed to reflect innovation within and between organizations. These are constantly upgraded to reflect the reality that underpins development at organizational, regional or national levels and guide decision making by policy makers. Howgrave-Graham (2008) and Howgrave-Graham (2009) built upon previous models to propose two closely related ones for sustainable and regional development respectively and this paper is directed towards testing these on a regional basis, as well as investigating the status of innovation in Australia as implemented through the nationwide Cooperative Research Centre program. Investigating the latter would give some insight into the program's success, while identifying where improvements can be made to enhance innovation and its commercialization.

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This is especially important because only small proportion of scientific discoveries go on to generate economically viable products, a great source of frustration for businesses which are focused on profit generation and growth. An example of an underlying failure to communicate is what Debackere and Veugelers (2005) refer to as the "European Paradox" in which only 10% of innovative firms in the European Union have cooperative agreements with universities, and there is a large gap between the high levels of scientific performance and its contribution to industrial competitiveness and new venture entrepreneurship. Giuliani and Arza (2009) further queried the benefits of university-industry linkages and proposed that selectivity should be applied in identifying and promoting such linkages. The intervention of a third party such as a government organization as suggested in the next paragraph, or a liason office such as a technology transfer office at a university may improve industry-science links as discussed by Debackere and Veugelers (2005) and other authors. Fostering cooperation between industry and science should promote mutual understanding and benefits to both parties and incentives or other drivers should be put in place to promote this, considering the differences in paradigms between scientists/academics and businesses/entrepreneurs.

Industry, University, NGO and Government Cooperation

Leydesdorff (2005) examined knowledge-based innovation systems based upon interconnections between university, industry and government partners, typical of the "Triple Helix" model (Etzkowitz and Leydesdorff, 2000) that became prominent in the technology policy literature since the late 1990's. Many authors support such partnerships for the innovative outcomes that they generate as a means to positively affect innovation performance through the diffusion of science knowledge to industrial partners. However, its universal application has been widely debated and Howgrave-Graham (2008) and Howgrave-Graham (2009) modified this model to address the concerns raised, such as the involvement of NGO's (their absence in the triple helix model being a concern to Bunders et al. , 1999) and alternate funding sources, while making it potentially applicable in Australia for sustainable and regional development respectively. In these models, government (national and state) was proposed as both legislator and funding source with Cooperative Research Centres as conduits in Australia.

In 1990, the Cooperative Research Centres (CRC's) Program was established by the Australian Commonwealth Government, along the principles of Etzkowitz and Leydesdorff's (2000) Triple Helix model to bring scientists from universities, the CSIRO, other government institutions, industry and private sector organizations together (Riedlinger, 2002) to enhance and expand the nation's scientific and technological research capability to support broadly stated national objectives. However, the Commonwealth of Australia (2008) report indicates that the objectives of the CRC program has changed over time to now have a heavy emphasis on supporting end-user driven research and research capable of producing a commercial return.

There have so far been 10 selection rounds resulting in 102 new CRC's being developed over the life of the program and this number declined to 49 in 2008-2009. Over the years, the Australian government has invested approximately A$3 billion with almost A$9 billion (in kind and in cash) contributed by participants, including approximately A$2.9 billion from universities, A$2.3 billion from industry, A$1.6 billion from government end-users and A$1.1 billion from CSIRO, Australia's largest research organization (Commonwealth of Australia, 2008). This report states that the economic impact of the CRC program has been considerable albeit primarily through end-user application of research rather than direct commercialization.

A similar phenomenon may be emerging in Australia to the "European Paradox" discussed by Debackere and Veugelers (2005) as the Commonwealth of Australia (2008) report indicates that only a small fraction (570) of all Australian firms have participated in CRC's. However, this report indicates that the CRC Program has had a whole industry impact where there is a strong drive from a strong industry intermediary, such as the beneficial effect of rural Research and Development Corporations' on large numbers of agricultural businesses. This reiterates the proposal above by Giuliani and Arza (2009) that selectivity should be applied in promoting and identifying linkages. One of the selection criteria that could be imposed is that suggested by the Commonwealth of Australia (2008), namely that future CRC applicants have impacts across broad grouping of end users. This is especially important in light of its observation that CRC's typically (with singular exceptions) appear not to have the know-how and resources to be particularly good at commercialization. It proposes that the future of the CRC Program needs to produce end-user driven research that allows rapid breakthrough business transformation.

One way to achieve this would be to introduce and embed a culture of "creative problems solving" as proposed by McFadzean (1998), in which new opportunities can be found by looking at today's problems, such as the discovery of a new substance by G.D. Searle and Co. that is now marketed as the well known artificial sweetener NutraSweet, although the research that led to this discovery was focused on an anti-ulcer drug (Robinson and Stern, 1997). Such identification of new opportunities while investigating other end user driven problems (whether related or not) can only enhance CRC outputs and has thus been proposed in the models published by Howgrave-Graham.

Australian Biotechnology

Despite all the literature on biotechnology in Australia, no consensus has been reached as to what is meant by "biotechnology", making it difficult to understand most of the publications that are focused on the "biotechnology industry" or "biotechnology sector". Biotechnology, in particular Australian biotechnology has, as a result, a poor report card when Acharya (1999)'s molecular biology-based definition, requiring significant advanced technical input, is used. On the other hand, no-one can refute that the quality of or market for Australian wines, produced using less advanced biotechnological methods, is world class. Three definitions of biotechnology were thus devised for this paper to cover the entire spectrum according to the literature to determine the true status of Australian biotechnology competitiveness at all levels of technological sophistication for the first time. These were: the broad definition which "involves the use of enzymes or microorganisms in industry, or the manufacture of biological products such as beer, wine, cheese, bread or yoghurt making, or the biological treatment of wastes"; the molecular biology definition which "involves nucleic acid techniques"; and the broadest definition "the manipulation or modification of living organisms (or parts of organisms) for gain". This last definition allows inhibition of organisms to be included such as plant pathology, corrosion prevention and weed control. The CRC's were asked to indicate their level of involvement in each of these. The measures of productivity investigated included basic and applied research output as well as commercialization outcomes to reflect innovation performance.

Measuring Innovation

Authors differ with respect to what they would consider good measures of innovation performance with Landry et al. (2006) investigating patents and spin-off creation while Hall and Bagchi-Sen (2007) took this further to investigate domestic and international patent applications and approvals, new product or process introductions and/or redesign, and R&D revenue expenditure. For this paper, CRC innovation is being investigated in terms of some of these measures, using licenses awarded and revenue generated from product sales as measures of successful product introduction, while CRC funding for R&D has been documented elsewhere but has been included in the CRC survey used for this paper. Other forms of innovation were also investigated for this papers such as licenses granted as suggested by Nelson (2009, p.1003) because “they provide the only reliable assessment of actual products released”; and those with a basic rather than applied focus, such as publications and post-graduate completions as these reflect the generation and publication of new knowledge, irrespective of whether the outcome was commercialized or not. Likewise, creative problem-solving by CRC’s was measured as these innovations are expected to have a cost (or other) benefit to the participant organizations.

Sustainable and Regional Development in Australia

Howgrave-Graham (2008) proposed a model on how sustainable development could be achieved through creative problem solving and collaboration within and beyond CRC members, to the benefit of both the research providers, and business end users such as those focused upon commercialization. Taking this one step further, Howgrave-Graham (2009) indicated how regional university campuses, as these research providers, could actively drive regional development, and outlined the knowledge and funding flows that would underpin this process. These models expand the Triple Helix model of Etzkowitz and Leydesdorff (2000) to address shortcomings listed by other authors such as Bunders et al. (1999) and Benner and Sandstrom (2000), while incorporating Australia-specific characteristics and drivers such as the CRC program, ethical considerations and NGO involvement. Figure 1 depicts one of these models which is discussed in more detail in Howgrave-Graham (2009) and was tested for this study, together with the Howgrave-Graham (2008) sustainability model using the Delphi method (Lee and Bereano, 1981; van den Ende et al., 1998). A primarily open-ended questionnaire was completed by senior representatives from industry, NGO, government and university in Latrobe Valley, Gippsland (Australia). The extent to which these models are/can be applied in terms of the linkages and serendipity-based opportunities (creative problem solving), linkages and knowledge flows was tested. In another survey, Australian CRC composition, structure, funding and output was determined using a separate on-line questionnaire. This paper is thus one that uses Gippsland as a case study to test the models proposed by Howgrave-Graham, while taking an Australia-wide exploratory approach to investigate national CRC’s in terms of their composition, productivity, funding and activities.

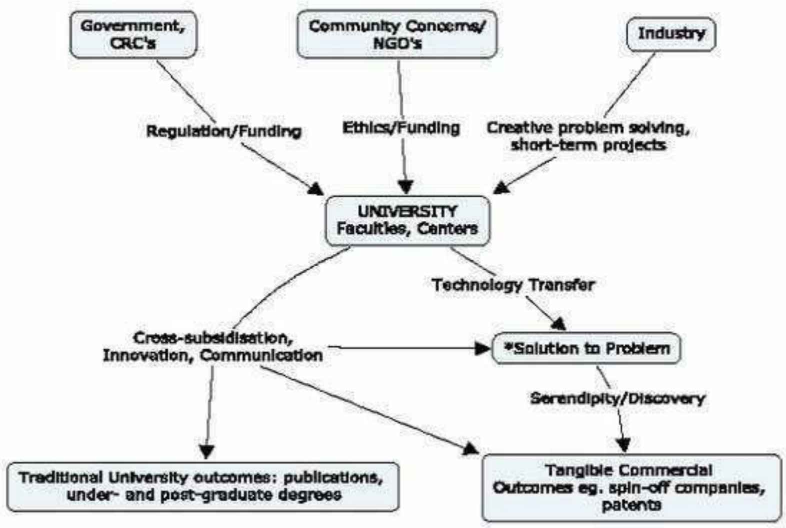

Figure 1: An Opportunity-driven model Illustrating Networks and Funding Sources Established by University- or Campus-based Facilitators to Maximise Economic and Academic Outcomes and Spin-offs from Creative Problem Solving (Howgrave-Graham, 2009)

Methods

Australian CRC and Centre Survey. A questionnaire was sent via http://surveymonkey.com to the contact people listed on http://www.crca.asn.au/print/709 as the contact person for each of the forty-nine CRC's (in existence for more than six months by December 2009) and two Australian university-based centres with a mandate to drive industry innovation. The questionnaire allowed the electronic entry of quantitative data on the composition, age, activities and productivity of each centre, and had a few open-ended questions on each centre's objectives, barriers to achieving these and how the global financial crisis had affected their activities.

Topics investigated by the quantitative portion of this survey (with occasional elaboration requested such as a request for an example to determine whether the question was understood) were:

- The centre's age and composition (number of affiliate universities, SME's, large businesses, government departments, NGO's, and other tertiary institutions)
- Its applied research output in the past five years (number of patents generated, spin-off company establishment, licenses generated and awarded as a research outcome, licenses received from outside organizations for commercialization, and number of applied research projects conducted (to test the level of creative problem solving, the proportion of these projects that have led to commercializable outcomes was investigated)

- Basic research output for the past five years in terms of the number of peer-reviewed publications and books or book chapters, as well as post-graduate completions. Participants were asked what proportion of their activities were considered basic, and what proportion applied research
- Funding sources for their research in terms of the proportions from government, venture capitalists, NGO's, product sales, consultancies, universities or other sources.
- Whether they conduct any biotechnology research in terms of each of the three definitions above and the percentage of their activities that falls within each definition
- The main champions/innovators of the centres (how many projects were initiated by universities, how many by government, individual businesses, industry groups/collectives, and how many by community groups/NGO's)
- Their role in sustainability in terms of the three prongs described by Howgrave-Graham (2008), namely what proportion of their activities could be considered to be commercialization of environmental technology, incorporating environmental considerations into developing new products, or are projects designed to limit the environmental impact of existing products or processes, such as cleaner production. In addition, respondents were asked the proportion of their activities that were designed to directly conserve natural environmental resources.
- To what extent their projects have led to development, whether it be metropolitan, regional, in Gippsland (to relate to the case-study questionnaire), or in Latrobe Valley (central Gippsland) and how many clusters (industrial or agricultural, regional or metropolitan) they had developed

The composition and age of the CRC's was related to both their outputs (both basic and applied) and inputs (funding sources), while the champions/innovators were identified. This information was related to the occurrence and nature of the CRC's biotechnology activities.

Application of the Delphi Technique in Latrobe Valley, Gippsland. This exploratory interview approach as discussed by Hair et al. (2003), involves the input of acknowledged experts and was applied as a written questionnaire to leaders at a Latrobe Valley (Gippsland) university as well as senior representatives from local and state government, NGO's and Latrobe Valley's three main industries. These were major role players related to the processing of coal and timber, and water supply. According to Latrobe City's Natural Environment Sustainability Strategy 2008-2013, power and water represent 54% of the region's exports and 26% of its gross revenue (http://www.latrobe.vic.gov.au/webfiles/council/services/sustainability). The questions were mostly open-ended and designed to test the models proposed by Howgrave-Graham (2008) for sustainable development and Howgrave-Graham (2009) to drive regional development by creating relevant knowledge networks, respectively. Participants were supplied with copies of these publications and asked to indicate in each case whether they believed the model could work in Latrobe Valley, Gippsland, Victoria, or Australia. They were asked what the positive attributes of the models were and hurdles that needed to be overcome for their successful implementation in Gippsland. In addition they were asked whether they were aware of CRC activity in Gippsland and Latrobe Valley, to what extent they believed biotechnology was conducted in terms of the three definitions discussed earlier in this paper. An additional section was included for general comments and in some cases, follow-up interviews were conducted at the request of the respondents to clarify issues. Written questionnaires were used as the starting point rather than interviews due to Hair et al. (2003)'s observation that this minimizes inconvenience to the experts, whose time is valuable.

Ethics approval was obtained for both surveys from the Monash University Human Research Ethics Committee (Project number CF09/1829-2009001037).

Results and Discussion

Seventeen CRC's and two university-based centres responded to the Australian CRC and centre survey, representing a 37% response rate. It should be noted that in a few cases, although the CRC/centre had responded, not all questions were answered. Eleven responses were obtained for the Delphi Technique survey presented to Latrobe Valley managers, three from industry, two from NGO representatives (representing five NGO's between them), three from a university and three from state and regional government officials.

Figure 2 represents the composition of the CRC's and centres that responded. Note that small to medium enterprises (between 3 and 250 staff) were the most numerous organizations, followed by large private enterprises, then universities and government. Eleven of the centres indicated that they had existed for less than ten years, the youngest being two years old. There was no clear distinction between the older and younger centres in terms of membership numbers. Of the two university-based centres, one had a membership of eight universities only, and the other had one university and membership of other organizations as well.

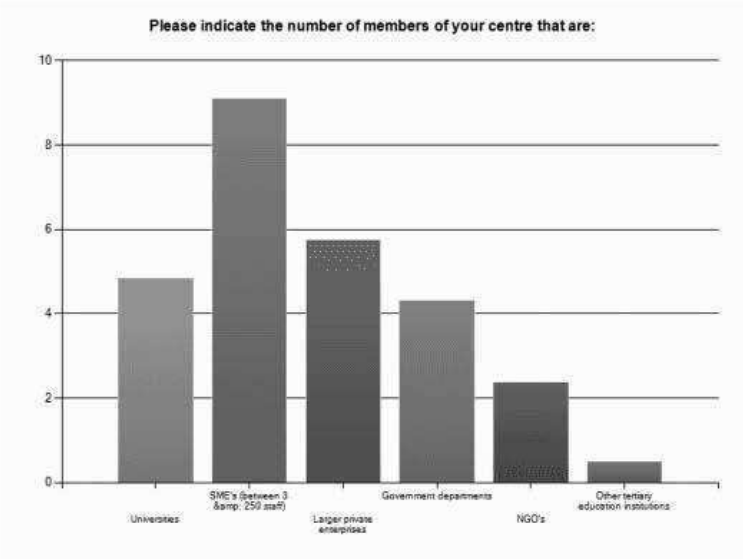

Figure 2: The Composition of Australian CRC's (seventeen) and University-based Centres (Two)

In terms of productivity, seven centres indicated that they had generated no patents and the maximum number generated was between six and nine in the past five years, as indicated by another seven centres. Four CRC's had spun off eight companies and one university-based centre another in the past five years while a total of over 35 license agreements were obtained by 10 centres, of which four centres had been awarded over five each. Nine centres had awarded a total of more than 37 licenses, six of these centres had awarded more than five licenses. In terms of applied research projects, five centres were conducting more than 30 of these each, three had between 0 and 5 such projects and the remaining centres fell between these. Of the research projects conducted, two centres indicated that 81-100% of their projects had generated commercializable outcomes (some possibly due to the serendipity associated with creative problem-solving), another two indicated that 61-80% of their projects had commercializable outcomes while twelve centres indicated that 0-20% of their applied projects had resulted in commercialization. It should be noted that the two CRC's that indicated 81-100% commercialization had over 30, or 25-30 applied research projects each. One of the two centres with 0-20% commercialization of applied research projects was conducting over 30 of these, possibly reflecting upon interpretation of the term "commercialization" to mean revenue-generating. This CRC was an agriculture-based one with 6-9 patents, one license awarded and another received but with the maximum academic output of over 30 publications and over 20 post-graduate student completions in the past five years.

In terms of academic output, all but one of the centres (a university-based one) had produced over 30 publications over the past five years and eight centres had generated over 20 post-graduate completions. Three centres had 11-20 postgraduate completions and only one CRC and a university-based centre had 0-5 completions in the past five years.

These results are interesting as they reveal a strong basic research output and, when related to figure 3 which reflects the source of funding for the CRC activities, suggest that much basic research is still conducted by CRC's. This contradicts the survey responses in which only five respondents reported doing less than 100% applied research (5, 10, 15 and 40% basic research each). Note from figure 3 that government, by contributing nearly 50% of the funds, is the largest sponsor of CRC activities, followed by industry then university contributions. Venture capital made no contribution while product sales and consultancies made relatively small contributions to support the activities of the CRC's that responded. From this it appears that the Commonwealth of Australia (2008) report may be correct in surmising that CRC's generally do not have the know-how or resources to be good at commercialization. This is also reflected in the response that less than half of the respondents indicated that more than 20% of their applied projects had resulted in commercialisable outcomes. It was mentioned that there are exceptions and the agriculture-based CRC referred to above would be a good example, as would the relative newcomer (2 years old) referred to below which obtains most of its funding from industry.

It is difficult to relate the funding obtained by the CRC's in figure 3 to the contributions listed quoted from the Commonwealth of Australia (2008) report because this combines cash plus in-kind contributions, and CSIRO contributions (government supported) but it can be seen that the respondents to this survey reveal a slightly higher proportion of industry funding than the 21% indicated in the 2008 report. This may be due to improvement over the past year, or that the respondents to this survey were better at attracting industry funds than the non-respondent CRC's.

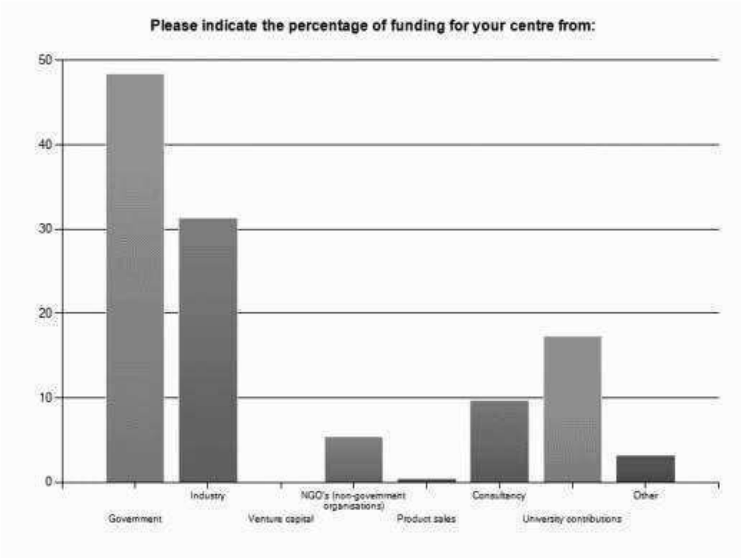

Figure 3: The Sources of CRC/centre Funding

Of the CRC/centres that responded to the survey, four do no biotechnology of any kind, two reported to doing only biotechnology with the molecular biology definition discussed above "…involves nucleic acid techniques"; the remaining centres indicated that some, and in two cases all their activities fall within the broadest definition "the manipulation or modification of living organisms (or parts of organisms) for gain". Six of these centres apply biotechnology in terms of another less broad definition "…which involves the use of enzymes or microorganisms in industry, or the manufacture of biological products such as beer, wine, cheese, bread or yoghurt making, or the biological treatment of wastes". Four of these centres use molecular biology techniques. One CRC, as its name suggests uses biotechnology as defined all three ways for 100% of its activities. There was no clear distinction between the biotechnology and non-biotechnology CRC's in terms of productivity or funding models although government supplies 75, 80 and 90% of the funding for three biotechnology CRC's, while one gets 84% of its funding from industry.

Figure 4 indicates the champions/innovators that initiate the CRC/centre projects. Individuals, farms, companies or industry collectives are clearly the main drivers of innovation, with universities the being third most important initiators. This suggests that CRC projects reflect the needs of industry rather than the interests of academia or government focus.

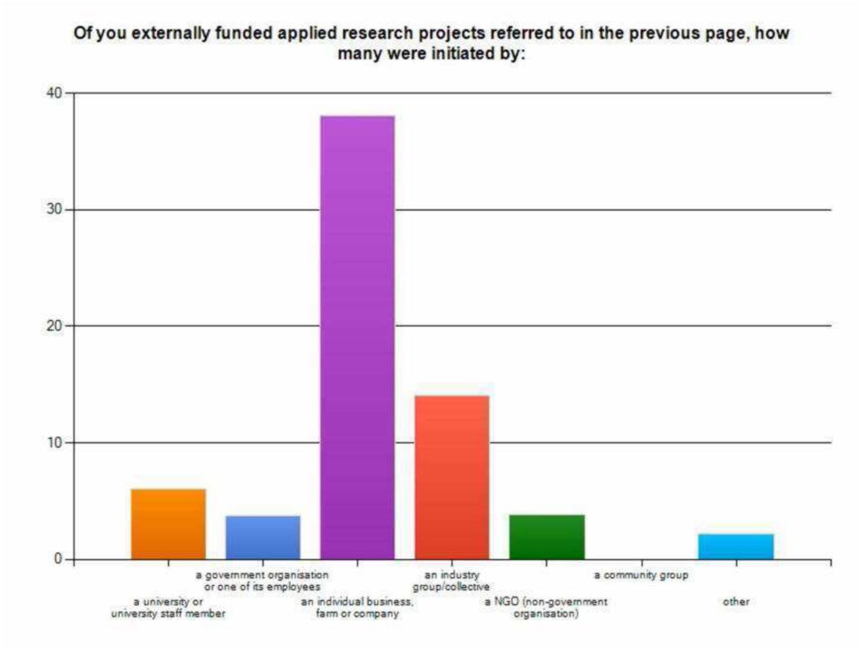

Figure 4: CRC/centre Champions/Innovators

With respect to sustainability, eleven of the CRC's indicated that they carried out activities that could be construed as commercialization of environmental technology, one indicating it was between 81 and 100% of their activities, another one each indicated that 61-80 and 41-60% of their projects incorporated this sustainability initiative. Eleven respondents indicated that they incorporated environmental considerations into developing new products (one each indicate that this was involved in 41-60, 61-80 and 81-100% of their activities). Fourteen centres responded to the question on what proportion of their projects are designed to limit the environmental impact of existing products or processes, such as cleaner production, all fourteen indicated that they had consideration for this sustainability initiative: two indicated that this comprised 81-100%; one each indicated 61-80 and 41-60% of their activity while three indicated 21-40%. The examples given by the centres reflected an understanding of these forms of sustainability, such as "lightweight automotive structures" and "wastewater treatment for reuse" indicating incorporation of environmental consideration in developing new products and minimizing environmental impacts respectively. Six centres indicated that they were directly involved in protecting environmental resources and for two, this represented 21-40% of their activity, while one each incorporated this into 41-60 and 61-80% of their activities.

Fourteen of the centres indicated that their projects have led to development (61-80% of them in one case and 41-60% in another three), twelve of the centres' activities resulted in regional development with two centres interestingly indicating that 81-100% of their projects led to regional development when they had recorded that only 61-80% and 21-40% of their projects had led to development. All fifteen centres that responded to this part of the questionnaire indicated that their projects would lead to further development.

Twelve of the respondent CRC's had clusters (between one and six each) of which 7 had regional clusters but none were in Latrobe Valley or Gippsland although five centres had member organizations in Gippsland (including one university-based centre in Latrobe Valley). Those CRC's with industrial/agricultural clusters were more productive in terms of the patents generated, licenses received and granted and spin off companies created than the three CRC's and one centre without clustering. Those without clusters averaged two of these outputs each, those with one cluster had over four each, those with two clusters had over nine each and those with four or six clusters averaged over 21 of these outputs each.

Eleven of the sixteen CRC's that responded to the question on whether the global financial crisis had affected them had been affected. The reduction in demand for luxury goods affected two, financial constraints and a drop in R&D funding affected five others, while one had two industries withdraw from the CRC, and another experience a reduction of engagement of industry personnel due to work pressures.

Testing the models described in Howgrave-Graham (2008) and Howgrave-Graham (2009) (figure 1), using the Delphi method revealed that all three senior local and state government respondents believed that the models could work (except for one government representative who felt that the model in figure 1 could not work because it is "too top heavy" and focuses too much on university outcomes). Some observations were that industries in Gippsland have the opportunities and recognize the need for innovation, the skills base in the region is present and, with greater stakeholder (especially university) involvement can address the challenges of climate change and water security. All three government respondents felt that a local champion is needed in the region and two indicated that it was local university's responsibility to strengthen relationships and trust between it, industry, NGO's, and the public sector. Several suggestions were made as to how this could be achieved.

All three industries did not believe the sustainability model proposed in Howgrave-Graham (2008) could work and two of the three indicated that the model in Howgrave-Graham (2009) (figure 1) could not work because financial (especially of R&D and sustainability issues), capital investment and intellectual property issues are not adequately addressed (one government respondent felt, however, that funding was adequately addressed). One industry did not believe that the R&D skills were present in the region and another indicated that "universities are notoriously inefficient in delivering projects in a realistic timeframe". One industry believe that the model in figure 1 (based upon the explanation in Howgrave-Graham, 2009) could succeed in Gippsland as it recognizes the importance of partnerships and networks and the value of "cross-subsidisation" as well as the value of university and commercial outcomes.

One NGO representative and one industry indicated that feedback was absent in the model such as back to government or industry while both NGO representatives believed the model in figure 1 could work in Gippsland, one indicating that it was "only part of the answer" (government research stations and independent industry research also contribute) and the other respondent (also a university employee) indicating that it implies university staffing with the skills and time to get out into the field and "extract problems" from potential customers. One point raised by an NGO and confirmed by a government representative was that universities needed to become more visible, or champions in the region. One NGO believed that the sustainability model in Howgrave-Graham (2008) could not work because

NGO's are not aware of the capabilities of universities with these being perceived as "teaching only". The NGO's reflect the government concerns that the local universities often need to increase their visibility and, in one case, "explain its scope". It was recognized that people were often too busy to do it, a point made by a university respondent who added that many staff do not have the skills or time to conduct industry type consultancy, resulting in consultants being employed instead.

Two of the three university staff managers (the third being from a university-based centre) indicated that the models could only work for certain projects and that they appeared too top-down and university-driven (a danger also pointed out by one industry and a government respondent). One university respondent indicated that the models could have additional applications if university funded the research and/or industry had an interest in basic research, and another pointed out that the starting point usually is industry developing a product or service. Another response was that Latrobe Valley's closeness to resources could give the models a natural "edge" which has to be exploited for projects to succeed. Another response indicated the need for longer term collaborations, partnerships and strategic alliances (possibly alluding to the project-by-project nature of the models).

Four respondents indicated that the models in Howgrave-Graham (2008) and Howgrave-Graham (2009) (figure 1) were similar. The former targets sustainability and the latter, regional development. All respondents except one government organization indicated, where the models were declared suitable or unsuitable, that this was for Latrobe Valley, Gippsland, Victoria and Australia. The exception was where one government respondent felt that, while the sustainability model in Howgrave-Graham (2008) was suitable for the rest of Australia, Latrobe Valley was not ready for it. Of the eleven respondents, only three were aware of CRC activities in Gippsland or Latrobe Valley. Six respondents indicated knowledge of biotechnology activities conducted in Latrobe Valley/Gippsland. Most fell under the category of the broad definition which involves the use of enzymes or microorganisms in industry, or the manufacture of biological products such as beer, wine, cheese, bread or yoghurt making, or the biological treatment of wastes with the lowest value given being 5% and the highest 50% of Gippsland's activity, and 4% and 30% of Latrobe Valley's activity respectively, the averages being 26% and 18% respectively. Some confusion was expressed at the term "activity" but these figures are probably realistic considering the considerable coal mining and power generation activity based at Latrobe Valley, and the winery and dairy industry spread throughout Gippsland. Molecular biology was designated 10% or less of both Gippsland and Latrobe Valley's activity.

Conclusions

Despite a high focus on commercialization and pressure to do so in future, Australian CRC's seem to have a greater productivity in academic pursuits, despite a large proportion of the projects being undertaken being initiated by end users such as farmers or industry. Biotechnology activity and output of those CRC's in a position to undertake these activities has generally been underestimated, due to other authors using too narrow a definition of biotechnology. Clustering within CRC's seems to enhance commercializable outputs and government is still the main sponsor of CRC activities. Most CRC's have sustainability incorporated into their activities, while development, whether regional or metropolitan, is another benefit.

Little CRC activity is conducted in Latrobe Valley or Gippsland and experts in the region had mixed opinions of the innovation models for development proposed to them. These models, based on Figure 1 in this paper, although applicable for some projects were flawed as the university was indicated as being the pivotal point despite industry indicating that delivery may be lacking; the models did not incorporate some organizations such as government laboratories; and feedback such as from industry or NGO's to government was not reflected. Government respondents were the most positive, feeling that the models were generally applicable but that universities should be more pro-active in identifying, driving and coordinating the collaborations and projects. University visibility, relationship building (as identified by one university respondent) and a clear demonstration of its intention to address industry needs would go a long way to building the trust required for these models to succeed. In essence the models, with minor modifications, should work in theory but most of the problems of implementation are associated with interactions and trust between the three pillars of the triple helix model (government, industry and university), and the additional ones incorporated into the models tested for this paper such as NGO's and community concerns. CRC's bring these organizations together to solve problems and increase productivity. The culture of close collaboration towards universal goals should overcome many of the misgivings that hamper application of the models proposed while the models underpinning this paper lend themselves to "open innovation" in which outside organizations develop nonstrategic initiatives, as suggested by Chesbrough and Garman (2009). Future models should incorporate the modifications proposed above, as well as concentrate on ways to depict and quantify the level of trust and interaction between collaborating organizations. Other issues raised, such as intellectual property and funding issues could be incorporated within the models' frameworks on a case-by-case basis during implementation.

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References

Acharya, R. (1999). The emergence and growth of biotechnology. *The Internationalisation of Biotech SME's*. J. Senker. Cheltenham, UK, Edward Elgar Publishing: 156-163.

Benner, M. and U. Sandstrom (2000). "Institutionalizing the triple helix: research funding and norms in the academic system." *Research Policy* 29(2): 291-301.

Bunders, J. F. G., J. E. W. Broerse, et al. (1999). "The triple helix enriched with the user perspective: A view from Bangladesh." *Journal of Technology Transfer* 24: 235-246.

Chesbrough, H. W. and A. R. Garman (2009). "How open innovation can help you cope in lean times." *Harvard Business Review* December: 68-76.

Commonwealth of Australia (2008). "Venturousaustralia: Building strength in innovation." from http://www.innovation.gov.au/innovationreview/Pages/home.aspx.

"CRC's - the Cornerstone of Australia's National Innovation System." Retrieved 2 December 2009, from http://www.crca.asn.au/print/709.

Debackere, K. and R. Veugelers (2005). "The role of academic technology transfer organizations in improving industry science links." *Research Policy* 34: 321-342.

Etzkowitz, H. and L. Leydesdorff (2000). "The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations." *Research Policy* 29(2): 109-123.

Giuliani, E. and V. Arza (2009). "What drives the formation of 'valuable' university-industry linkages?: Insights from the wine industry." *Research Policy* 38(6): 906-921.

Hair, J. F., B. Babin, et al. (2003). *Essentials of Business Research Methods*. Hoboken, USA, John Wiley & Sons.

Hall, L. A. and S. Baghchi-Sen (2007). "An analysis of firm-level innovation strategies in the US biotechnology industry." *Technovation* 27(1-2): 4-14.

Howgrave-Graham, A. R. (2008). "An interdisciplinary knowledge transfer approach to facilitate sustainable development: Australia as an example." *The International Journal of Environmental, Cultural, Economic and Social Sustainability* 4(4): 11-16.

Howgrave-Graham, A. R. (2009). "An innovation and development model for regional university campuses." *The International Journal of Technology, Knowledge and Society* 5(1): 76-88.

Landry, R., N. Amara, et al. (2006). "Patenting and spin-off creation by Canadian researchers in engineering and life sciences." *The Journal of Technology Transfer* 32(3): 217-249.

"Latrobe City's Natural Environmental Sustainability Strategy 2008-2013." Retrieved 16 November 2009, from http://www.latrobe.vic.gov.au/webfiles/council/services/sustainability.

Lee, A. M. and P. L. Bereano (1981). "Developing technology assessment methodology: some insights and experiences." *Technological Forecasting and Social Change* 19(1): 15-31.

Leydesdorff, L. (2005). "The Triple Helix Model and the study of knowledge-based innovation systems." *The International Journal of Contemporary Sociology* 42(1): 12-27.

McFadzean, E. S. (1998). "The creativity continuum: Towards a classification of creative problem solving techniques." *Creativity and Innovation Management* 7(3): 131-139.

Nelson, A. J. (2009). "Measuring knowledge spillovers: What patents, licenses and publications reveal about innovation diffusion." *Research Policy* 38(6): 994-1005.

Riedlinger, M. (2002). "Cooperative Research Centres going strong in the biosciences." *Today's Life Sciences* 14(3): 36-39.

Robinson, A. G. and S. Stern (1997). *Corporate Creativity: How innovation and improvement actually happen*. San Francisco, Berret-Kohler Publishers.

"Surveymonkey." Retrieved 16 November 2009, from http://surveymonkey.com.

van den Ende, J., K. Mulder, et al. (1998). "Traditional and modern technology assessment: towards a toolkit." *Technological Forecasting and Social Change* 58(17): 5-21.

7. Case Studies on Environmental Sustainability in Australia: A Multi-level Review

Alan R. Howgrave-Graham

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Case Studies on Environmental Sustainability in Australia: A Multi-level Review

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Abstract: Three surveys were conducted to determine uptake and/or implementation of environmental sustainability in Australia. A questionnaire was distributed to all of Australia's cooperative research centres (CRC's), and two university-based centres with an environmental sustainability focus, to evaluate implementation of environmental sustainability practises across Australia, especially in industries involving biotechnology in its broadest sense. Seventeen of the CRC's (a 35% response rate) and both '"sustainability" centres responded, with between eleven and fourteen CRC's indicating, using examples, that they conducted sustainable practises according to one or more of the three versions of environmental sustainability published elsewhere, as did both university-based centres. A previously published sustainability model was tested regionally in Latrobe Valley, Victoria using an open-ended questionnaire to eleven senior representatives from local and state government, academia, the main local natural resource-based industries and NGO's. These managers commented on the model's suitability in its current form and on ways that it could be improved for practical application at regional, state and/or national levels. At the state level, a semi-quantitative telephone survey was used to determine cleaner production uptake by 140 small to medium enterprises (SME's) in Western Australia. All the above instruments had a mixture of simple and open-ended questions and gave insight into the extent of environmental sustainability practises and attitudes in Australia while supplying suggestions on how they could be enhanced. These will be discussed in this paper as will a proposed new innovation model that incorporates stakeholder comments.

Keywords: Environmental Sustainability Initiatives, Cleaner Production Uptake, Australia, Innovation Model

Introduction

IN LIGHT OF the rapid increase in the world's human population over the past few centuries and the demand it creates on natural resources, it is imperative that these resources are used wisely and conserved for as long as possible. These resources include those that are renewable or recyclable and those that are considered to be in a 'fixed state' which would not end up in the earth's biogeochemical cycles without human intervention. These include oil, coal and minerals. Other human interventions to underpin developments include the manufacture of recalcitrant compounds such non-biodegradable plastic from petrochemicals, the skewing of the biogeochemical cycles by, for example adding fertilizers or dumping organic waste which, in turn affects the world's populations of micro- and macro-organisms. These are just the immediate effects of human intervention without even considering more controversial longer term effects of development such as global warming.

The need to develop, test and implement multi-disciplinary strategies and policies to progress towards more sustainable societies was recognised by Bonilla et al. (2009) among

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others. These authors, in concentrating upon sustainable development, reflected upon the complexity of such a mission. Every dimension has its own peculiarities which have to be accessed from a holistic point of view to integrate the parts and achieve permanent and positive results. They continued by pointing out sustainable development requires a new set of visions, paradigms, policies, methodological tools and applicable procedures and that each dimension must be thoroughly researched and solutions scientifically verified.

A good start in making development and practises sustainable would be to create a universally applicable model that could be applied on a national or even international level. There is a wealth of innovation literature to be drawn upon for this purpose and current trends include those embracing "open innovation" (Chesbrough and Garman, 2009; Dahlander and Gann, 2010; Lee et al. 2010) in which internal and external ideas (or product paths to market) are capitalised upon for growth, and those involving "continuous innovation" (Bessant, 2005) in which reflexive cycles are used to evaluate performance and improve on the basis of feedback. The literature often depicts the necessary interaction for innovation to occur as innovation models, often firm-based but more recently increasing incorporating more stakeholder involvement. One of these models is the triple helix model of university-industry-government relations by Etzkowitz and Leydesdorff (2000), a useful starting point for national sustainability models since Bonilla et al. (2009) among others recognised the crucial role of governmental rules and regulations to serve as a framework and catalyst for company leaders to move towards sustainable development and Waas et al. (2009) reported that academic institutions worldwide have increasingly embraced the sustainable development movement with opportunities lying in "university research for sustainable development".

Howgrave-Graham (2008) proposed an interdisciplinary knowledge transfer model to address shortcomings of the triple helix model as reported by other authors such as Bunders et al. (1999) and allow economies of scale to maximise academic and commercialisable outputs while conducting 'creative problem solving' for industry. Howgrave-Graham (2008) reflected upon how the focus of such sustainability 'problems' could be on the commercialisation of environmental technology such as building infrastructure to harness renewable energy; incorporating environmental considerations into developing new products through life cycle management and integration and incorporating recyclable materials; and improving existing products or processes such as by including cleaner production strategies – for which Howgrave-Graham and van Berkel (2007) identified there was a need among Australian SMEs. One issue that was not addressed was the need for environmental and ecological sustainability without incorporating development aspects. This became apparent from the identity of Cooperative Research Centre (CRC) respondents when the Howgrave-Graham (2008) model and its natural extension to incorporate the required knowledge networks described in Howgrave-Graham(2009) was tested for its practicality for policy development in a natural resource and fossil fuel dependent region (Latrobe Valley in Gippsland, Victoria). Three of the seventeen Australian CRCs that responded to the questionnaire discussed below would, by their names, have been focussed upon ecological sustainability.

This paper brings together three studies on the status of sustainability and sustainable development in Australia. The first study was on cleaner production uptake by small to medium enterprises (SMEs) in Western Australia (predominantly), South Australia and Queensland. A second study was on the nature of sustainability practises throughout Australia by its government-supported CRCs, as described in Howgrave-Graham and Galvin (2005) for the biotechnology industry; and thirdly, a more localised study on the suitability of the Howgrave-

Graham (2008) model. As a result of these studies and recent literature the previously described model is fine-tuned so that it can be applied as a practical framework to guide policymakers, current and future CRCs towards more successful sustainable development outcomes. The first study was used to gauge the level of SME innovation and thus whether there is a requirement for systems (underpinned by innovation models) to be put in place in Australia to facilitate improvement in this sector especially with respect to sustainability through cleaner production. The second study on CRCs was used to identify whether and how current cooperative systems embed sustainability into their practises while the third study was designed to draw comments from government, industry, NGO and university strategists on further improvements that can be made to the Howgrave-Graham (2008) model to better underpin advances in SME sustainability and that of the Australian economy as a whole. Each study will thus be discussed individually here and then a model proposed that brings together what has been learned from each of the projects.

Methods

Cleaner Production by SMEs. To determine the level of consideration and implementation of cleaner production by SMEs a structured telephone interview had been conducted by Howgrave-Graham and van Berkel (2007) on a sample of 428 drycleaners, printers and bookbinders, food-related industries and ship/boat builders extracted from the yellow pages. Telephone surveys were used in preference to mail surveys due to the low and selective response rates and socially-preferred bias (respondents saying what they think the surveyor would like to hear) expected from the latter. The method is described in more detail in Howgrave-Graham and van Berkel (2007), where it was used to develop an assessment method for wider application. Note that respondents were asked what innovations the business had implemented "to improve efficiency and cut costs" early in the telephone interview to allow any sustainability or cleaner production initiatives to emerge (if present) before the topic was raised, thus preventing socially-preferred bias. Published and unpublished information from that study is used here to complement the two other studies about to be discussed.

Sustainability and Sustainable Development by CRCs. For the second study, to determine the composition and activity of Australian CRCs, http://surveymonkey.com was used to distribute on-line questionnaires to the contact people listed on http://www.crca.asn.au/print/709for each of the forty-nine CRC's (in existence in December 2009); and two Australian university-based centres with a mandate to drive industry sustainability and sustainable development. The findings of this questionnaire in terms of the composition, age, activities of the centres was published in Howgrave-Graham(2010) and related to their roles in development (regional or otherwise) and productivity (academically and towards commercialization). A few open-ended questions on each centre's objectives, barriers to achieving these and how the global financial crisis had affected their activities were also described. Although sustainability was fairly extensively investigated in the above survey, it was only briefly touched upon by Howgrave-Graham (2010). CRC and centre sustainability initiatives will be more extensively described in this paper. Findings determined through closed and open-ended questions on their role in sustainability are described in terms of the three prongs proposed by Howgrave-Graham (2008), namely:

- what proportion of their activities could be considered to be commercialization of environmental technology,
- what proportion incorporates environmental considerations into developing new products,
- or are projects designed to limit the environmental impact of existing products or processes, such as cleaner production.

Respondents were also asked the proportion of their activities that were designed to directly conserve natural environmental resources. These sustainability activities were related to other centre properties as determined through the questionnaire.

Development of a New Sustainable Development Model. To determine the regional suitability of the Howgrave-Graham (2008) sustainability model for Latrobe Valley, Gippsland and Australia, a written questionnaire was submitted together with two publications (Howgrave-Graham, 2008; Howgrave-Graham, 2009) depicting the model and its knowledge networks for evaluation by leaders at a Latrobe Valley (Gippsland) university and senior representatives from local and state government, NGO's and Latrobe Valley's three main resource-based industries. The latter were major role players related to water supply and the processing of coal or timber. According to Latrobe City's Natural Environment Sustainability Strategy 2008-2013 (Latrobe City, 2008), power and water represent 54% of the region's exports and 26% of its gross revenue. The questions were mostly open-ended and, in some cases, followed up with interviews to clarify questions or responses. The positive attributes of the model and hurdles that needed to be overcome for their successful implementation on a regional or national level determined. Additional aspects related to biotechnology, CRC activity in Gippsland and Latrobe Valley were explored and reported in Howgrave-Graham (2010). In light of these comments and recent relevant publications, the model has been modified in this paper to propose a more workable one for sustainable development. Ethics approval was obtained for the surveys from the Monash University Human Research Ethics Committee (Project number CF09/1829-2009001037).

Table 1: The Three Australian Studies and Further Relevant Reading

Study and Method	Purpose	Further Reading
1.Cleaner Production by SMEs. Telephone survey	To determine the level of innovation (in cleaner production) by SMEs and the role of networking	Altham (2006) Howgrave-Graham and van Berkel (2007)
2. Sustainability by CRCs. On-line survey	To determine to what extent sustainability and innovation is incorporated into CRC practices, and identify key roleplayers	Howgrave-Graham (2010)
3. Model testing by strategists from different sectors. Paper-based survey to influential group, mainly open-ended questions	To identify regional and nationally relevant shortcomings of earlier models and suggest improvements	Howgrave-Graham (2010)

Table 1 is a summary of the three studies and their methods and purpose. Information obtained from the surveys was used to determine whether there is a need for greater sustainability innovation and a new innovation model and to identify and address flaws in previous innovation models. This would allow development of the new model proposed here. The references cited in table 1 give more data and information to support some of the arguments made here.

Results and Discussion

Cleaner Production by SMEs. As reported by Howgrave-Graham and van Berkel (2007), of the 428 SME CEOs contacted, 140 agreed to be interviewed, a response rate of 32.7%. Scores awarded for cleaner production: awareness (related to an understanding of cleaner production and eco-efficiency); management (CEO knowledge of his/her accounts and the existence of an environmental management policy or plan); and implementation (innovations aligned with cleaner production or eco-efficiency) were uniformly low (only one score was higher than 50%). These results confirm observations by Bonilla et al. (2010) and Giorgio et al. (2009) that cleaner technologies and cleaner production are diffusing comparatively slowly through industry despite it being known that their implementation has had great benefits in systems where they have been implemented. On the other hand, it raises the question of the suitability of the survey instrument used by Howgrave-Graham and van Berkel (2007), and its findings. These authors reported the difficulty of devising a suitable assessment method as one is trying to measure what "no longer exists (i.e. the avoided waste stream or resource consumption)" and cited other authors' findings that, despite their errors that were being avoided by using a telephone interview, cleaner production practises were still being reported as under-utilised by SMEs. The three main shortcomings of the assessment method described in Howgrave-Graham and van Berkel (2007) are:

- Its subjectivity – in this study qualitative data from open-ended questions were evaluated by a panel of two experts (the authors) and converted into quantitative data.
- The obvious discrepancy between scores for the majority of SMEs (irrespective of sector) and the small group of drycleaner SMEs that had participated in a cleaner production program (see Altham, 2006), with those having been introduced to cleaner production programs scoring much higher.
- Its initial open-ended questions being too vague – asking what innovations implemented to improve operation efficiency and cut costs (and then being restricted to five examples) would allow early emergence of e.g. cutting staff but the sixth innovation to be reported may be a significant cleaner production one.

To overcome the first and third shortcomings above, the questionnaire to CRCs (to be discussed next) took the approach of embedding more specific questions with a quantitative response (e.g. how many projects…) and requesting an example (to reflect whether the respondents understood the terms and the question). Despite the above problems, the Howgrave-Graham and van Berkel (2007) study confirms, for Australian SMEs, the findings by others that cleaner production uptake is below optimal, despite authors such as Zeng et al. (2010) reporting that the business performance of firms is positively impacted if cleaner production is adopted. These authors reported that low-cost schemes had a greater contribution to financial performance whereas high-cost schemes made a greater contribution to non-financial performance such as corporate reputation and shareholder confidence.

Cleaner production is a key tool for driving sustainability and sustainable development and grouped with other "existing product or process improvement to limit environmental impact" in the next section and to a lesser extent with "incorporating environmental considerations into developing new products".

Sustainability and Sustainable Development by CRCs. Howgrave-Graham (2010) reported that eleven of the seventeen CRCs indicated that they conducted commercialisation of environmental technology, one indicating that is was between 81 and 100% of its activities (this is no surprise, considering the name and objectives of this CRC), while another indicated 61-80% of its projects targeted commercialisation of environmental technology and another reported that 41-60% of its projects targeted this initiative (as a condition of ethics approval, the identities of specific respondents may not be revealed). Additional information from the survey not reported in Howgrave-Graham (2010) indicated that the remainder of CRCs that responded positively to this question targeted environmental technology initiatives in between 1 and 40% of their activities while the remaining CRCs indicated either no activities along these lines or did not respond to this question. Examples given of such activities included increasing profitability of its specific 'livestock' industry and its contributions to the economy of many parts of rural Australia (depending upon the activities, it is debatable as to whether this could be considered "commercialisation of environmental technology"). Other activities are more clear-cut, such as "automotive hybrid development", "lightweight automotive structures" and "granulated biomass". Of the two university-based centres, only one targeted commercialisation of environmental technology with this comprising about 60% of its activity, the example cited being "treatment of industrial wastewater for reuse". Again this would depend on the whether the technology involves novel intellectual property. It should be noted that biotechnology in its broadest sense "the manipulation of living organisms for gain" is quite strong here and example of commercialisable environmental biotechnology are reported by the Environmental Biotechnology CRC (2007) and the CRC for Contamination Assessment and Remediation of the Environment (2007).

Howgrave-Graham (2010) reported that eleven respondents (this figure included the two university-based centres) indicated that they incorporated environmental considerations into developing new products (one each indicate that this was involved in 41-60, 61-80 and 81-100% of their activities). Unreported examples given for this initiative included genetics vs. environmental interactions (suggesting biotechnology in the form of breeding or genetic engineering to produce less damaging/hardier stock); replacement of cyanide in gold processing, using organic green waste for compost medium (environmental biotechnology), compelling all projects to undergo life cycle analyses, waterproofing cardboard, incorporating waste paint into concrete, improved forestry practices and various by-product research.

Fourteen centres (including both university-based centres) responded to the question on what proportion of their projects are designed to limit the environmental impact of existing products or processes, such as cleaner production, all fourteen (including both university-based centres) indicated that they had consideration for this sustainability initiative: two reflected that 81-100%; one each indicated 61-80 and 41-60% of their projects considered this initiative while three indicated 21-40%. Unreported examples given here were "best management practises", "methane reduction", "mineral processing tailings management", "reduced water and energy used in metal plating", lower carbon emissions, industrial symbiosis research, bioenergy from biosolids, efficient nitrogen use by plants, reduced feed and energy use, increasing transport efficiency and improved food processing.

Responses to questions on the last two approaches of sustainable development as described by Howgrave-Graham (2008) are promising, in light of the examples given, and reflect that cooperation within CRCs result in positive environmental outcomes beyond the commercialisation ones for which most of them were set up. This study was probably more revealing than the SME cleaner production one as the relevant questions were more specific and requested practical examples of implementation for verification.

The final sustainability question in this survey revealed that six centres (including the two university-based ones) were directly involved in protecting environmental resources. For two, this represented 21-40% of their activity, while one each indicated that this was incorporated into 41-60 and 61-80% of their projects. This question was less revealing as it was open to interpretation and could be better phrased to exclude the above sustainability initiatives and incorporate natural habitat "conservation" or "management" and a suitable description. With this in mind, two of the CRCs that did not respond to this question would, by their name, be included and others excluded.

Sustainability by CRCs has been discussed above at some length but sustainable development, defined by Brundtland (1987) as "development that meets the need of the present without compromising the ability of future generations to meet their own needs" has not been dealt with in any detail although the three sustainability approaches discussed in Howgrave-Graham (2008) and related to CRC activities above does include initiatives in which this is a consideration. It should be noted that all of the CRCs indicated that their projects have, or will lead to development. Insight Economics(2006) attempted to put a figure on the economic impact of the entire CRC programme and indicated that a "best estimate" was that Australia's gross domestic product (GDP) was $2,554 million higher as a result of investment in CRCs than if the investment was left with taxpayers (such as through tax deductions). It was also estimated that, by 2010, the CRC programme would have increased the GDP to $2,877 million above that expected if the funds were left with taxpayers. This growth may have been hampered by the financial crisis which reportedly affected all respondents to this survey through a lack of demand for their products, reduced capital and investment in R&D, risk aversion by investors, businesses withdrawing or work pressures on members. This further emphasises the need for a robust model to underpin the creation of new CRCs and support the sustainable growth of existing ones. All potential opportunities must be identified to enhance survival and growth of such collaborative ventures.

This study was extremely rich in data and, despite this being the second paper on CRCs using a single detailed questionnaire, revealed enough information to be able to relate the productivity and environmental performance of CRCs to their size, age, activities, funding models and composition but this the topic of another study.

Development of a New Sustainable Development Model. As discussed, innovation models have evolved to reflect current and emerging trends and the triple helix model is an early one to reflect university-government-industry interactions to allow innovation and technology development and diffusion to benefit all participants. However, many authors have reported shortcomings of the model (discussed by Howgrave-Graham, 2008 and addressed in his model). More recently, one of the triple helix model developers (Leydesdorff) reported in Park and Leydesdorff (2010) how the model can become dysfunctional, such as happened in South Korea when pressure by the government was put on academics to increase publications in prestigious journals. This resulted in a breakdown in university-industry relations and a potential drop in commercialisation productivity. Such a scenario was anticipated in the Howgrave-Graham (2008) model which is why economies of scale and serendipity are promoted in such a way that solving an industrial problem coincides with the generation of publications by academia and hopefully a new product and spin-off company can emerge due to an unexpected opportunity emerging (such as suggested in the open innovation literature). This model has worked well for this author in his research in environmental biotechnology but not all projects or circumstances are the same. That is why the model was tested on senior managers (at strategic levels) of the main industries, government departments, NGOs and the local university in a resource intensive region in Australia. Table 2 reflects the stakeholder responses on the suitability of the Howgrave-Graham (2008) sustainable development model for application in Australia nationally and regionally. Of the industry respondents in table 2, one indicated that the model was suitable for Gippsland and Latrobe Valley but not for Victoria or Australia and one believed the reverse to be true. Only one university respondent felt that the model could be applied universally in Australia but the remaining two indicated that it could work if it were "tweaked" as the model reflected only "part of the answer", an issue that this study aims to address. One NGO indicated that the model could not work but then indicated that it was applicable for all of Australia and the regions listed in table 2, explaining that, although it is a good model, putting into practice was difficult because of graduates leaving the region, the time constraints on academics and university not marketing itself well enough. The other NGO respondent indicated that the model was applicable for Latrobe Valley and Gippsland (especially if feedback was incorporated) but the rest of Australia has different situations and challenges.

Table 2: Results from Testing of the Howgrave-Graham (2008) Sustainable Development Model in Latrobe Valley, Gippsland

Sector	Number of Respondents	No. Respondents Indicating that the Model would Work for:			
		Latrobe Valley	Gippsland	Victoria	Australia
Government	3	2	3	3	3
Industry	3	1	1	1	1
University	3	1	1	1	1
NGOs	2	2	2	1	1
Total score	Max = 11	6	7	6	6

Comments by the above stakeholders were incorporated into the model to rather make it an innovation framework that could underpin applications for the creation of new CRCs in Australia. It would also allow existing ones to monitor their activities, ensuring that all opportunities are identified and capitalized upon, especially for sustainable development.

Howgrave-Graham (2010) reported additional concerns on the applicability of Howgrave-Graham (2008) model as being that senior local and state government respondents believed that the model could work (except for one government representative who felt that it is "too top heavy" and focuses too much on university outcomes). Some observations were that Gippsland industries have the opportunities and recognize the need for innovation, the skills base in the region is present and, with greater stakeholder (especially university) involvement can address the challenges of climate change and water security. All three government respondents identified the need for a local champion in the region and two indicated that local university should strengthen relationships and trust between it, NGO's, industry and the public sector.

Several suggestions were made on how to make the model work at especially a regional level. One government representative indicated the following requirements: it should be mandatory for local university funding applications to be developed in partnership with industry and/or public sector bodies, there should be improved relationships and alliances between university industry and external agencies, it should be mandatory for committee/advisory boards to exist with external agency involvement, research should be based upon industry needs, faculties need to align and strengthen with opportunities. The model was indicated to be a good one for universal application but it was felt that "Gippsland has a long way to go making this model a success!" The other two government managers made similar suggestions but added that all stakeholders should be closely engaged, better trust and communication from university is required and one suggestion was to bring in a specialist with commercial experience to identify industry need and university capability match. Other suggestions were to appoint a champion to promote the model and provide the mechanism to link stakeholders and the requirement to adhere to timelines. One government representative felt it was a good model for overall application but that it was too early to implement it in Latrobe Valley as the "Power industry is not well placed economically to listen to the argument. Maybe in 1-2 years dependent upon government drivers, CPRS (sic) and economy". A carbon price is expected to be a driver for change in the brown coal industry.

All three industries did not believe the sustainability model proposed in Howgrave-Graham (2008) could work because financial (especially of R&D and sustainability issues), capital investment and intellectual property issues are not adequately addressed (one government respondent felt, however, that funding was adequately addressed). One industry believed that the R&D skills were absent from the region and another indicated that "universities are notoriously inefficient in delivering projects in a realistic timeframe". One industry believed that the model did recognize the importance of partnerships and networks and the value of "cross-subsidisation" as well as the value of university and commercial outcomes.

As reported by Howgrave-Graham (2010), one NGO representative and one industry indicated that feedback was absent in the model such as back to government or industry while both NGO representatives believed the model could work in Gippsland, one indicating that it was "only part of the answer" (government research stations and independent industry research also contribute). The other NGO respondent (also a university employee) indicated that it implies university staffing with the skills and time to get out into the field and "extract problems" from potential customers. An NGO confirmed government's requirement for universities to become more visible, or regional champions. One NGO believed that the sustainability model in Howgrave-Graham (2008) could not work because NGO's are not aware of university capabilities which are perceived as being "teaching only". The NGO's confirmed government concerns that local universities need to increase their visibility and promote their capabilities. It was recognized that people were often too busy to do it, a point made by a university respondent who added that many staff do not have the skills or time to conduct industry type consultancy, resulting in consultants being employed instead.

Two of the three university staff managers indicated that the models could only work for certain projects and confirmed the top-down and university-driven concern by an industry and a government respondent. One university respondent indicated that the models could have additional applications if university funded the research and/or industry had an interest in basic research, and another pointed out that the starting point usually is industry developing a product or service. Many of these issues have been reported in Howgrave-Graham (2010) together with less significant ones but there was enough information to modify the model to address the main concerns with the other operational ones to be addressed in on a project-by-project or CRC-by-CRC basis. As such, the model in figure 1 represents a framework which could be used to devise an innovation strategy to simultaneously support commercialization and basic research while addressing sustainability issues that may be raised by stakeholders outside the government-university-industry partnership of the triple helix.

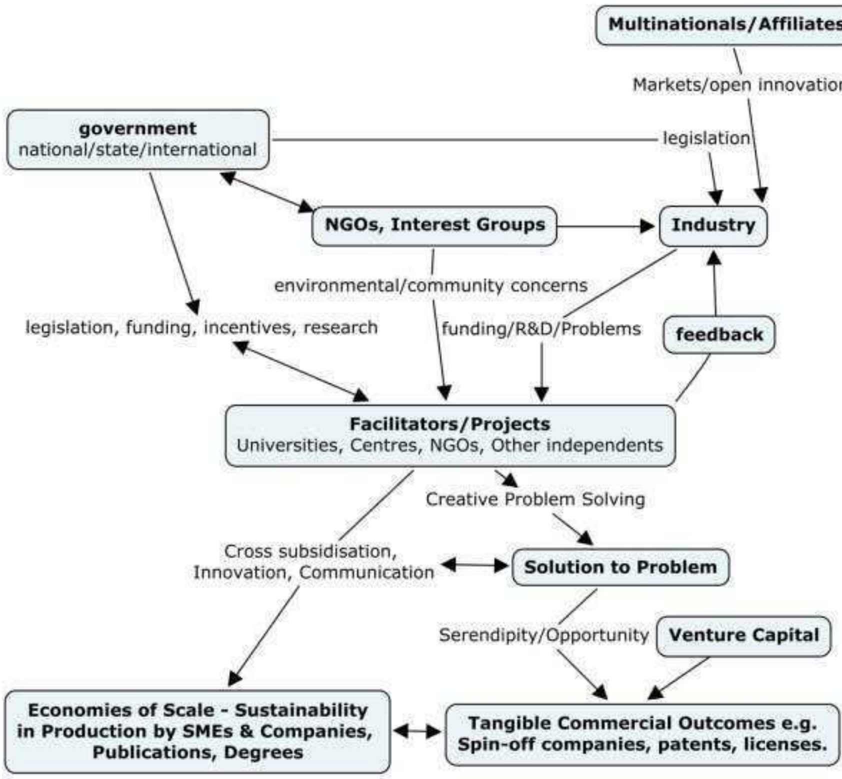

Figure 1: A Stakeholder-driven Innovation Model for Sustainable Development

Figure 1 is a modification of the one depicted in Howgrave-Graham (2008) which addresses shortcomings of the triple helix model and incorporates information gleaned from the three studies of this paper. The low level of sustainability innovation by SMEs in Australia was identified here and by Howgrave-Graham and van Berkel (2007), while Altham (2006) and the cleaner production study described here identified the importance of networking which is thus retained for the model in figure 1. This observation was further confirmed in the CRC investigation as cooperation within these centres clearly incorporated all aspects of sustainability as discussed in Howgrave-Graham (2008). Networking is thus clearly important for sustainable development. The misgivings of senior strategists drawn from the main stakeholders canvassed for this study was also addressed as the Howgrave-Graham (2008) model has now been modified to reflect the replacement of "universities, faculties, centres" with "Facilitators/Projects", including universities, centres, NGOs and other independents as central role players due to concerns expressed about the added responsibility of universities in sustainable development. Such a change was supported by the fact that most of the CRC innovators were actually from outside the university sector. The above model also reflects concerns by the diverse strategists in the third study of this paper that funding had not been adequately addressed (venture capital has now been added to the model), that government research stations had not been included (now reflected as one of the government roles), that independent industry research was not recognised (multinationals and affiliates are now added to partially reflect this plus the more recent trend towards open innovation). The third survey of diverse strategists also reflected that the Howgrave-Graham (2008) model did not adequately reflect feedback to e.g. government from NGOs. The arrows in figure 1 have now been drawn bi-directionally to address this issue.

The interests of a wider group of stakeholders have now been incorporated in the model as has feedback to them. The university, despite government indicating that it should be given a pivotal role in promoting sustainable development, has been listed as only one of the potential facilitators because of the CRC "champions/innovators" less than 10% were from universities with a clear majority being individual businesses, farms or companies (Howgrave-Graham, 2010).The role of intermediaries/facilitators and partnerships is important for successful innovation diffusion as explained by Kirkels and Duysters (2010) and Lee et al. (2010) for SMEs, confirming Howgrave-Graham and van Berkels (2007) findings with drycleaners brought together by a university centre for cleaner production.

As indicated by government respondents to the questionnaire evaluating the model in Howgrave-Graham (2008), university should be more pro-active in driving sustainable development. Ways to achieve this are by promoting the expertise on campus, aligning better with industry needs and increasing its experience by taking on such projects and ensuring that the outcome is successful as Bruneel et al. (2010) determined that trust through prior experience of collaborative research lowers barriers to future collaborations. The issue of time to do so considering other commitments such as teaching, as revealed by one university respondent, and the pressure from government to publish in prestigious journals as reported by Park and Leydesdorff (2010) as being detrimental to successful implementation of the triple helix model in South Korea are concerns. As suggested by a government respondent, this could be overcome by appointing someone able to identify university-industry (or other organisation) synergies and complementarities at a regional level.

Figure 1 is an open innovation model in which external knowledge is either tacit, and thus available to all, or is imported via multinationals or other overseas affiliates that may want to have R&D conducted on e.g. carbon sequestration locally. In exchange, knowledge is made available tacitly, to external stakeholders, or exported into a new start-up business such as an ecopreneur (Pastakia, 1998) if an environmental innovation is to be commercialised. This model supports Lee et al. (2010) in that the focus is on technology exploitation (discovered as serendipity from creative problem solving) as preferred by SMEs, rather than technology exploration typical of larger organisations doing R&D for high technology product development.

Table 3: Modifications to the Howgrave-Graham (2008) Model and the Studies Precipitating these Changes

Change	Study Responsible
1.More extensive networking and feedback	1.Cleaner Production by SMEs 2. Sustainability by CRCs 3. Model testing by strategists from different sectors
2.Less university-centred	2. Sustainability by CRCs 3. Model testing by strategists from different sectors
3. Incorporation of more stakeholders such as venture capitalists, multinationals and affiliates	3. Model testing by strategists from different sectors
4. Greater role for government and NGOs	3. Model testing by strategists from different sectors

Table 3 summarises improvements made to the earlier Howgrave-Graham (2008) model for sustainable development. Although a great improvement on previous innovation models, problems anticipated in implementation are those highlighted by Geels (2010) in which sustainability transitions are hampered by conflicting goals and interests resulting in a power struggle with dominant forces using a variety of means to protect their interests. He reports that many unsustainable industries have many economic resources and good political contacts which may hinder, delay or water down strict environmental regulations. This may have contributed to a government respondent's opinion that, although the rest of Australia is ready for the previous version of figure 1, Latrobe Valley is not yet. The greater role of other stakeholders such as NGOs (including conservation groups) depicted figure 1 hopefully will overcome dominance by any group while Geels (2010) reports that overarching environmental goals such as the Kyoto protocol should assist in their translation into policy instruments. Potts (2010) took this one step further in listing environmental policy frameworks, emerging markets for products and services, local and regional innovation strategies and knowledge as drivers in his "natural advantage model" for integrating innovation, sustainability and regional development. The "natural advantage model" unfortunately does not list the stakeholders or accountable parties and has the added disadvantages of not mentioning existing markets (such as those for products to reduce power distribution costs, or for cleaner production) and appearing too top-down (a danger highlighted by Brannback et al. (2008) and confirmed for Australia on the basis of the high number of individuals or businesses that were listed as innovators/champions in CRCs). These issues are addressed in figure 1.

If the figures of Insight Economics (2006) on the economic impact of the CRC programme on Australia's GDP were extended through the creation of more CRCs, the improvement to the economy would be significant, especially considering that the Commonwealth of Australia (2008) reported that only a small fraction of all Australian firms have participated in CRCs. Figure 1 reflects a framework within which such development could be done sustainably. According to Potts (2010), in discussing two Australian regions, there are some local attempts to increase the dialogue between communities, local businesses and universities around innovation and the environment, a promising sign as is Latrobe City's (2008) release of a natural environmental sustainability strategy for 2008 to 2013.

Conclusions

From the first study it was determined that SMEs have a long way to go in Australia to fully embrace cleaner production knowledge into their enterprises. CEOs awareness of their utility accounts was their strongest point but they had a poor knowledge of cleaner production and eco-efficiency. Few of their recently implemented innovations incorporated cleaner production principles and exposure to a cleaner production working group through a university intermediary delivered positive results. However, a telephone survey with questions that were too 'open-ended' may have skewed results, reflecting poorly upon the businesses – it would be better to measure actual cleaner production as improvement over a period of time. There is thus scope for improved SME innovation and a model is proposed here that could facilitate it through greater collaboration.

The second study identified that Australian CRCs, in addition to the positive economic impact reported elsewhere for the country, were aware of sustainability practises and were incorporating some innovative ones into their development activities. Most of their champions/innovators were, contrary to expectations, not government or universities but individuals or discreet businesses. This has been built into the new model depicted in figure 1. As in the cleaner production study discussed in the previous paragraph, the benefits of collaboration driven by a champion/innovator was evident.

A new model was derived and depicted in figure 1 to represent a framework most likely to succeed for sustainable and regional development as it has addressed all of the issues raised by previous authors on, for example the triple helix model, and by a wide range of regional stakeholders. A major contribution towards development of this model was input from a wide range of strategists canvassed for the third study in which previous published models were tested. The next step would be to set this framework up in such a way that new CRCs or collaborations with government support can determine that all stakeholders have been identified (with their roles and input), all variables and scenarios anticipated and sustainability issues addressed. Also important is that a procedure has been put in place to ensure continued stakeholder support and the detection of new opportunities through serendipity that arise from the academic output and creative-problem solving initiatives. As mentioned by one respondent, not all projects are the same but figure 1 addresses all the issues that should be considered and in many cases can be discarded, such as whether NGO involvement is required when relatively harmless projects are conducted.

An example of how this model could be applied practically is a project in which academics collaborate with industry (the facilitator) using government finance. The aim is for carbon dioxide pollution to be sequestered by algae which are digested anaerobically to generate methane which is burned for energy, the carbon dioxide again trapped by algae etc. Such a project, if a carbon tax were imposed, would be an opportunity for cleaner production to be applied in coal power generation and would supply three products, namely algae (used for other purposes besides renewable energy generation), partially purified water and biogas energy. Publications, post-graduate degrees and employment are other spin-offs and, depending upon the siting of the infrastructure, community and NGO concerns should be negligible. Environmental biotechnology especially lends itself to application of the model and other projects or collaborations should be considered on a case-by-case basis.

References

Altham, W. (2006). Benchmarking to trigger cleaner production in small businesses: Drycleaning case study. *Journal of Cleaner Production*, *15*, 798-813.

Bessant, J. (2005). Enabling continuous and discontinuous innovation: Learning from the private sector. *Public Money and Management, January*, 35-42.

Bonilla, S. H., Almeida, C. M. V. B., Gianetti, B. G., & Huising, D. (2010). The roles of cleaner production in the sustainable development of modern societies: An introduction to this special issue. *Journal of Cleaner Production, 18*, 1-5.

Brannback, M., Carsrud, A., Krueger, N., & Elfving, J. (2008). Challenging the triple helix model of regional innovation systems: A venture-centric model. *International Journal of Technoentrepreneurship*, *1*(3), 257-277.

Brundtland, G. (Ed.). (1987). *Our common future: The World Commission on Environment and Development.* Oxford: Oxford University Press.

Bruneel, J., D'Ester, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university-industry collaboration. *Research Policy*, *39*, 858-868.

Bunders, J. F. G., Broerse, J. E. W., & Zweekhorst, M. B. M. (1999). The triple helix enriched with the user perspective: A view from Bangladesh. *Journal of Technology Transfer*, *24*, 235-246.

Chesbrough, H. W., & Garman, A. R. (2009). How open innovation can help you cope in lean times. *Harvard Business Review*, *December*, 68-76.

CRC for Contamination Assessment and Remediation of the Environment. (2007). Biosensors to probe the metals menace. *Australiasian BioTechnology*, *17*(4), 10-12.

CRCs - the Cornerstone of Australia's National Innovation System. Retrieved 2 December 2009, from http://www.crca.asn.au/print/709

Dahlander, L., & Gann, D. M. (2010). How open is innovation? *Research Policy*, *39*, 699-709.

Environmental Biotechnology CRC. (2007). A cleaner, greener, whiter future. *Australasian BioTechnology*, *17*(4), 5-8.

Etzkowitz, H. (2002). *The triple helix of university-industry-government implications for policy and evaluation.* Stockholm: Science Policy Unit.

Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy*, *39*, 495-510.

Giorgio, D., Ferenc, F., Donald, H., & Jaromir, K. J. (2009). Cleaner energy for sustainable future. *Journal of Cleaner Production, 17*, 889-895.

Howgrave-Graham, A. R. (2008). An interdisciplinary knowledge transfer approach to facilitate sustainable development: Australia as an example. *The International Journal of Environmental, Cultural, Economic and Social Sustainability, 4*(4), 11-16.

Howgrave-Graham, A. R. (2009). An innovation and development model for regional university campuses. *The International Journal of Technology, Knowledge and Society, 5*(1), 76-88.

Howgrave-Graham, A. R. (2010). The composition and productivity of Australian cooperative research centres, with emphasis on their participation in biotechnology, regional and sustainable development. *The International Journal of Technology, Knowledge and Society, 6*(3), 67-81.
Howgrave-Graham, A. R., & Galvin, P. (2005). Cooperative research centres and industrial clusters: Implications for Australian biotechnology strategies. In A. G. Rainnie, M. (Ed.), *New regionalism in Australia* (Vol. 1, pp. 87-102). Aldershot, England: Ashgate Publishing Limited.
Howgrave-Graham, A. R., & van Berkel, R. (2007). Assessment of cleaner production uptake: Method development and trial with small businesses in Western Australia. *Journal of Cleaner Production, 15*, 787-797.
Insight Economics. (2006). *Economic impact study of the CRC Programme*. Melbourne: Australian Government Department of Education, Science and Training.
Kirkels, Y., & Duysters, G. (2010). Brokerage in SME networks. *Research Policy, 39*, 375-385.
Latrobe City. (2008). Latrobe City's Natural Environmental Sustainability Strategy 2008-2013. Retrieved 16 November 2009, from http://www.latrobe.vic.gov.au/webfiles/council/services/sustainability
Lee, S., Park, G., Yoon, B., & Park, J. (2010). Open innovation in SMEs - An intermediation network model. *Research Policy, 39*, 290-300.
Park, H. W., & Leydesdorff, L. (2010). Longitudinal trends in networks of university-industry-government relations in South Korea: The role of programmatic incentives. *Research Policy, 39*, 640-649.
Pastakia, A. (1998). Grassroots ecopreneurs: Change agents for a sustainable society. *Journal of Organisational Change Management, 11*(2), 157-173.
Potts, T. (2010). The natural advantage of regions: linking sustainability, innovation, and regional development in Australia. *Journal of Cleaner Production, 18*, 713-725.
Surveymonkey. Retrieved 16 November 2009, from http://surveymonkey.com
Waas, T., Verbruggen, A., & Wright, T. (2010). University research for sustainable development: definition and characteristics explored. *Journal of Cleaner Production, 18*, 629-636.
Zheng, S. X., Meng, X. H., Yin, H. T., Tam, C. M., & Sun, L. (2010). Impact of cleaner production on business performance. *Journal of Cleaner Production, 18*, 975-983.

8. Conclusions

This thesis starts with an overview of innovation, which is the main topic to permeate throughout, whether in biotechnology, or for sustainability or regional and national development. The history leading up to the latest innovation theories and models (and model applications) was compiled and reasons discussed for considering this study to be one of Science, Technology and Innovation (STI) policy research, specifically for economic growth (STIG) as described by Aghion, David and Foray (2009). As expanded upon in the introduction this is a broad field as many aspects can be investigated as can be seen by the wide range of examples cited by Morlacchi and Martin (2009). This study started with a review of the relevant literature to describe the status of knowledge networks (Cooperative Research Centres (CRCs) and clusters) and policies to underpin biotechnology innovation in Australia (chapter 2[1]). The next study was a telephone survey to determine the level of small to medium enterprise (SME) innovation with emphasis on their sustainability practices, in preparation for the STI policy studies on sustainability more in line with those of Nill and Kemp (2009) and Potts (2010). Although the next two chapters in this thesis predate the papers of these authors, they were novel in that policy models and associated knowledge networks were proposed to address previously reported shortcomings of earlier published models and were underpinned by the preceding two chapters. The models depicted here were distinct due to incorporation of greater stakeholder involvement but still needed testing to more rigorously comply with the aim of STI policy research namely to serve the ends of society by helping to construct more effective policy tools for STI, as suggested by Morlacchi and Martin (2009).

[1] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59

The final two papers in this thesis were directed at building upon the earlier models proposed in this thesis by testing them and developing a practical framework for wider application towards innovation in sustainable and regional development. To develop such a policy guidance tool, a wide range of stakeholders were canvassed to determine (in the case of CRCs) their innovation practices and outcomes, and (through regional stakeholders) the suitability of the models previously proposed here for national and regional sustainable development. Comments gleaned through the relevant surveys were used to finalise a model (figure 1 in this chapter) that incorporates greater stakeholder involvement, feedback and funding sources. This would allow its wider application as a policy guidance tool (or map) than previously published models. The introduction of entrepreneurs and innovators and their roles as facilitators or intermediaries in the final model is highlighted but universities, due to stakeholder comments, were downgraded from being central in this role to being only one of several possible innovators or entrepreneurs in the final model. This is thus a progressive study in which each chapter leads to the next one with new information emerging from the literature being added as it emerges to underpin and further hone the following material.

Although chapter 6[1] refers to the "European Paradox" as applicable in Australia due to a low number of firms (570) participating in CRCs, reference was made to Insight Economics (2006) in chapter 5[2], reflecting that Australia's GDP was increased by $2,877 million above that expect if the funds were left with taxpayers. The fact that such a high national reward was generated by a small proportion of Australian firms indicates that huge gains can be made by increasing the participation rate. This is why this thesis has concentrated on ways to better capitalise on Australia's innovation capacity. Collaboration along the lines of the

[1] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[2] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105

triple helix model for university-industry-government cooperation discussed in most chapters of this thesis is the key. However, authors have identified shortcomings of this model to include under-emphasis or the lack of involvement of other stakeholders such as NGOs, funding organisations, or other potential innovators.

Improved models were proposed here to enhance innovation for regional and sustainable development. These models were published in chapters 4 [1]and 5[2] and were adapted from the triple helix model to address shortcomings indicated in the literature and incorporate this author's experiences in environmental microbiology and the diversity of projects conducted for regional and sustainable development. Chapter 1[3], figure 3 reflects the author's understanding of the triple helix model as proposed in the literature whereas subsequent models in the thesis depict and explain improvements upon previously published models such as opportunities for economies of scale that allow serendipity to increase both academic and commercialisable outputs identified while conducting creative problem-solving. A key component of these models is identification of the necessity to collaborate, not always easy when this is between competitors, but extensively endorsed in the literature. Improvements in performance as a result of such collaboration are clearly demonstrated in chapter 3 in which SMEs that participated in a cleaner production group were better at this activity.

Chapter 3[4] was an interesting scoping exercise in which SMEs in competitive industries were questioned on their innovations with special focus on cleaner production for sustainability. In this chapter, a clear distinction was found between those in the dry cleaning industry that did cooperate using an intermediary (Centre of Excellence in Cleaner Production) and those that

[1] Innovation and Development Model for Regional University Campuses, p.93
[2] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105
[3] Literature Review
[4] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80

did not. This raised the issue of suspicion preventing collaboration, making the presence of an intermediary such as a university important once there is trust in its impartiality. For this reason, university faculties and centres were drawn centrally in the models proposed in this thesis as they would be able to draw competing firms together and capitalise on government funding to advance their own regions economically. This idea is not new and facilitation for innovation has been extensively covered in the literature. However, putting it in the Australian context and identifying how all participants can benefit from interactions is novel; as is the incorporation of the "lucky accidents" or serendipity by realising other unexpected commercialisable opportunities while conducting creative problem solving for industry or government. Throughout this thesis, achievable examples which fit within the description of open innovation (the latest development in innovation modeling) are given. Although chapter 3 [1]gave useful insight to this thesis on the need for innovation to be enhanced within Australian SMEs and the great benefits of collaboration, it did hint that universities should be the active drivers of innovation. This was shown to be false in subsequent chapters and the model proposed in chapter 7 [2]modified accordingly. This highlights a point made regularly throughout the thesis that the innovations should be approached on a case-by-case basis. Cleaner production implementation is expected to garner different stakeholder responses than, for example, introduction of genetically modified organism cultivation or waste treatment facility placement. The models proposed are intended as best-fit guidelines to follow in the implementation of any innovative technology. The perils of using earlier innovation models are clearly portrayed in the literature review (and other relevant chapters) with examples to illustrate how things can go wrong, at great cost.

[1] Cleaner Production Uptake Assessment: Trial with Small Businesses, p.80
[2] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

This thesis identifies benefits that collaborative systems of innovation and knowledge sharing can have for business, whether SMEs or larger firms that could absorb knowledge on the latest technology from both competitors and collaborators without divulging their own intellectual property. SMEs could, for example, share knowledge on cleaner technologies without divulging their customer base or marketing strategies. Other beneficiaries are the regions where employment in new spin-off companies to capitalise on innovations would create employment, indirectly benefiting government and GDP growth. Universities, especially in regional areas would benefit because the academics would obtain the funding for specific projects, such as clean coal technology for Latrobe Valley, to cross-subsidise publications and post-graduate completions. Stakeholders that were conspicuous by their absence in previous models but are incorporated in models here include NGOs which would be involved in the decision-making processes, such as on whether an environmentally sensitive project should proceed or not, and venture capitalists. Both of these groups have considerable power over whether further R&D should be financially supported and a new product brought to market, or whether genetically modified organism technology should be adopted in a region, or a paper mill built.

The diversity of the above stakeholders makes one thing apparent about the models proposed in this thesis. This is that each interaction and collaboration would differ according to the project. It could be a two-way or three-way collaboration or may even have more stakeholders involved, sometimes in conflict such as occurs when trying to balance employment growth with environmental conservation when choosing the site for a development project. Naturally the models cannot cover every variation and they are limited in that they are perceived subjectively by stakeholders according to their own interests and circumstances. To address this issue, the thesis canvassed a range of stakeholders to determine the suitability of the models proposed using Latrobe Valley as a case study but also requesting projection of the models' suitability for application in Gippsland and Australia. Senior officials representing key industries, local and state government, NGOs and a regional university campus completed largely open-ended questionnaires followed by interviews to determine their opinions. Government respondents generally supported the models, believing that they could work and agreed with the central role depicted (unintentionally) for regional universities whereas the university respondents felt that the university should play a less central role.

The industries (all resource intensive) did not believe the sustainability model proposed in the thesis would work and a government representative indicated that it was too early for Latrobe Valley. Concerns were raised that feedback was not adequately addressed (by an NGO) and that capital investment and intellectual property issues were not adequately addressed, nor were the R&D skills available in the region (industry), making the models proposed "only part of the answer". Mistrust of universities' ability to deliver was an issue raised by one industry but the overall impression was that the recognition of partnerships and networks was important.

To address these issues, these models should be modified to reflect feedback with arrows going in both directions as depicted in figure 1 of this chapter and in chapter 7. Universities, although central to the economies of scale being achieved could be depicted on an equal footing with the other stakeholders such as government, industry and NGO's. New stakeholders should be added such as venture capitalists and international collaborators to reflect a more 'open' innovation system. Other concerns such as intellectual property should not be included but dealt with on a case-by-case basis, drawing upon the legal expertise available. In chapter 7, a single model was proposed that incorporates the required modifications and could be used for both policy development and the identification of suitable projects with their expected outcomes and funding (among other things) clearly identified. This model is reproduced from chapter 7 for easier cross referencing below.

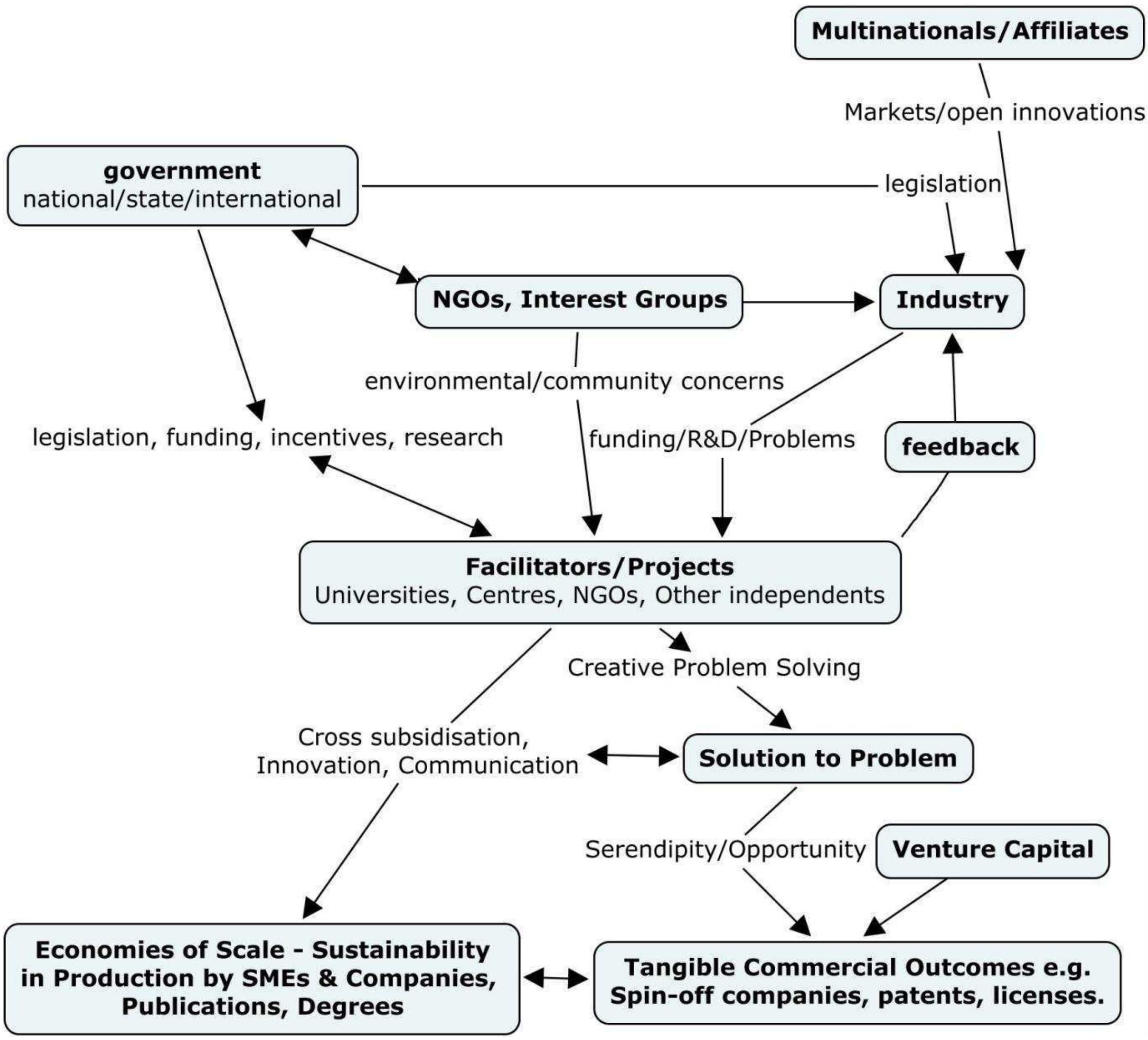

Figure 1: A Stakeholder-Driven Innovation Model for Sustainable Development (reproduced from chapter 7[1])

[1] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

The research conducted in this thesis, from the scoping of the Australian innovation environment to determining innovation in Australian SMEs (albeit with a cleaner production focus) and to compiling literature on, and determining the nature and activity of CRCs, allowed the development of more advanced innovation models than those proposed to date in the literature. On the basis of suggestions made, the literature and groundwork models depicted in chapters 4 and 5, the final model in chapter 7[1] (reproduced above) was generated. Such a modified model could be used as a blueprint for policymaking and government should then insist that, in application for the creation of future CRCs, the individual components (such as participating government departments or NGOs to be consulted) be identified as pertaining to the project desired. This would ensure that new initiatives have addressed the desires and concerns of all stakeholders, enhancing the chance of successful implementation. Possible deviations or omissions from the central model should be highlighted according to the purpose of the new CRC, such the lack of a need for venture capital if it is to be created for environmental conservation, or the requirement for model to be extended to indicate markets or customers for e.g. a commercialisable product.

As a body of work, this thesis started off by identifying the broadest definitions of terms such as “innovation” and “entrepreneur”, and later “commercialisation” and “biotechnology”. This has allowed the advancement of innovation theory to incorporate a wider group of stakeholders and interactions than those within a firm to be incorporated through the models proposed, enhancing their chances of success.

[1] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

The Australian innovation environment is then described as a background facilitating informed decisions to drive alterations in development of the models proposed in chapters 4 and 5, which build upon those in described in the literature review by incorporating more stakeholders and funding sources. Incremental changes are made to these models on the basis of information gleaned through research involving Australian CRCs and regional managers and more literature as it emerged in the interim. The results of this research were published and are presented in chapters 6[1] and 7[2]. Chapter 7 depicts a new model in which the innovation is considered in its broadest context and research output includes those that are commercialisable as well as academic. Creative problem solving and "lucky accidents" (or serendipity) are still the focus as they were in chapters 4[3] and 5[4] but greater opportunities for feedback are depicted and the identity of the entrepreneur is less well defined. The university is now only one of the possible innovators expected to drive any project identified (universities were depicted as being central to the innovation process in chapters 4 and 5 while the CRC survey indicated that most innovators were actually from industry).

In addition to the adoption of the broadest possible definitions for terms used in this thesis allowing greater stakeholder participation (such as farmers and food technologists being considered biotechnologists), the investigation was at multiple levels, drawing data from SMEs, CRC representatives reflecting the Australian national innovation framework, and local strategists from various local stakeholder groups having input as a regional level. As such it is currently the most inclusive study made towards the development of an innovation model and has advanced theory to incorporate practical considerations at national, regional

[1] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[2] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131
[3] Innovation and Development Model for Regional University Campuses, p.93
[4] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105

and sector (such as SME) levels in both sustainable and regional development. The models proposed throughout the thesis are advancements upon previous theoretical innovation models as they have been adapted in response to mistakes reported from applying the earlier models at policy levels. In addition, the focus here has shifted further from firm-based innovation models to introduce wider stakeholder involvement. Theory is further advanced in chapter 4[1] where the knowledge networks and knowledge flows have been modified to fit the model proposed.

Although other authors have described the Australian corporate and government environment in which innovation is to take place, chapter 2 [2]summarises this work in the context of this thesis.

The earlier literature-based chapters highlight the need for improved innovation models and then for sustainability innovation in Australia (with cleaner production as example), and depict the Australian environment in which they are to be implemented. This literature underpinned the research project in which SME implementation of innovation, especially in sustainability practices, was investigated and was found to be woefully inadequate. The literature and cleaner production research thus confirmed the need for suitable innovation models. The results of these studies prompted the development of the improved literature-based models proposed in chapters 4 and 5 [3]which were designed to overcome problems in implementation of earlier innovation models such as the triple helix model.

[1] Innovation and Development Model for Regional University Campuses, p.93
[2] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59
[3] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105

The next study was aimed at determining the effectiveness of the CRC environment described in chapter 2 [1]at achieving commercialisable and research outcomes, a key point for consideration when developing a more refined model. It was found that commercialisation outcomes of the CRCs were lower than expected but that the research output was still high. Despite this, the above figures by Insight Economics (2006) indicated that money supplied to the CRC programme was well spent and the more refined model in chapter 7 includes their input and chapter 6[2] and 7[3] suggest an increase in participant numbers to overcome the "European Paradox" problem reported above. This study also highlighted that universities were seldom the innovators behind specific projects and the model in chapter 7 was modified accordingly to increase the number of entrepreneurial agencies that may initiate and drive an innovation project as noted earlier. This was also prompted by results of the third study in which regional university respondents (especially) disagreed with the central role that universities were depicted in the models of chapters 4 and 5 to take in such initiatives. The results of the third study (in which university, industry, government and NGO strategists completed questionnaires and had follow-up interviews) also revealed that feedback mechanisms depicted in chapters 4[4] and 5[5] were inadequately represented, as were funding sources and government facilities. The models in chapters 4 and 5 were modified to address these issues and published as an improved model in chapter 7.

Although the model in chapter 7 (and reproduced above) is closer to suitability for application in policy development and project planning than those in chapters 4 and 5, there

[1] Cooperative Research Centres and Industrial Clusters: Australian Biotechnology Strategies,p.59
[2] Australian CRC Composition and Productivity, their Participation in Biotechnology, Regional and Sustainable Development, p.114
[3] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131
[4] Innovation and Development Model for Regional University Campuses, p.93
[5] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105

are some limitations, firstly in how the model may be applied, and secondly in how it was derived. These need to be highlighted, as should future directions for related research.

The models proposed in this thesis were intended for developing a strategic direction or regional policy. As they are the starting point of any of these and do require STI policy research, they cannot easily accommodate unforeseen eventualities or competition such as described by Nill and Kemp (2009) and will have to be revisited in light of such an eventuality. Another problem in implementation of the improved chapter 7[1] model is that it has to be recognised that each initiative and goal would determine how a model should be applied. The models proposed in this thesis promote higher stakeholder involvement than other innovation models in the literature and allow additional spin-offs through serendipity or the "lucky accidents" discussed by Tidd (2006, p.4). However, omission of one key stakeholder can derail a project as discussed below.

The models proposed are 'ideal world' ones and to improve their effectiveness, the "European Paradox" problem has to be overcome by getting those working on similar projects to collaborate rather than working in isolation, 're-inventing the wheel' and competing with each other. Further, chapter 7 clearly identifies how strong lobby groups and 'hidden agendas' can also derail otherwise sound projects. Another issue that may arise from the wider stakeholder involvement in the model is the reaching of an *impasse* in which, for example developers are pitted against environmentalists. However, this may be beneficial as the model allows issues to emerge early in the planning process rather than having to discard

[1] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

a project due to the late emergence of stakeholder concerns when the project is already well advanced.

Despite every attempt to identify all stakeholders in the models depicted in this thesis, there are still those that have not been included, such as suppliers, intellectual property experts and marketers. However, some of these may be recruited at a later stage once a ‘lucky accident’ happens and a commercialisable opportunity arises. A key stakeholder missing from the models is the customer. Care must thus be taken to ensure that such potential customers are identified and involved immediately following emergence of potentially commercialisable spin-offs from researching a problem. The model also does not include projects that could be directed at commercialisable product or process from the beginning. In such cases, the potential customers must be canvassed at an early stage and economists recruited to determine the costs and benefits associated with commercialisation. This is important to ensure that technology push does not supercede market pull forces.

The final shortcoming of this study and the resulting models is related to rigour. In the first study, over 400 SMEs were interviewed to determine the need for enhanced sustainability practices and the role of intermediaries. This study may have been enhanced by similarly interviewing larger industries to get a wider perspective. The second study, although it elicited a wealth of information from CRCs (much of which is still not published) the response rate was just over 30% of all existing Australian CRCs. Although all CRCs were approached and sent reminder letters, personal interviews may have enhanced the response rates. The third study had only eleven respondents to the open-ended questionnaires, all senior strategists from government, the key industries, university and NGOs in Latrobe

Valley. This represents a small proportion of the opinions that could have been elicited for this open-ended questionnaire (with follow-up interviews) and this response rates could have been enhanced by canvassing more Latrobe Valley candidates (e.g. upstream suppliers from the coal mining or forestry industries, the service, wine and/or dairy sectors) or widening the survey area to include other parts of Australia. The latter strategy would most likely have diluted the responses from Latrobe Valley with ones from a region with different strengths. Further interesting research in this regard would be a comparative study as industry elsewhere may be more receptive to sustainability aspects of the models proposed in chapters 4 [1]and 5[2] than were Latrobe Valley enterprises. This study could have been further expanded by extending it to a Delphi or Policy Delphi method as discussed by van Dijk (1990) and Rayens and Hahn (2000) respectively. To do so, the model in chapter 7[3] would have to be shown to the same strategist respondents for comments and possible further "tweaking". Such an exercise would be particularly useful considering that open-ended questions were primarily used to obtain the opinions. Considering the problem that questions were too broad (in hindsight) after interviewing the SMEs, further investigation on whether expectations had been met in the final model in chapter 7 would be useful. However, one issue that has been addressed in this thesis is that of the time constraints, identified by NGOs interviewed and given by many potential respondents as a reason for not responding to the surveys. The policy models presented here allow a combination of economies of scale and serendipity to enhance output. Although academic institutions are less prevalent in the model above and in chapter 7 than the earlier models to allow greater variety in the identity of champions to emerge, academics can use the creative problem solving to generate the funds for relief teaching, freeing them to become more involved in relevant projects.

[1] Innovation and Development Model for Regional University Campuses, p.93
[2] Interdisciplinary Knowledge Transfer to Facilitate Sustainable Development: Australia as Example, p.105
[3] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

Stakeholders that must be involved in initiating and implementing a strategic innovation for regional and sustainable development were identified in this thesis. In most cases the processes are evident from the identity of these stakeholders. However, additional models proposed by Bernstein and Singh (2006) and Potts (2010) for Australia should also be considered as they both concentrate on the mechanisms and processes in innovation such as market pull vs. technology push and communication for biotechnology firms by the former authors and the drivers and activities for the "natural advantage" model for regional and sustainable development by Potts (2010). However, none of these authors indicate the detailed framework of accountable participants and stakeholders depicted in the models of this thesis, indicating that this thesis would be a good starting point for policymakers.

Policy makers and funders could use the model proposed in chapter 7[1] to set up a framework, e.g. with the incorporation of a spreadsheet, in which those proposing to start up a CRC or requesting funding need to indicate that they have identified the specific stakeholders to be involved in their CRCs or projects, and have identified where potential resistance or opportunities lie. When coupled with potential markets or other outcomes, such as in environmental conservation, employment creation, and/or technological feasibility, these policymakers would have a powerful tool to assist in decision making about whether a project or CRC should be supported or not.

Some further research that would build upon this study has been indicated above but the most telling projects would be those in which the models and findings are acted upon as suggested and then doing hindsight investigations to determine the level of success. The innovation

[1] Case Studies on Australian Environmental Sustainability: A Multi-level Review, p.131

models proposed in this thesis have built upon previous ones to respond to their practicality shortcomings, as identified in subsequent application of the models. This thesis is intended to be a considerable improvement for directing policy and projects. Application of the knowledge conveyed and subsequent reports should be used to further hone regional and sustainable development.

Bibliography

. CRCs - the Cornerstone of Australia's National Innovation System. Retrieved 2 December 2009, from http://www.crca.asn.au/print/709

. Latrobe City's Natural Environmental Sustainability Strategy 2008-2013. Retrieved 16 November 2009, from http://www.latrobe.vic.gov.au/webfiles/council/services/sustainability

. Surveymonkey. Retrieved 16 November 2009, from http://surveymonkey.com

Oxford English Dictionary. (1989). (2nd ed.). Oxford: Clarendon Press.

. CRC's - the Cornerstone of Australia's National Innovation System. (2009) Retrieved 2 December, 2009, from http://www.crca.asn.au/print/709

ACCI. (2003). Eco-Efficiency Survey 2002-2003 (pp. 24). Canberra (ACT), Australia: Australian Chamber of Commerce and Industry.

Acharya, R. (1999). The emergence and growth of biotechnology. In J. Senker (Ed.), . *The Internationalisation of Biotech SME's* (pp. 156-163). Cheltenham, UK: Edward Elgar Publishing.

Aghion, P., David, P. A., & Foray, D. (2009). Science, technology and innovation for economic growth: Linking policy research and practise in "STIG Systems". *Research Policy, 38*(4), 681-693.

Alcorta, L., & Peres, W. (1998). Innovation systems and technological specialisation in Latin America and the Caribbean. *Research Policy, 26*, 857-881.

Altham, J. (2004). *Benchmarking to Trigger and Sustain the Implementation of Cleaner Production in Small to Medium Sized Enterprises.* PhD, Curtin University of Technology, Perth (WA), Australia.

Altham, W. (2006). Benchmarking to trigger cleaner production in small businesses: Drycleaning case study. [journal]. *Journal of Cleaner Production, 15*, 798-813.

American Institute for Innovation Excellence. (2009). Continuous innovation loop. Retrieved 10 October, 2010, from http://thinkforachange.com/wordpress/wp-content/uploads/2009/11/Continuous-Innovation-Loop.jpg

Andrews, S., Stearn, K., & Orbell, J. (2002). Awareness and Adoption of Cleaner Production in Small to Medium-sized Businesses in the Geelong Region, Victoria, Australia. *Journal of Cleaner Production, 10*, 373-380.

Australian Commonwealth. (2008). Venturousaustralia: Building strength in innovation, from http://www.innovation.gov.au/innovationreview/Pages/home.aspx

Australian Institute for Commercialisation. (2006). Inside commercialisation -> ideas ->opportunities -> outcomes: Annual Review 2005/1006 (pp. 1-23). Brisbane: Australian Institute for Commercialisation

Ball, S. (1995). Intellectuals or technicians? The urgent role of theory in educational studies. *British Journal of Educational Studies., 43*, 255-271.

Baptista, R., & Swann, P. (1998). Do firms in clusters innovate more? *Research Policy, 27*, 525-540.

Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. . *Progress in Human Geography, 28*, 31-56.

Bellini, N., & Piccaluga, A. (2000). The role of the university in constituency-building for industrial and territorial innovation: Reflections on an Italian Experience. In R. E. Lopez-Martinez & A. Piccaluga (Eds.), *Knowledge Flows in National Systems of Innovation* (pp. 122-152). Cheltenham, UK: Edward Elgar.

Beluzzi, F., Sammarra, A., & Sedita, S. R. (2010). Learning at the boundaries in an "Open Regional Innovation System": A focus on firms' innovation strategies in the Emilia

Romagna life science industry. *Research Policy, 39*(2010), 710-721.
Benner, M., & Sandstrom, U. (2000). Institutionalizing the triple helix: research funding and norms in the academic system. *Research Policy, 29*(2), 291-301.
Bernstein, B., & Singh, P. J. (2006). An integrated innovation process model based on practices of Australian biotechnology firms. *Technovation, 26*(5-6), 561-572.
Bessant, J. (2005). Enabling continuous and discontinuous innovation: Learning from the private sector. *Public Money and Management, January*, 35-42.
Binnings, D. (2002). Money or nothing: Australia versus Singapore Inc. *Australian Biotechnology News, Vol., 1*(24), 16-21.
BitE. (2001). A Measure of Progress: guidelines on measuring environmental performance (pp. 60). Longon, UK: Business in the Environment and Ernst and Young.
Bonilla, S. H., Almeida, C. M. V. B., Gianetti, B. G., & Huising, D. (2010). The roles of cleaner production in the sustainable development of modern societies: An introduction to this special issue. *Journal of Cleaner Production, 18*, 1-5.
Brannback, M., Carsrud, A., Krueger, N., & Elfving, J. (2008). Challenging the triple helix model of regional innovation systems: A venture-centric model. *International Journal of Technoentrepreneurship, 1*(3), 257-277.
Brostrom, A. (2010). Working with distant researchers - Distance and content in university-industry interaction. *Research Policy, 39*, 1311-1320.
Brown, R. (1992). Managing the 'S' curves of innovation. *Journal of Business and Industrial Marketing, 7*(3), 41-52.
Brown, J. S., & Duguid, P. (2002). *The social life of information.* Boston: Harvard Business School Press.
Brown, T. C. (1984). The concept of value in resource allocation. *Land Economics, 60*, 231-246.
Brundtland, G. (Ed.). (1987). *Our common future: The World Commission on Environment and Development*. Oxford: Oxford University Press.
Bruneel, J., D'Ester, P., & Salter, A. (2010). Investigating the factors that diminish the barriers to university-industry collaboration. *Research Policy, 39*, 858-868.
Bryman, A., & Bell, E. (2007). *Business Research Methods.* (2nd Edition ed.). Oxford: Oxford University Press.
Bunders, J. F. G., Broerse, J. E. W., & Zweekhorst, M. B. M. (1999). The triple helix enriched with the user perspective: A view from Bangladesh.. *Journal of Technology Transfer, 24*, 235-246.
Carlsson, B. (2006). Internationalisation of innovation systems: a survey of the literature. *Research Policy, 35*, 56-67.
Cassiman, B., Di Guardo, M. C., & Valentini, G. (2010). Organising links with science: Cooperate or contract? A project-level analysis. *Research Policy, 39*, 882-892.
Ceballos, G. C. P., Erlich, J.; Soberon, I.; Salazar, I.; Fay, J.P. (2005). Global mammal conservation: what must we manage? *Science, 309*, 603-607.
Chang, C. M. (2008). Engaging the creative minds - the Engage Model. *International Journal of Innovation and Technology Management, 5*(1), 149-165.
Chertow, M. R. (2000). *Accelerating commercialization of environmental technology in the United States: Theory and case studies.* PhD, Yale University, Connecticut.
Chesbrough, H. W. (2003). The logic of open innovation: Managing intellectual property. *California Management Review, 45*(3), 33.
Chesbrough, H. W., & Garman, A. R. (2009). How open innovation can help you cope in lean times. Harvard Business Review, December, 68-76.
Cimoli, M., & Constantino, R. (2000). Systems of innovation, knowledge and networks: Latin america and its capability to capture benefits. In R. E. Lopez-Martinez & A. Piccaluga (Eds.), *Knowledge flows in national systems of innovation* (pp. 56-81).

Cheltenham, UK: Edward Elgar.
Coehen, R. (1996). Challenges of networking in technology assessment. *Technological Forecasting and Social Change, 51*, 49-54.
Commonwealth Biotechnology Ministerial Council. (2000). National Biotechnology Strategy Canberra.
Commonwealth of Australia. (2008). Venturous Australia: Building strength in innovation. Retrieved 2 December, 2009, from http://www.innovation.gov.au/innovationreview/Pages/home.aspx.
Correa, C. M. (2000). University-enterprise linkages in the area of biotechnology In R. E. Lopez-Martinez & A. Piccaluga (Eds.), *Knowledge Flows in National Systems of Innovation* (pp. 155-167). Cheltenham, UK: Edward Elgar Publishers Ltd.
Cote, R., Booth, A., & Louis, B. (2006). Eco-Efficiency and SMEs in Nova Scotia, Canada. *Journal of Cleaner Production, 14*(6-7), 542-550.
CRC, E. B. (2007). A cleaner, greener, whiter future. *Australasian BioTechnology, 17*(4), 5-8.
Dahlander, L., & Gann, D. M. (2010). How open is innovation? *Research Policy, 39*, 699-709.
Davenport, T. H., & Prusak, L. (1998). *Working knowledge: How organizations manage what they know.* Boston: Harvard Business School Press.
De Bruijn, T. (1996). Pollution Prevention Projects in The Netherlands. *Journal of Cleaner Production, 4*(1), 41-53.
De Bruijn, T., & Hoffman, P. (2000). Pollution Prevention and Industrial Transformation: evoking structural changes within companies. *Journal of Cleaner Production, 6*, 215-223.
de Faria, P., Lima, F., & Santos, R. (2010). Cooperation in innovation activities: The importance of partners. *Research Policy, 39*, 1082-1092.
de Hoo, S., Brezet, H., Crul, M., & Dieleman, H. (1991). Manual for the Prevention of Waste and Emissions (L. O. Networ, Trans.). In M. Crul (Ed.), *PREPARE Manual and Experiences* (pp. 84). The Hague, The Netherlands: Ministry of Economic Affairs (for EuroEnviron).
De la Rosa, L., & Martin, B. E. (2000). The role of the biotechnology and pharmaceutical scientific and productive clusters in the Cuban innovative activity. In R. E. Lopez-Martinez & A. Piccaluga (Eds.), *Knowledge Flows in National Systems of Innovation* (pp. 163-183). Cheltenham, UK.: Edward Elgar Publishers Ltd.
Debackere, K., & Veugelers, R. (2005). The role of academic technology transfer organizations in improving industry science links. *Research Policy, 34*, 321-342.
Decter, M., Bennet, D., & Leseure, M. (2007). University to business technology transfer - UK and USA comparisons. *Technovation, 27*(3), 145-155.
DEH. (2004). Eco-Efficiency and Cleaner Production Case Studies Retrieved 19 January, 2004, from http://www.deh.gov.au/industry/corporate/eecp/casestudies/,
Department of State and Regional Development Science and Technology Division. (2001). Biotechnology: Strategic Development Plan for Victoria Melbourne.
DeSimione, L., & Popoff, F. (Eds.). (1997). *Eco-Efficiency: the business link to sustainable development* (1 ed.). Cambridge, MA: The MIT Press (for WBCSD).
Dieleman, H., Van Berkel, R., Reijenga, F., de Hoo, S., Brezet, H., Cramer, J., & Schot, J. (1991). Choosing for Prevention is Winning (L. O. Network, Trans.). In M. Crul, H. Brezet & S. de Hoo (Eds.), *PREPARE Manual and Experiences* (pp. 112). The Hague, The Netherlands: Ministry of Economic Affairs (for EuroEnviron).
Dooley, L., & O'Sullivan, D. (2001). Structuring innovation: A conceptual model and implementation methodology. *Enterprise and Innovation Management Studies., 2*(3), 177-194.

Dorfman, M., Muir, W., & Miller, C. (1992). Environmental Dividends: cutting more chemical waste (pp. 272). New York, USA: Inform.
Duarte, A. P. M., P.; Alexandre, J. (2007). Pro-active behaviour induction by integration of sustainability in business strategic management: INOVE project case study. [Journal]. *Journal of Cleaner Production, In Press*, 1-15.
Environment, C. f. C. A. a. R. o. t. (2007). Biosensors to probe the metals menace. *Australiasian BioTechnology, 17*(4), 10-12.
Ernst and Young. (2001). Australian Biotechnology Report 2001. Canberra.
Etzkowitz, H. (1998). The norms of entrepreneurial science: Cognitive effects of the new university-industry linkages. *Research Policy, 27*(8), 823-833.
Etzkowitz, H. (2002). The triple helix of university-industry-government implications for policy and evaluation (pp. 1-16). Stockholm: Science Policy Unit.
Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy, 29*(2), 109-123.
Evangelista, R., Sandven, T., Sirilli, G., & Smith, K. (1998). Measuring innovation in European industry. *International Journal of the Economics of Business, 5*(3), 311-333.
Fritsch, M., & Franke, G. (2004). Innovation, regional knowledge spillovers and r&d cooperation. *Research Policy*, 33(2), 245-255.
Frost, G., & Wilmshurst, T. (1996). Going Green …but not yet. *Australian Accountant., 66*(8), 36-39.
Galvin, P., & Davies, J. (2002). *Innovativeness in industrial clusters: a theoretical explanation of differences in innovation levels in industry clusters and science parks*. Paper presented at the Academy of Management Conference, Denver.
Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy, 39*, 495-510.
Giorgio, D., Ferenc, F., Donald, H., & Jaromir, K. J. (2009). Cleaner energy for sustainable future. *Journal of Cleaner Production, 17*, 889-895.
Giuliani, E., & Arza, V. (2009). What drives the formation of 'valuable' university-industry linkages?: Insights from the wine industry. *Research Policy, 38*(6), 906-921.
Goldberg, D. (2002a). Biotech in South Australia: dancing with the elephants. *Australian Biotechnology News, 1*(8), 28.
Goldberg, D. (2002b). Biotech in NSW: United they stand. *Australian Biotechnology News, 1*(5), 30-31.
Goldberg, D. (2002c). Waste CRC warns on revenue expectations. *Australian Biotechnology News, 1*(11), 19.
Gosch, E. (2007, 13 June 2007). CRCs' future in the balance, *The Australian,* p. 30.
Greene, D. (1999). Carrots, Sticks and Useful Tools: A Study of Measures to Encourage Cleaner Production in Australia. Sydney (NSW), Australia: University of New South Wales: CRC for Waste Management and Pollution Control.
Hair, J. F., & Babin, B. (2003). *Essentials of Business Research Methods* Hoboken, USA: John Wiley & Sons.
Hall, L. A., & Baghchi-Sen, S. (2007). An analysis of firm-level innovation strategies in the US biotechnology industry. *Technovation, 27*(1-2), 4-14.
Heany, D. F. (1983). Degrees of product innovation. *Journal of Business Strategy, 3*(4), 3-14.
Herbig, P. A., & Miller, J. C. (1992). The United States versus the United Kingdom, Canada, and Australia. *Technological Forecasting and Social Change, 41*, 423-434.
Hillary, R. (2004). Environmental Management Systems and the Smaller Enterprise. *Journal of Cleaner Production, 12*(6), 561-569.
Hollis, T. (2002). Biotech in South Australia: how a 15-minute city bred a biohub. *Australian*

Biotechnology News, 1(8), 24-27.
Hollis, T., & Trudinger, M. (2002). Biotech in Victoria: smaller players face big issues *Australian Biotechnology News, 1*(6), 32.
Holmes, D., & Girardi, G. (1999). Survey of Productivity and Environmental Strategies and Practises in Australian Manufacturing Companies. Melbourne (Vic), Australia: Australian Industry Group and Monash Centre for Environmental Management.
Howgrave-Graham, A. R. (2008). An interdisciplinary knowledge transfer approach to facilitate sustainable development: Australia as an example. *The International Journal of Environmental, Cultural, Economic and Social Sustainability, 4*(4), 11-16.
Howgrave-Graham, A. R. (2009). An innovation and development model for regional university campuses. *The International Journal of Technology, Knowledge and Society, 5*(1), 76-88.
Howgrave-Graham, A. R. (2010). The composition and productivity of Australian cooperative research centres, with emphasis on their participation in biotechnology, regional and sustainable development. *The International Journal of Technology, Knowledge and Society, 6*(3), 67-81.
Howgrave-Graham, A. R., & Galvin, P. (2005). Cooperative research centres and industrial clusters: Implications for Australian biotechnology strategies. In A. G. Rainnie, M. (Ed.), *New regionalism in Australia* (Vol. 1, pp. 87-102). Aldershot, England: Ashgate Publishing Limited.
Howgrave-Graham, A. R., Kirstine, W., & Larkins, J.-a. (2009). Benefits of the scientific method to business and how business and science can learn from each other. In J. E. Michaels & L. F. Piraro (Eds.), *Small Business: Innovation, Problems and Strategy* (pp. 117-134). New York: Nova Science Publishers Inc.
Howgrave-Graham, A. R., & van Berkel, R. (2007). Assessment of cleaner production uptake: Method development and trial with small businesses in Western Australia. *Journal of Cleaner Production, 15*, 787-797.
Howgrave-Graham, A. R. G., P. (2005). Cooperative research centres and industrial clusters: Implications for Australian biotechnology strategies. In A. G. Rainnie, M. (Ed.), *New regionalism in Australia* (Vol. 1, pp. 87-102). Aldershot, England: Ashgate Publishing Limited.
Howgrave-Graham, A. R. v. B., R. (2007). Assessment of cleaner production uptake: Method development and trial with small businesses in Western Australia. [Journal]. *Journal of Cleaner Production, 15*, 787-797.
http://microtechnologycrc.com/aboutus.html. Retrieved 25 August, 2002
http://www.bioinnovationsa.com.au/template/php. Retrieved 15 June, 2002
http://www.botany.unimelb.edu.au/envisci/nick/prop-biotech_nat_strategy.pdf. Retrieved 15 June, 2002
http://www.treasury.qld.gov.au/budget/budget99/smartstate/biotech1.html. Retrieved 5 August, 2002
Huppes, G., & Ishikawa, M. (2005). A Framework for Quantified Eco-Efficiency Analysis. *Journal of Industrial Ecology, 9*(4), 25-42.
Insight Economics. (2006). Economic impact study of the CRC Programme. Melbourne: Australian Government Department of Education, Science and Training.
Insight Economics. (2006). *Economic Impact Study of the CRC Programme*. Insight Economics Pty Ltd.
ISO. (2000). AS/NZS ISO 14031:2000 Environmental Management - environmental performance evaluation - guidelines (pp. 32). Sydney (NSW), Australia: Standards Australia.
Jackson, T. (1993). Principles of Cleaner Production: an operational approach to the preventative paradigm. In T. Jackson (Ed.), *Developing Preventative Environmental*

Management in the Industrial Economy (pp. 143-164). Boca Raton: Lewis Publishers.
Jeyaretnam, T., Tunney, J., & Hughes, T. (1999). Public Environmental Reporting: where does Australia stand? Melbourne (Vic), Australia: Snowy Mountains Engineering Corporation.
Jorgensen, T. H. (2007). Towards more sustainable management systems: through life cycle management and integration. *Journal of Cleaner Production, In Press*, 1-22.
Katrak, H. (1998). Economic analyses of industrial research institutes in developing countries: The Indian experience. *Research Policy, 27*, 337-347.
Kelley, B. (n.d.). Business Strategy Innovation Retrieved 23 October, 2010, from http://www.business-strategy-innovation.com
Kern, F., & Smith, A. (2007). Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. Sussex Energy Working Paper, SPRU. Brighton: University of Sussex.
Kestigian, M. (1991). The Greening of Accountancy. *Australian Accountant., 61*(8), 20-27.
Kim, W. C., & Mauborgne, R. (1999). Creating new market space. *Harvard Business Review, 77*(1), 83-93.
Kirby, D. A. (2006). Creating entrepreneurial universities in the UK: Applying entrepreneurship theory to practise. *Journal of Technology Transfer, 31*, 599-603.
Kirkels, Y., & Duysters, G. (2010). Brokerage in SME networks. *Research Policy, 39*, 375-385.
Knox, S. (2002). The boardroom agenda: Developing the innovative organisation. *Corporate Governance, 2*(1), 27-39.
Koontz, H., & Weirich, H. (1990). *Essentials of Management*. Singapore: McGraw-Hill.
Landis-Gabel, H., & Sinclair-Desgagne, B. (1998). The Firm, its Routines and the Environment. In T. Tietenberg & H. Folmer (Eds.), *The International Yearbook of Environmental and Resource Economics 1998-1999; a survey of current issues*.
Landry, R., & Amara, N. (2006). Patenting and spin-off creation by Canadian researchers in engineering and life sciences. *The Journal of Technology Transfer, 32*(3), 217-249.
Latrobe City's Natural Environmental Sustainability Strategy 2008-2013. (2009) Retrieved 16 November, 2009, from http://www.latrobe.vic.gov.au/webfiles/council/services/sustainability.
Lee, A. M., & Bereano, P. L. (1981). Developing technology assessment methodology: some insights and experiences. *Technological Forecasting and Social Change, 19*(1), 15-31.
Lee, S., Park, G., Yoon, B., & Park, J. (2010). Open innovation in SMEs - An intermediation network model. *Research Policy, 39*, 290-300.
Leibenstein, H. (1968). Entrepeneurship and Development. *American Economic Review, 38*(2), 72-83.
Leydesdorff, L. (2005). The Triple Helix Model and the study of knowledge-based innovation systems *The International Journal of Contemporary Sociology, 42*(1), 12-27.
Leydesdorff, L., & Etzkowitz, H. (1997). A Triple Helix of university-industry-government relations. In H. L. Etzkowitz, L. (Ed.), *Universities and the global knowledge economy* (Vol. 1, pp. 155-162). London: Pinter.
Leydesdorff, L. E., H. (1997). A triple Helix of university-industry-government relations. In H. L. Etzkowitz, L. (Ed.), *Universities and the global knowledge economy* (Vol. 1, pp. 155-162). London: Pinter.
Malaska, P. (2001). A futures research outline of a post-modern idea of progress. *Futures, 33*, 225-243.
Marques, J. P. C., Caraca, J. M. G., & Diz, H. (2006). How can university-industry-government interactions change the innovation scenario in Portugal? - the case of the

University of Coimbra. *Technovation, 26*(4), 534-542.
Massey, D., & Wield, D. (1992). Science parks: a concept in science, society, and space (a realist tale) *Environment and Planning, 12*, 411-422.
Maxwell, D. v. d. V., R. (2003). Developing sustainable products and services. *Journal of Cleaner Production, 11*, 883-895.
McFadzean, E. S. (1998). The creativity continuum: Towards a classification of creative problem solving techniques. [journal]. *Creativity and Innovation Management, 7*(3), 131-139.
McFadzean, E. S., O'Loughlin, A. M., & Shaw, E. (2005). Corporate entrepreneurship and innovation Part 1: The missing link. *European Journal of Innovation Management, 8*(3), 350-372.
Metcalf, J. S. (1995). Technology systems and technology policy in an evolutionary framework. *Cambridge Journal of Economics, 19S*, 25-46.
Meyer-Kramer, F., & Schmoch, U. (1998). Science-based technologies: university-industry interactions in four fields. *Research Policy, 27*, 835-851.
Mezias, J. M., & Grinyer, P. (2001). Changing collective cognition: A process model for strategic change. *Long Range Planning, 34*, 71-95.
Mitchell, G. R. (1999). Global technology policies for global change. *Technological Forecasting and Social Change, 60*, 205-214.
Mohnen, P., & Roller, L. H. (2001). Complementarities in innovation policy, Discussion Paper 2712. London: Centre for Economic Policy Research.
Monfreda, C. W., M.;Deumling, D. (2004). Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessments. *Land Use Policy, 21*, 231-246.
Moran, D. D. W., M.; Kitzes, J.A.; Goldfinger, S.H.; Boutaud, A. (2007). Measuring sustainable development - Nation by nation. *Ecological Economics, in Press*, 1-13.
Morlacchi, P., & Martin, B. R. (2009). Emerging challenges for science, technology and innovation policy research: A reflexive overview. *Research Policy, 38*(4), 571-582.
Moses, V., & Moses, S. (1995). *Exploiting Biotechnology*. Chur, Switzerland: Harwood Academic Publishers.
Mytelka, L. K., & Smith, K. (2002). Policy learning and innovation theory: An interactive and co-evolving process. *Research Policy, 31*, 1467-1479.
Nelson, A. J. (2009). Measuring knowledge spillovers: What patents, licenses and publications reveal about innovation diffusion. *Research Policy, 38*(6), 994-1005.
Nill, J., & Kemp, R. (2009). Evolutionary approaches for sustainable innovation policies: From niche to paradigm? *Research Policy, 38*(4), 668-680.
Nonaka, I. (1994). A dynamic theory of organisational knowledge creation. *Organizational Science, 5*(1), 14-37.
Nonaka, I., & Takeuchi, H. (1995). *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation* New York: Oxford University Press.
NwMexEPA. (2001). The Nothing to Waste Manual: incorporating pollution prevention into small businesses. *Green Zia Environmental Excellence Program*: New Mexico Environmental Protection Agency.
Office of the Gene Technology Regulator (OGTR). (2000). Commonwealth Gene Technology Act. Canberra.
Park, H. W., & Leydesdorff, L. (2010). Longitudinal trends in networks of university-industry-government relations in South Korea: The role of programmatic incentives. *Research Policy, 39*, 640-649.
Parrish, B. D. (2007). Designing the sustainable enterprise. *Futures*, 39(7), 846-860.
Pastakia, A. (1998). Grassroots ecopreneurs: Change agents for a sustainable society. *Journal of Organisational Change Management, 11*(2), 157-173.

Pearce, J. A., & Robinson, R. B. (1997). *Formulation, Implementation, and Control of Competitive Strategy*. Chicago: Irwin.
Peneder, M. (2010). Technological regimes and the variety of innovation behaviour: Creating integrated taxonomies of firms and sectors. *Research Policy, 39*, 323-334.
Peters, L., & Groenewegen, P. (1998). A comparison of networks between industry and public sector research in materials technology and biotechnology. *Research Policy, 27*, 255-271.
Poolton, J., & Ismail, H. (2000). New developments in innovation. *Journal of Managerial Psychology, 15*(8), 795-811.
Porter, M., & van der Linde, C. (1995). Green and Competitive: ending the stalemate. *Harvard Business Review*(September - October 1995), 120-134.
Potts, T. (2010). The natural advantage of regions: linking sustainability, innovation, and regional development in Australia. *Journal of Cleaner Production, 18*, 713-725.
Rayens, M. K., & Hahn, E. J. (2000). Building consensus using the policy delphi method. *Policy, Politics & Nursing Practise, 1*(4), 308-315.
Reinhardt, F. (1999). Bringing the Environment Down to Earth. *Harvard Business Review*(July-August 1999), 149-157.
Riedlinger, M. (2002). Cooperative Research Centres going strong in the biosciences. [Journal]. *Today's Life Sciences, 14*(3), 36-39.
Robinson, A. G., & Stern, S. (1997). *Corporate Creativity: How innovation and improvement actually happen* San Francisco: Berret-Kohler Publishers.
Rundenauer, I., Gensch, C., Griesshammer, R., & Bunke, D. (2005). Integrated Environmental and Econommic Assessment of Products and Processes: a method for eco-efficiency analysis. *Journal of Industrial Ecology, 9*(4), 105-116.
Sarmiento, F. (2004). Assessment of the Impact of E2P3 Project on the Uptake of Pollution Prevention in Equador. *Journal of Cleaner Production, 12*, 283-296.
Senker, J., Faulkner, W., & Velho, L. (1998). Science and technology knowledge flows between industrial and academic research: A comparative study. In H. Etzkowitz, A. Webster & P. Healy (Eds.), *Capitalizing Knowledge: New intersections of industry and academia* (pp. 111-132). Albany, NY: State University of New York Press.
Sherblom, J. P. (1991). Ours, theirs, or both? Strategic planning and deal making. In R. D. Ono (Ed.), *The Business of Biotechnology: From the Bench to the Street* (pp. 213-224). Boston: Butterworth-Heinemann.
Smith, S., & Pech, R. J. (2006). A template for commercialising science and facilitating innovation: A case study of Victoria, Australia. *European Journal of Innovation Management, 9*(3), 279-299.
Sorensen, F., Mattson, J., & Sundbo, J. (2010). Experimental methods in innovation research. *Research Policy, 39*, 313-322.
SRT/WRC. (1999). Swan Canning Industry Survey: Pilot Survey Findings. Perth, WA: Swan River Trust and Waters and Rivers Commission.
Stevenson, R. (2004). Impact of the ASEAN Environmental Improvement Project on the Adoption of Waste Minimisation Practices in the Phillipines. *Journal of Cleaner Production, 12*, 297-303.
Stewart, J. M. (1991). Capitalising on new opportunities: Entrepreneurship in biotechnology In R. D. ono (Ed.), *The Business of Biotechnology: From the Bench to the Street,* (pp. 23-38). Boston: Butterworth-Heinemann.
Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy, 15*, 285-305.
Tidd, J. (2006). Innovation models (pp. 1-15). London: Tanaka Business School, Imperial College.
Tidd, J., Bessant, J., & Pavitt, K. (2001). *Managing Innovation: Integrating technological*

market and organizational change (Second Edition). Chichester, England: John Wiley & Sons.
Tijssen, R. J. W. (2006). Universities and industrially relevant science: Towards measurement models and indicators of entrepreneurial orientation
Research Policy, 35, 1569-1585.
Trajtenberg, M. (2002). Government support for commercial R&D: Lessons from the Israeli experience. *Innovation Policy and the Economy., 2*, 79-134.
Trott, P., Cordey Hayes, M., & Seaton, R. (1995). Inward Technology Transfer as an Interactive Process. *Technovation, 15*(1), 25-43.
Trudinger, M. (2002). The other big Australian. *Australian Biotechnology News, 1*(25), 18-20.
UNEP. (1993). Cleaner Production Worldwide (pp. 36). Paris, France: United Nations Environment Programme.
UNEP. (1994). Government Strategies and Policies for Cleaner Production (pp. 32). Paris, France: United Nations Environment Programme.
USEPA. (1988). Waste Minimisation Opportunity Assessment Manual (pp. 26). Cincinnatti (OH), USA: United States Environmental Protection Agency.
USEPA. (1997). Pollution Prevention 1997: a national progress report (pp. 286). Washington DC, USA: United States Environmental Protection Agency.
USEPA. (2001). An Organisational Guide to Pollution Prevention. Cincinnati (OH), USA: United States Environmental Protection Agency.
van Berkel, C. (1996). *Cleaner Production in Practice: methodology development for environmental improvement of industrial production and evaluation of practical experiences.* University of Amsterdam, Amsterdam.
van Berkel, R. (2000). Cleaner Production in Australia: revolutionary strategy or incremental tool? *Australian Journal of Environmental Management, 7*(3), 132-146.
van Berkel, R. (2001). Cleaner Production Perspectives: Cleaner Production and Industrial Development. *Industry and Environment Review, 24*(1-2), 28-32.
van Berkel, R. (2004). Assessment of the Impact of the DESIRE Project on the Uptake of Waste Minimisation in Small Scale Industries in India (1993-1997). *Journal of Cleaner Production, 12*, 269-281.
van Berkel, R., Chandak, S., Sethi, P., & Luken, R. (1995). From Waste To Profits: towards financial and environmental dividends from waste minimization in small scale industries in India. Vienna, Austria: United Nations Industrial Development Organisation.
van Berkel, R., Willems, E., & Lafleur, M. (1997). The Relationship between Cleaner Production and Industrial Ecology. *Journal of Industrial Ecology, 1*(1), 51-66.
van den Ende, J., & Mulder, K. (1998). Traditional and modern technology assessment: towards a toolkit." *Technological Forecasting and Social Change, 58*(17), 5-21.
van Dijk, J. A. G. M. (1990). Delphi questionnaires versus individual and group interviews. *Technological Forecasting and Social Change, 37*, 293-304.
van Geenhuizen, M. (2008). Knowledge networks of young innovators in the urban economy: Biotechnology as a case study. *Entrepreneurship & Regional Development, March*, 161-183.
Vickers, I., & Cordey-Hayes, M. (1999). Cleaner Production and Organizational Learning. *Technology Analysis & Strategic Management, 11*(1), 75-94.
Waas, T., Verbruggen, A., & Wright, T. (2010). University research for sustainable development: definition and characteristics explored. *Journal of Cleaner Production, 18*, 629-636.
WBCSD. (2000). Eco-Efficiency: creating more value with less impact (pp. 32). Geneva, Switzerland: World Business Council for Sustainable Development.

WBCSD. (2000). Measuring Eco-Efficiency: a guide to reporting company performance (pp. 36). Geneva, Switzerland: World Business Council for Sustainable Development.

WBCSD/UNEP. (1996). Eco-Efficiency and Cleaner Production: charting the course to sustainability (pp. 18). Geneva, Switzerland/Paris, France: World Business Council for Sustainable Development and United Nations Environment Programme.

Wickham, P. A. (2004). *Strategic Entrepreneurship* (3rd Edition ed.). Harlow, England: Pearson Education Limited.

Wieandt, A., & Amin, N. (1994). Biotechnology: the emerging battlefield for US and Japanese pharmaceutical companies. *Technology Analysis and Strategic Management, 6*(4), 423-435.

Willoughby, K. W. (1999). Strategies for the Local Development of Advanced Technology Industry: Clues from the Case of Biotechnology in New York State Perth: Graduate School of Management, University of Western Australia.

Woolgar, S., Vaux, J., Gomes, P., Ezingeard, J. N., & Grieve, R. J. (1998). Abilities and competencies required, particularly by small firms, to identify and acquire new technology. [journal]. *Technovation, 18*(8/9), 575-584.

Young, P. (2002a). Biotech in Queensland: beautiful one day, smart the next. *Australian Biotechnology News, 1*(4), 24-28.

Young, P. (2002b). Bioclusters: get it together *Australian Biotechnology News, 1*(31), 26-28.

Zahra, S. A. (1995). Corporate entrepreneurship and financial performance: The case of management leveraged buyouts. *Journal of Business Venturing., 10*(3), 225-247.

Zheng, S. X., Meng, X. H., Yin, H. T., Tam, C. M., & Sun, L. (2010). Impact of cleaner production on business performance. *Journal of Cleaner Production, 18*, 975-983.

Zikmund, W. (2000). *Business Research Methods* (6th ed.). Orlando (Fl), USA: The Dryden Press.

Zutshi, A., & Zohal, A. (2002). Environmental Management Systems Adoption by Australasian Organisations: Part 1: Reasons, Benefits and Impediments. *Technovation*.

Zutshi, A., & Zohal, A. (2003). A Study of the Environmental Management System Adoption Process within Australasian Organisations: Part 2: Role of Stakeholders. *Technovation, 23*.

Appendices

1. Copyright permission
2. Human Ethics certificate of approval
3. Open-ended Questionnaire to test the Validity/Practicality of Models proposed for regional development and sustainability.
4. SurveyMonkey questionnaire
5. Chapter 5 Cooperative Research Centres and Industrial Clusters: Implications for Australian Biotechnology Strategies

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Contribution to 'Cooperative Research Centres and Industrial Clusters: Implications for Australian Biotechnology Strategies' x Inbox x

Peter Galvin to me

show details 11 Aug (5 days ago)

The DBA thesis of Alan Howgrave-Graham contains a book chapter on which both Alan and myself are both listed as authors.

In respect of this publication (Cooperative Research Centres and Industrial Clusters: Implications for Australian Biotechnology Strategies) Alan contributed approximately 85% to the paper and myself the remaining 15%. My contribution was limited to some of the theoretical framing in the early stages and focussing the ideas at the very late stages. All remaining work was undertaken by Alan.

Kind regards,
Peter

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Newcastle Business School is ranked 6th for Graduate Level Employability and 23rd (out of 93) for Business in 'The Sunday Times Good University Guide 2011'

Vienna, 12th August 2011

Subject: "Assessment of Cleaner Production uptake: method development and trial with small businesses in Western Australia', by Alan HOWGRAVE GRAHAM and Rene VAN BERKEL, published in Journal of Cleaner Production, Vol 15 (2007), pg 787 – 797.

The above paper is based on a desk top and (telephone) survey research project by Dr Howgrave-Graham while he was working during 2001-2002 under my supervision at the Centre of Excellence in Cleaner Production at Curtin University of Technology (Perth Australia), where I was at the time the Director and Founding Professor in Cleaner Production.

I provided the conceptual and methodological foundations for this exploratory research, which Dr Howgave-Graham operationalized in a survey instrument, which he applied in the pilot assessment. He assumed full responsibility for the sampling, surveying and data-analysis and interpretation. The resulting research paper was drafted in an iterative and collaborative manner.

I fully support the inclusion of the subject paper in the DBA thesis of Dr Howgrave-Graham as the respective research provided a building block upon which he further developed his thesis after his resignation from the Centre of Excellence in Cleaner Production.

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Appendix 2 Human Ethics certificate of approval

MONASH University

Monash University Human Research Ethics Committee (MUHREC)
Research Office

Human Ethics Certificate of Approval

Date:	**30 July 2009**
Project Number:	**CF09/1829- 2009001037**
Project Title:	**Testing innovation and development models for regional and sustainable development**
Chief Investigator:	**Dr Alan Howgrave-Graham**
Approved:	**From: 30 July 2009** **To: 30 July 2014**

Terms of approval

1. The Chief investigator is responsible for ensuring that permission letters are obtained, if relevant, and a copy forwarded to MUHREC before any data collection can occur at the specified organisation. **Failure to provide permission letters to MUHREC before data collection commences is in breach of the National Statement on Ethical Conduct in Human Research and the Australian Code for the Responsible Conduct of Research.**
2. Approval is only valid whilst you hold a position at Monash University.
3. It is the responsibility of the Chief Investigator to ensure that all investigators are aware of the terms of approval and to ensure the project is conducted as approved by SCERH.
4. You should notify MUHREC immediately of any serious or unexpected adverse effects on participants or unforeseen events affecting the ethical acceptability of the project.
5. The Explanatory Statement must be on Monash University letterhead and the Monash University complaints clause must contain your project number.
6. **Amendments to the approved project (including changes in personnel):** Requires the submission of a Request for Amendment form to MUHREC and must not begin without written approval from SCERH. Substantial variations may require a new application.
7. **Future correspondence:** Please quote the project number and project title above in any further correspondence.
8. **Annual reports:** Continued approval of this project is dependent on the submission of an Annual Report. This is determined by the date of your letter of approval.
9. **Final report:** A Final Report should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected date of completion.
10. **Monitoring:** Projects may be subject to an audit or any other form of monitoring by MUHREC at any time.
11. **Retention and storage of data:** The Chief Investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.

Ben Canny

Professor Ben Canny
Chair, SCERH

Postal – Monash University, Vic 3800, Australia
Building 3E, Room 111, Clayton Campus, Wellington Road, Clayton
Telephone +61 3 9905 5490 Facsimile +61 3 9905 3831
Email muhrec@adm.monash.edu.au www.monash.edu/research/ethics/human/index/html
ABN 12 377 614 012 CRICOS Provider #00008C

Appendix 3 Open-ended Questionnaire to test the Validity/Practicality of Models proposed for regional development and sustainability.

MONASH University

15 August 2009

Explanatory Statement : Alan Howgrave-Graham

Title: Testing innovation and development models for regional and sustainable development

My name is Alan Howgrave-Graham and I am a lecturer in the School of Applied Sciences and Engineering at Monash University.

Because of your position in a Gippsland local organisation directly or indirectly involved in regional and/or sustainable development I request that you complete the following questionnaire. The purpose is to test a couple of models that I proposed and published in the International Journal of Environmental, Cultural, Economic and Social Sustainability (2008), and the International Journal of Technology, Knowledge and Society (2009).

Your response will be collated with those from those of other organisations to determine the status of innovation, sustainability and regional development in Australia or Gippsland. The models proposed in the above publications suggest novel ways in which productivity can be enhanced and this study is aimed at determining to what extent the proposed linkages exist and are already generating the hoped-for productivity in Australia. My background is in biotechnology in the broadest sense and I have thus included a couple of questions to enable me to compare biotechnology-based CRC's and activities to those that are not involved in biotechnology.

I would ultimately like to publish this research in a journal and then use the publication as the key chapter for completion of my Doctorate of Business Administration thesis, for which I am registered with Curtin University of Technology.

These published works would indicate how well knowledge flows currently occur in Australia and Gippsland to enhance regional and national productivity. Identification of barriers to innovation would generate suggestions of how to overcome them, and the suitability of the published models for practical implementation (nationally and locally) by policymakers determined.

This questionnaire has mostly open-ended questions and is to be submitted to a few senior Government, NGO, University and Industry representatives, requesting that they identify the advantages and limitations to the models proposed. It is anticipated that this questionnaires should take about 20-40 minutes, depending upon the length of the responses, and involves the critical evaluation of the two journal articles mentioned above.

The questions have been designed so that no disclosure of confidential information is requested (except your contact details) and that, due to the aggregation of results, your identity and that of your organisation is not to be made public in the journal article or the thesis. My intention is to limit any inconvenience to that of time lost through completion of the questionnaire, for which I apologise.

Due to the extra effort required for this open-ended questionnaire, and a limited budget to reward this effort, I am in a position to offer a 2GB memory stick as a reward to the participants that are asked to complete this questionnaire and do so.

Being in this study is voluntary and you are under no obligation to consent to participation and have the option to respond anonymously if you wish to do so. If you do consent to participate, you may only withdraw prior to the questionnaire being submitted unless you have entered your contact details, in which case you can do so any time within fourteen days of submitting your questionnaire.

Confidentiality
Neither you, nor your organisation will be identified in the publication or thesis unless I have your written permission to do so. Results are to be de-identified and aggregated to ensure anonymity and it is unlikely that you will be approached after the results have been analysed, unless it is for permission to be identified on the basis of an anomaly such as excellence at a particular activity.

Storage of data
Storage of the data collected will adhere to the University regulations and kept on University premises in a locked cupboard/filing cabinet for 5 years. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

Use of data for other purposes
The anonymous data collected for this study may be used for other purposes and because it is anonymous, nobody will be named or identified. In the unlikely event of a specific request to investigate an aspect of this study further requiring the identity of a participant to be revealed, written permission from this individual/organisation will be obtained before such information is revealed.

Results
If you would like to be informed of the aggregate research finding, please contact Alan Howgrave-Graham on (03) 99026439 or e-mail alan.howgrave-graham@sci.monash.edu.au. The findings will accessible upon publication of the results, or if unsuccessful at this endeavour, until the end of 2010.

If you would like to contact the researcher about any aspect of this study, please contact the Chief Investigator: Alan Howgrave-Graham	**If you have a complaint concerning the manner in which this research CF09/1829-2009001037 is being conducted, please contact:**
School of Applied Sciences and Engineering **Telephone: (03)99026439 or 51226439 (from Vic)** **Fax: (03) 99026738 or 51226738 (from Victoria)** **e-mail: alan.howgrave-graham@sci.monash.edu.au**	**Executive Officer, Human Research Ethics Monash University Human Research Ethics Committee (MUHREC)** **Building 3e Room 111** **Research Office** **Monash University VIC 3800** **Tel: +61 3 9905 2052 Fax: +61 3 9905 3831** **Email: muhrec@adm.monash.edu.au**

Thank you.

Alan Howgrave-Graham

Open-ended Questionnaire to test the Validity/Practicality of Models proposed for regional development and sustainability.

Dear participant,

You have been selected on the basis of your knowledge, seniority and affiliation as being one of the few experts who would be able to critically evaluate the models I have proposed to drive regional development and sustainable development, with Gippsland as the main region under investigation.

I therefore request that you peruse the models diagrammatically represented in my two publications on these topics (attached) and answer the following questions concerning their viability and practicality as pertaining to Gippsland and/or Latrobe Valley. The results of this survey are to be de-identified and aggregated with those of the other experts I have also approached for this input, prior to publication.

As a reward for your participation, I would like to present you with a complimentary 2GB USB memory stick upon the return of your completed questionnaire.

Questionnaire

Name and position :____________________________

Affiliation :______________________________

Contact details: email_______________________

Telephone number (W)______________________

Postal Address: ________________________________

____

____

QUESTIONS:

In your response to each of the following questions, please enter as many items as you think are relevant, from the most important to the least important. If you think that less than 5 items are relevant in any particular question, please feel free to expand on any other item listed in the space provided.

With respect to the attached publication, "An Interdisciplinary Knowledge Transfer Approach to Facilitate Sustainable Development: Australia as an example":

A1) I believe the model proposed on page 14 **Can/Cannot** (indicate whichever is applicable) succeed in Gippsland (please indicate where you are referring to Latrobe Valley only) because:

a)____

b)____

c)____

d)____

e)____

A2) The following positive attributes are already being met by the model proposed (please indicate where you are referring to Latrobe Valley only):

a)____

b)____

c)____

d)____

e)____

A3) **The following hurdles need to be overcome for the model proposed to succeed in Gippsland (please indicate where you are referring to Latrobe Valley only):**

a)____

b)____

c)____

d)____

e)____

A4) **These hurdles can be overcome by:**

a)____

b)____

c)____

d)____

e)____

A5 **Do you think this is a good model for:**

Latrobe Valley	Yes	☐	No	☐
Gippsland	Yes	☐	No	☐
Victoria	Yes	☐	No	☐
Australia	Yes	☐	No	☐

A6) **Comments:**____

____

With respect to the attached publication, "An Innovation and Development Model for Regional University Campuses":

B1) I believe the model proposed on pages 80 and 82 **Can/Cannot** (indicate whichever is applicable) succeed in Gippsland (please indicate where you are referring to Latrobe Valley only) because:

a)____

b)____

c)____

d)____

e)____

B2) The following positive attributes are already being met by the model proposed (please indicate where you are referring to Latrobe Valley only):

a)____

b)____

c)____

d)____

e)____

B3) The following hurdles need to be overcome for the model proposed to succeed in Gippsland (please indicate where you are referring to Latrobe Valley only):

a)____

b)____

c)____

d)____

e)____

B4) These hurdles can be overcome by:

a)____

b)____

c)____

d)____

e)____

B5) Do you think this is a good model for:

Latrobe Valley	Yes	☐	No	☐
Gippsland	Yes	☐	No	☐
Victoria	Yes	☐	No	☐
Australia	Yes	☐	No	☐

B6) Comments:____

____

Are you aware of Cooperative Research Centre (CRC) activities in:

C1) Gippsland Yes ☐ No ☐ If your answer is yes, which CRC('s)?

____

____

C2) Latrobe Valley Yes ☐ No ☐ If your answer is yes, which CRC('s)?

____

____

D) Please indicate to what extent you believe biotechnology is conducted in Gippsland in terms of:

(a) The broad definition which involves the use of enzymes or microorganismin industry or the manufacture of biological products such as beer, wine, cheese, bread or yoghurt making, or the biological treatment of wastes?

____________________% of the region's activity.

(b) The molecular biology definition which involves nucleic acid techniques?

____________________% of the region's activity.

(c) Another broad definition: "the manipulation or modification of living organisms (or parts of organisms) for gain" – this may include anything covered in (a) and (b) as well as their inhibition, such as in preventing food spoilage, controlling plant pathogens, or preventing the microbial corrosion or metal or wood.

____________________% of the region's activity.

2) Please indicate to what extent you believe biotechnology is conducted in Latrobe Valley in terms of:

(d) The broad definition which involves the use of enzymes or microorganisms in industry or the manufacture of biological products such as beer, wine, cheese, bread or yoghurt making, or the biological treatment of wastes?

____________________% of the region's activity.

(e) The molecular biology definition which involves nucleic acid techniques?

____________________% of the region's activity.

(f) Another broad definition: "the manipulation or modification of living organisms (or parts of organisms) for gain" – this may include anything covered in (a) and (b) as well as their inhibition, such as in preventing food spoilage, controlling plant pathogens, or preventing the microbial corrosion of metal or wood.

____________________% of the region's activity.

PLEASE NOTE: Your identity and affiliation will IN NO WAY BE LINKED TO YOUR RESPONSES ON THIS QUESTIONNAIRE. Your responses will be kept anonymous and be aggregated with responses from other participants. All responses will be locked away for a period of five years before being destroyed.

Please complete this questionnaire within two weeks of receiving it and e-mail it to me or post it to me at:

Dr Alan Howgrave-Graham
School of Applied Sciences and Engineering
Monash University Gippsland Campus
Churchill VIC3840

If you have any queries, please do not hesitate to contact me at:

alan.howgrave-graham@sci.monash.edu.au

On the other hand, if you have any complaints regarding how this survey was handled, please contact:

SCERH
Building 3E Room 111
Research Office
MONASH UNIVERSITY VIC 3800
OR
Email: scerh@adm.monash.edu.au

THANK YOU FOR YOUR INPUT!!!

Please sign here once you receive your 2GB Memory Stick__________________________

Appendix 4 SurveyMonkey questionnaire

Enter a Name for your Report

Name: New Report (max 50 characters)

Select the Questions to Include (Select All / Unselect All)

☐ About your centre

- ☑ **Q1.** Please indicate the number of members of your centre that are:
- ☑ **Q2.** Please give the name of your centre/CRC
- ☑ **Q3.** How long has your centre existed?

☐ Productivity of your centre

- ☑ **Q4.** Please indicate the number of patents generated by your centre in the past 5 years:
- ☑ **Q5.** Please indicate the number of spin-off companies created by your centre in the past 5 years:
- ☑ **Q6.** Please indicate of the number of license agreements your centre has obtained in the past five years:
- ☑ **Q7.** Please indicate the number of licenses for products your centre has awarded to affiliated or external entities in the past 5 years:
- ☑ **Q8.** Please indicate the number of publications (books, book chapters, peer-reviewed journal articles, peer reviewed conference papers) generated by your centre in the past 5 years:
- ☑ **Q9.** Please indicate the number of post-graduate research degree completions (masters and doctorates) completed at your centre in the past 5 years:
- ☑ **Q10.** Please indicate the number of applied research projects undertaken in the past 5 years by your centre that were/are funded by government or industry and seen as having short-term practical outcomes (within 2 years) in terms of cost-saving, infrastructure development, problem-solving, environmental benefits or profit-making:
- ☑ **Q11.** Please estimate the proportion of projects in the above question (7) that have resulted in specific commercially beneficial outcomes such as patents, spin-off companies or licenses:

☐ Champions or innovators in your centre

- ☑ **Q12.** Of you externally funded applied research projects referred to in the previous page, how many were initiated by:

Biotechnology at your centre

- **Q13.** Is your centre involved in any biotechnology in terms of the broadest definition "the manipulation or modification of living organisms (or parts of organisms) for gain" - this may include the production of biological products such as beer, wine, cheese, bread, yoghurt, enzymes or antibodies, or the biological treatment of wastes. Or it may involve inhibition of microorganisms such as preventing the microbial corrosion of metal or wood, preventing food spoilage or controlling animal or plant pathogens?
- **Q14.** If your answer above is yes, please indicate what percentage of your centre's projects involve this type of biotechnology.
- **Q15.** Is your centre involved in any biotechnology in terms of a narrower definition "the use of enzymes or microorganisms in industry or the manufacture of biological products such as beer, wine, cheese, bread, yoghurt, enzymes or antibodies, or the biological treatment of wastes"?
- **Q16.** If your answer above is yes, please indicate what percentage of your centre's projects involve this type of biotechnology.
- **Q17.** Is your centre involved in any biotechnology in terms of the narrowest definition ie. the molecular biology one in which nucleic acid/molecular biology techniques are applied?
- **Q18.** If your answer above is yes, please indicate what percentage of your centre's projects involve this type of biotechnology.

Sustainability and regional development

- **Q19.** What proportion of the projects at your centre target the commercialisation of environmental technology (such as developing infrastructure to harness renewable energy, or developing novel wastewater treatment processes)?
- **Q20.** Please give an example.
- **Q21.** What proportion of the projects at your centre formally incorporate environmental considerations into the development of new products (such as the deliberate use of recycleable materials into new product design)?
- **Q22.** Please give an example.
- **Q23.** What proportion of the projects at your centre are focussed upon improving existing products or processes to limit environmental impact (such as using less material, water, or energy, or emitting less greenhouse gases during manufacture or harvesting)?
- **Q24.** Please give an example.
- **Q25.** What proportion of the projects at your centre target protection of environmental resources such as forests and water bodies?

- ☑ **Q26.** What proportion of the projects at your centre have led to development in terms of employment growth or revenue generation?
- ☑ **Q27.** What proportion of the projects at your centre have lead to development outside major metropolitan areas (Australian capital cities)?
- ☑ **Q28.** What proportion of the projects at your centre should (but have not yet) led to development outside major metropolitan areas (Australian capital cities) in terms of employment growth or revenue generation?
- ☑ **Q29.** Does your centre conduct any of its activities in Gippsland, Victoria?
- ☑ **Q30.** Does your centre conduct any of its activities in Latrobe City, Gippsland?

☐ Funding, Research and Clusters

- ☑ **Q31.** Please indicate the percentage of funding for your centre from:
- ☑ **Q32.** What percentage of your centre's research do you see as being:
- ☑ **Q33.** Does your centre have any "clusters" (geographical grouping of member institutions in close proximity to exchange ideas)?
- ☑ **Q34.** If yes, how many?
- ☑ **Q35.** How many of these clusters are in regional areas (away from Australian capital cities)?
- ☑ **Q36.** Are any of these clusters in Gippsland, Victoria?
- ☑ **Q37.** Are any of the clusters in Latrobe Valley, Gippsland?

☐ Open-ended questions

- ☑ **Q38.** What are the main objectives of your centre?
- ☑ **Q39.** What are the greatest barriers to your centre achieving its objectives?
- ☑ **Q40.** Has the global financial crisis (2007-2009) affected your centre's activities?
- ☑ **Q41.** If the answer to the last question was "Yes", please indicate how.

Chapter 5

Cooperative Research Centres and Industrial Clusters: Implications for Australian Biotechnology Strategies

Alan Howgrave-Graham and Peter Galvin

Introduction

The success of various high technology industry clusters around the world has prompted governments at all levels to try and emulate this success through the introduction of technology policies that will develop many of the key aspects thought to be driving the success of these clusters. Rarely have governments been able to truly replicate the success of the best known clusters such as IT in Silicon Valley and the Route 128 region, and biotechnology in the South Bay area of greater San Francisco; however, these policies have often been instrumental in improving the competitiveness of a local high technology industry. This paper reviews the Australian Government's policies, especially that of utilizing a CRC (Cooperative Research Centre) model, as well as the strategies of individual Australian states. This review considers the appropriateness of the CRC model for the development of the Australian biotechnology industry and investigates how this model integrates with the development strategies used by various Australian states.

This paper will compare published state and national Australian strategies with each other and relate these to current infrastructure and practices by CRCs and industrial clusters to support them. The most crucial concepts to be investigated include Australia's productivity, alignment, complementarity and knowledge transfer mechanisms in biotechnology. Its current international standing and reasons for this position will be mentioned and the potential for it to be more significant globally will be discussed, together with the strategies it should pursue to be more successful.

What is Biotechnology?

For thousands of years, old (or traditional) biotechnologies have been used to generate a profit in the fermentation industries, for example in the making of cheese, wine, beer, yoghurt and other foodstuffs. Many of the processes would have been discovered by accident resulting from a lack of proper preservation methods. Inhibition of microbe induced deterioration by high concentrations of inhibitors such as salt or sugar would also have been observed while the treatment of infections using antibiotic-producing organisms was practiced by the ancient Egyptians. Thus while biotechnology in its traditional sense has been around for a considerable period of time, difficulties transporting biotechnology-based products limited the competitiveness of any one region to the extent that most regions engaged in basic biotechnology processes.

The emergence of new biotechnology applications, the advancement of supporting technologies, and globalization have created significant opportunities for the exploitation (in a commercial sense) of biotechnology. 'Old' and 'new' biotechnologies now run concurrently though where the boundaries lie definitionally are not entirely clear. Acharya (1999, p. 15) relies upon different definitions including 'the industrial use of recombinant DNA, cell fusion and novel bioprocessing techniques' and another as being 'any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses'. Moses and Moses (1995, p. 1) take a slightly different approach, suggesting that biotechnology has two major attributes, namely that 'it is a technology, a set of techniques for doing practical things, all of them with implications for the commercial and/or the public sectors'. These authors continue by saying that it involves 'making products and providing services which can be sold for a price in the marketplace, or paid for from the public purse'. In the 2000 Australian National Biotechnology Strategy (http://www.botany.unimelb.edu.au/envisci/nick/prop-biotech_nat_strategy.pdf, a precise definition is not attempted but 'modern biotechnology', using recent more advanced nucleic acid-based techniques is distinguished from 'traditional fermentation technologies', representing the 'older' biotechnologies. The *Biotechnology: Strategic Development Plan for Victoria* (Department of State and Regional Development, 2001, p. 7) defines biotechnology as 'the application of knowledge about living organisms and their components to make new products and to develop new industrial processes'. It is thus apparent that semantics is the first problem policy makers and strategists encounter when attempting to prioritize or fund 'biotechnology' initiatives. Not least of these is the dismissive attitude that 'old biotechnologies' or 'traditional fermentation technologies' are already established and have little room for improvement.

In this paper, the definition 'the manipulation or modification of living organisms (or parts of organisms) for gain' is being embraced to encompass both the 'modern' and the 'old' biotechnologies (across the fields of biomedicine, agriculture, environment, mining and bioinformatics), hence including more stakeholders and a wider range of networks and associations.

The Current State of Australian Biotechnology

The United States was the leader in this field in the early 1990s (Herbig and Miller, 1992), largely due to President Reagan's 1982 policies including universities being permitted to take title to technologies developed using federal funding (Stewart, 1991). The United States' current leadership is largely due to its high R&D expenditure by both government and industry (Mitchell, 1999), being approximately US $28 billion in 1999 (Department of State and Regional Development, 2001, p. 14). Europe was slow to follow the United State's lead, largely due to policy issues creating a negative external environment for the exploitation of biotechnology (Senker, 1998). In Japan, the only other country (outside North America and Europe) Acharya (1999, p. 32) identified as being 'industrialized', the government has more recently made extensive efforts to build up biotechnology disciplines. Here, the lack of private finance and the strong actions of the state in funding major research agencies have led to the clustering of biotechnology and pharmaceutical firms around national laboratories (Wieandt and Amin, 1994). Government support in the above countries has contributed to the formation of high technology clusters, which have been associated with exceptionally high rates of technological innovation (Baptista and Swann, 1998).

In contrast, a lack of government support until recently has severely hampered Australia's biotechnology competitiveness and the economy has been branded in news reports as being 'commodity based' as recently as 2001, leading to a drive to emulate the success of the above industrialized countries. Ernst and Young (2001) paint a brighter picture of Australia emerging over the past decade during which government policy has provided opportunities to identify and add value to the fundamental research base. These authors identified that Australian biotechnology continues to grow but remains small in global terms with almost $1 billion in revenue in the 2000/2001 tax year with three sectors dominating namely: human health; equipment and services; and agriculture. This followed an expenditure of approximately $447 million on biotechnology R&D in the previous year.

The Role of Government in Developing Biotechnology

In light of a vast array of opportunities in biotechnology, many of which require expensive research before they can be considered 'market ready', external funding is often required for success in these ventures (Sherblom, 1991). Acharya (1999, p. 54) in describing biotechnology in industrialized nations indicated that success has been dependent upon the scientific base, activities of the private sector and the importance of government in developing a suitable environment for it to flourish.

According to Acharya (1999, p. 32) governments in developed countries encouraged the formation of biotechnology firms by providing finance in the form of loans or grants, or by developing links between research and production through the formation of networks. Methods to try and build networks were identified such as the creation of science or technology parks. The governments' regulatory role was also considered significant. However, within developed countries such as the USA for example, Willoughby (1999) identified that New York was less competitive than other states, partly because of regulatory and economic constraints imposed by state government.

Australian Government Biotechnology Input

In order to foster the environment alluded to above, in which biotechnology could flourish, the Federal Government initiated a Cooperative Research Centre (CRC) Program more than ten years ago to boost the competitiveness of Australian industry. Both Federal and state governments also have additional funding available to support strategically important biotechnology initiatives, although historically this has been nowhere near as much as Australia's major competitors have invested in this field.

In addition, the federal and state governments have developed regulatory frameworks in which biotechnology research and commercialization can be conducted in an ethical manner. The greatest challenges in the development of new products are to ensure public health and safety and the preservation of Australia's unique environment. For example, the Commonwealth Gene Technology Act (2000) establishes a national scheme to regulate gene technology and provides a framework to achieve coordination across all levels of government. The regulatory framework for biotechnology is outlined in more detail in a document with the same name, produced by Victoria State Government's Department of Human Services (2002). A fine balance exists between under-regulation, which can have catastrophic consequences to the region concerned and its customers, and over-regulation that would stifle industry growth. It is still too early to determine the consequences, or even appropriateness of Australia's regulatory framework. Besides the public liability threats to biotechnology research, civil cases such as the Canadian one involving Monsanto's transgenic canola are set to test intellectual property rights in the courts.

More recently, the Commonwealth and most State Governments have formulated biotechnology strategy documents to outline the respective governments' vision and support for biotechnology. The national strategy and a few state examples are outlined and compared below and related to state-specific outcomes.

Australian Government Biotechnology Strategies

Australian organizations have been conducting biotechnology research for some time but the Commonwealth and State Governments, realizing the potential benefits of developing this technology for commercialization, recently started to take an active interest in this field, releasing a series of strategy documents during 2000 and 2001.

In 1999, the Biotechnology Consultative Group (BIOCOG) was formed to advise Biotechnology Australia and the Commonwealth Biotechnology Ministerial Council on the development of the recently released National Biotechnology Strategy. It is intended to provide a framework for Government and key stakeholders to capture the benefits of biotechnology development for Australia (Australian National Biotechnology Strategy, 2000).

In 2000 the Commonwealth Government published a biotechnology strategy document in which it outlined its national strategy. This concentrated on safeguarding human health and the environment through regulation; facilitation of community education and involvement in public policymaking; productive investment in biotechnology and biotechnology training; enhancing economic and community benefits of biotechnology by enhancing links between the research sector and industries as well as better management of intellectual property.

The states in turn have expressed visions or missions with Victoria's State Government expressing their desire to be recognized as one of the world's top five biotechnology locations by 2010 (Department of State and Regional Development, 2001, p. 2); South Australia aiming to accelerate its bioscience development, enabling the creation of 50 new bioscience companies by 2010 (http://www.bioinnovationsa.com.au/template/php); New South Wales initiated its BioFIRST strategy, enabling the state to create and respond to biotechnology opportunities through growth in its infrastructure, intellectual and capital wealth; while Queensland aims to be the Asia Pacific biotechnology hub (http://www.treasury.qld.gov.au/budget/budget99/smartstate/biotech1.html).

All of these strategy documents were developed since 1999 and list the competitive advantages, limitations and challenges particular to the nation and each state, as well as commitment to funding and actions to be taken to realize their objectives. The CSIRO was identified as a key player in Australian biotechnology and launched its own strategy in 2002 to 'understand what we are doing and where we are going' (Head, cited by Trudinger, 2002).

The strategies were generally prepared by individuals appointed or requested to do so and may thus be considered 'top-down'. This is dangerous considering public opposition to many of the genetic engineering aspects of biotechnology. However, this problem was overcome by making each strategy broad enough to allow individual decisions to be made with stakeholder inputs and incorporating both regulatory and ethical considerations.

The States' Current Biotechnology Activities

South Australia is one of Australia's emerging states with respect to biotechnology innovation and Hollis (2002) cites the proximity between all the academic institutions and biotechnology firms as well as a high level of communication as major reasons. BioInnovations SA is the state government's instrument for driving biotechnology innovation and has helped the state to develop expertise in genomics, clinical research and drug testing, diagnostics, oral and injectable pharmaceuticals and antivenin development, as well as contract research. Specific applications of these technologies include those in aquatics, pig and poultry production, crop improvement (such as salt tolerant varieties), crop disease diagnostics, cancer treatment. The state government has put $6.3 million into establishing a bionomics research facility in the Thebarton Biotechnology Precinct, which houses Bionomics and other biotechnology companies (Goldberg, 2002a). Bionomics attracted $3.3 million in Federal government funding and has already discovered 137 genes that could be useful in diagnostics or drug development. According to Trudinger (2002), a $1.5 million Biotechnology Fellowship Fund was recently launched by the BioInnovations SA, to be matched by three universities for bringing three eminent researchers to the state.

In Queensland, the biotechnology corridor is stretched between the Gold Coast and Brisbane with a thin band of technology parks and companies between them (Young, 2002a). State government has taken a different approach by not investing directly but being generous in supporting infrastructure, providing the right climate and a high level of encouragement for bioindustry efforts through the Department of Innovation and Information Economy. Despite being considered smaller than New South Wales and Victoria with respect to its biotechnology productivity (Young, 2002a), Queensland is very active in this field with significant Australian Research Council investment in its R&D. It has a range of unique ecologies, encouraging bioprospecting from its marine and other biota while its concentration on the treatment of cancer, vaccine development, disease diagnostic (such as for blood clots) and bioinsecticides are attracting attention, as is its ability to span genomics, structural biology, molecular design and medicinal chemistry (Young, 2002a). A growing number of biotechnology companies are establishing in Queensland, some of which could be considered 'blue chip', while a few recent start-ups have attracted Australian Research Council grants of up to $250,000. State government has also increased its R&D expenditure by more than 300 per cent to about $200 million since the beginning of 2000.

Victoria has a proud history of research and development and Victorian companies comprise 23 of the 62 listed biotech stocks and account for more than half of the $14.9 billion capitalization (Hollis and Trudinger, 2002). In addition, a Biotechnology Platform Technology Working Party has been established to determine and establish infrastructure needs and the state receives a significant proportion of NHMRC funding to complement state and City of Melbourne financial support. Victoria is, with significant state government funding, concentrating on the development of platform technologies such as the synchrotron as well as embryonic stem cell lines and gene targeted mice for supplying the pharmaceutical biotech and medical research industries. These facilities are (and will be) based at precincts such as Parkville and the Monash STRIP and can be used by industries and researchers from throughout Australia and the world. Victoria is also concentrating its efforts and funds on specializing in neurosciences, control of infectious diseases, stem cell research and tissue repair, plant biotechnology, proteomics as well as attracting world-class researchers (Hollis, 2002). Although it is considered to be the medical research capital of Australia, Victoria also hosts 16 research institutes, several CRC nodes and centres targeting agriculture such as the Plant Biotechnology Centre, The Victorian Institute of Dryland Agriculture, AgGenomics (offering plant genomic services) and the Victorian Institute of Animal Science. Its expertise in reproduction and development was identified in Hollis (2002) as being threatened by competition from Brisbane.

Unlike other states, Goldberg (2002b) pointed out that New South Wales (NSW) has not received a lot of infrastructure support from state government, nor had it needed it. Recently there has, however, been more pressure from the biotechnology sector for government to accelerate the growth of the industry through the development and support of relevant projects and strategies. The Hunter Valley project to link six major health and medical research institutions is one example of such a project. NSW is currently leading Australia in infrastructure support for hospital-based clinical research (Goldberg, 2002b). Efforts by state government to overcome the disadvantage of the Sydney sprawl by strengthening existing research relationships are now paying off. BioLink was recently created to link all the research efforts in NSW to make the state more competitive through cooperation (Goldberg, 2002b). Most of Australia's venture capital firms are based in Sydney and the government launched its BioFirst program at the end of 2000 involving several departments focusing on issues such as business outcomes, platform technologies and ethics. NSW is currently home to 40% of Australia's biotechnology and pharmaceutical companies, generating $2.8 billion in annual sales. It intends to bring back expert expatriates to assist in developing key platform technologies for research into agriculture, medicine and the environment.

Australia's other states and territories, although active in biotechnology, have not advanced as rapidly or as far as the above four states but have other geographical and resource advantages such as Tasmania's proximity to the Antarctic and Western Australia's wealth of mineral resources which have stimulated marine biotechnology and mineral leaching using bacteria respectively. Agricultural biotechnology is also a key activity for these states. Due to Australia's size, the states differ with respect to the problems and opportunities that can be addressed using biotechnology, and these are usually investigated by the affected regions. However, there is also often overlap such as salinity which can be addressed across state boundaries through Cooperative Research Centres (CRCs).

Cooperative Research Centres and Australian Biotechnology

As can be seen from the above synopsis of the most significant biotechnology activities in Australia, there is a bewildering array of participants scattered throughout the country creating the perception that competition between states would often supercede collaboration, potentially leading to considerable duplication of facilities. Such an image can be disastrous in attempts to attract overseas and local venture capital.

The Commonwealth Government introduced a system of Cooperative Research Centres (CRCs) more than ten years ago to bring scientists from Universities, CSIRO, other government institutions, industry and private sector organizations together (Riedlinger, 2002). There are currently 65 centres in diverse fields and, according to Ernst and Young (2001), of the 91 CRCs that were launched since the program's inception, 24 have had significant biotechnology components. Each CRC is funded by both Federal Government and industry, is national and brings research and industry together to work on specific R&D projects that will benefit from the critical mass of effort (http://microtechnologycrc.com/aboutus.html). Riedlinger (2002) mentioned that CRCs have an average annual budget of $7 million while Ernst and Young (2001) indicated that they are selected following a competitive process approximately every two years with funding typically provided for up to seven years. The CRCs practising biotechnology are in the categories of medical science and technology, the environment and agriculture (Riedlinger, 2002).

The CRCs are distributed across states and regions throughout Australia and meet on a fairly regular basis to discuss relevant issues. Some are struggling to meet revenue targets such as the CRC for Waste Management and Pollution Control (Goldberg, 2002b) while others, such as the Adelaide-based CRC for Tissue Growth and Repair are on the verge of transforming into independent companies once government funding expires. Many of the CRCs have commercial arms, such as the CRC for Vaccine Technology with its commercial arm, Vaccine Solutions, in Queensland (Young, 2002b).

Clustering in Biotechnology

The benefit of clustering firms, academic institutions, supporting infrastructure and sometimes even customers and suppliers in geographical proximity to enhance competitiveness has long been recognized with Silicon Valley cited as being the most prominent example in the USA. The formation of 'geographical clusters' defined by Baptista and Swann (1998) as 'strong collections of related companies and located in a geographical area, sometimes centred on a strong part of a country's science base' would be important in enhancing innovation (de la Rosa and Martin, 2000), one of the main objectives of such a strategy. The groupings have been referred to interchangeably as technology parks, precincts, hubs or clusters (Young, 2002b). Massey and Wield (1992) distinguished between clusters and science parks, indicating that the former have had considerable economic success while most science parks have been marginally successful at best.

Galvin and Davies (2002) reflected upon this discrepancy, highlighting the distinction between these two types of grouping. Clusters tended to be less formal networking between organizations in close proximity. Willoughby (1999) identified that successful clusters are characterized by strong 'biotechnology milieux' and are nurtured by rich networks for sharing knowledge both globally and locally. This departs from the 'industrial location factors' perspective described by Willoughby (1999), in which firms are attracted to relocate through reducing the cost of doing business locally. In the 'local technological milieux' perspective, interorganizational communication (locally and globally) is facilitated, primarily by government. This type of grouping is much more formal and many technology parks would fit this description (Galvin and Davies, 2002). Government artificially induces the grouping through incentives such as tax relief or more relaxed regulatory requirements. This is less sustainable in the long term and is sometimes referred to as the 'race to the bottom' as the major incentive is the reduced costs of doing business. The spontaneous generation of informal networks so crucial for knowledge exchange between like-minded organizations is usually absent.

The purpose of clustering, according to Young (2002b) is to achieve critical mass through shared resources (both infrastructure and intellectual) plus knowledge interchange across the boundaries of different disciplines and organizations. A biocluster was described by Bradley (cited by Young, 2002b) as being 'a geographical concentration of interconnected companies, specialized suppliers and service providers and associated academic and medical research institutions which compete but also cooperate'. They have all the components – service providers, incubators, large commercial companies that can contract research out to small companies, financiers and academic research institutes. This describes the basic structure of a cluster but one vital component for success has not been adequately researched and thus described, and that is techniques for micro-managing the flow of knowledge and information between the staff of the different cluster components.

Quoting from interviews with practitioners, Young (2002b) mentioned that setting up cross-organizational information channels is more an art than a science and the linkages within a cluster must be set up at different levels. A lot of interaction is random and spontaneous and, by clustering people in a fairly concentrated physical environment, the chances of it occurring increase.

In Australia, there are no substantial bioclusters that could be compared with those overseas such as in Boston or the South Bay area of greater San Francisco (USA). According to Young (2002b) there are plenty of tech parks, yet we may be ten to 15 years from having a substantial cluster (Monash Research Cluster for Biomedicine possibly being the most likely candidate in the near future). Many of the smaller bioclusters throughout Australia accommodate CRC nodes such as the CRC for Water Quality and Treatment, that has nodes in Western Australia, Queensland, Victoria, South Australia and New South Wales, mainly centred near universities.

Of the more successful Australian states facing the greatest challenges in making clusters work, New South Wales has had less proactive state government support than Victoria or Queensland (Young, 2002b) and the distances between discrete regions and organizations practicing biotechnology are high. South Australia, on the other hand, is pursuing the 'local technological milieu' model, with some duplication and less collaboration than desired including with respect to intellectual property.

The Importance of Networking for National Competitiveness

The underlying purpose of clusters, CRCs and technology parks is to develop and enhance innovation. As alluded to above, a factor significant for the building and retaining of innovation at a national level is the formation and maintenance of linkages and interactions between government support organizations, businesses and academia. Alcorta and Peres (1998) attribute the lack of competitiveness in technological specialization by the Caribbean and Latin American (except Mexico) countries to low investment in intangibles and human capital as well as the fragmentation of such linkages. India successfully founded Industrial Research

Institutes (Katrak, 1998) for research and development collaboration and commercialization while Cuba's success in modern medical biotechnology follows largely from its regime's policy in medicine and health care, support by the Centre for Biological Research (Acharya, 1999, p. 58), and the Cuban Technology Innovation System (de la Rosa and Martin, 2000). Such institutions are important for the formulation and support of biotechnology policies and strategies as well as to support linkages between universities and the productive sectors to ensure the commercialization of research. Such networks, according to Coehen (1996) 'must produce some synergetic effects or additional benefits for its members or it must increase the efficiency of the activity on which the network is focused'. Cluster and CRC formation should enhance innovation and support such networks. Dense networks of contacts made possible through clusters improve innovative capacity and foster economic growth (Peters *et al.*, 1998) if fully exploited. It is just as important to identify the core competencies to be pursued by the cluster or CRC for enhanced competitiveness with inter- and intra-organizational knowledge generation and diffusion being critical to share ideas and eliminate repetition.

University-enterprise linkages were cited by Correa (2000), Fisher (1998) and Meyer-Kramer and Schmoch (1998) as being crucial although the difference in the knowledge developed by universities and that used by and developed in enterprises is cited by Correa (2000) as being an inhibitory factor. The gap between these two types of knowledge is larger for the mature technologies such as food and textiles but less apparent in the high technology industries. For this reason technology transfer offices have been created in many universities to facilitate contractual relationships with enterprises and other potential clients. It can thus be concluded that the nature of the biotechnology (mature or high technology) embraced for competitive advantage by a country or state would determine the type and level of government investment to facilitate R&D and network creation. A scheme of existing and potential linkages in Australian biotechnology is represented in Figure 5.1.

Emphasis is often on which of the 'grand strategies' listed by Pearce and Robinson (1997, p. 217), such as product development, innovation, integration or diversification, to pursue, rather than the cognitive aspects of change. Mezias *et al.* (2001) cite this as a major reason for strategic reorientations being difficult to achieve. Nonaka and Takeuchi (1995) criticize Porter for his under-emphasis on knowledge creation and diffusion. Most strategies rely on either top-down knowledge transfer that emphasizes explicit knowledge transfer, as in a bureaucracy, or a bottom-up approach that concentrates on tacit knowledge transfer through socialization. Nonaka and Takeuchi (1995) thus suggested a 'middle-up-down' approach to management dealing with both types of knowledge. Community and customer input is crucial for biotechnology strategy development due to the controversial nature of some products such as genetically modified foods, while biotechnology practitioners would have the technical knowledge to assess the feasibility of products being considered.

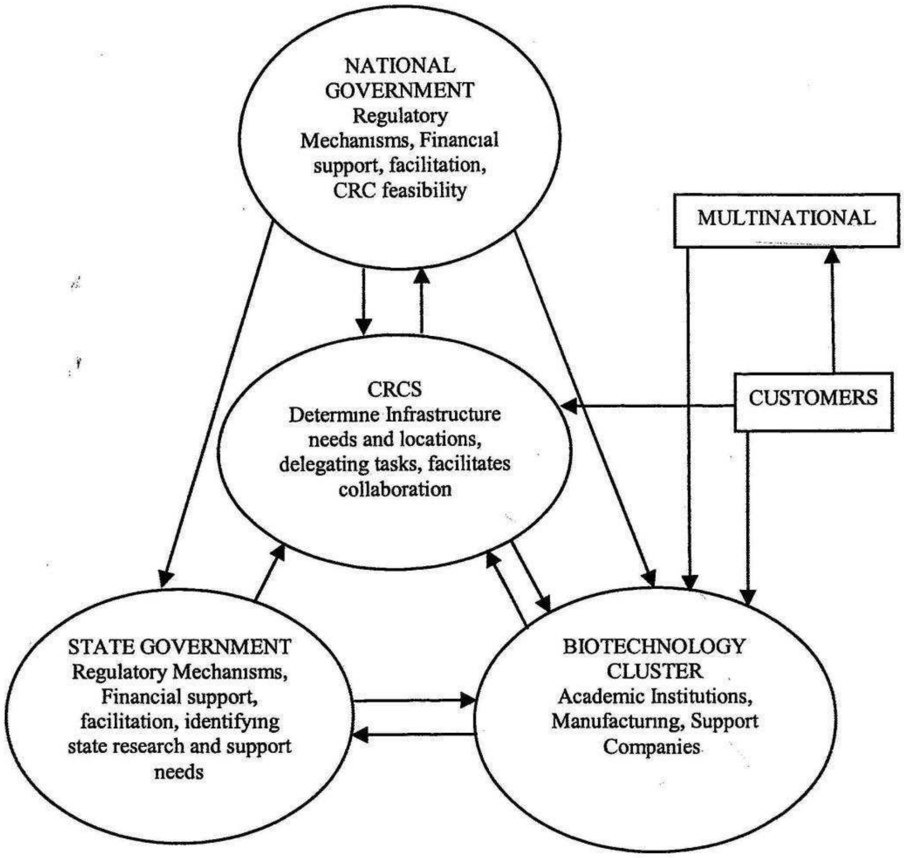

Figure 5.1 Knowledge flows to support Australian biotechnology

Tacit knowledge is socialized in Australia through informal meetings and relevant seminar presentations followed by opportunities to network within and between the organizations such as at the Westmead biomedical cluster in New South Wales (Young, 2002b). On-line discussion forums and e-mail allow the dissemination of previously subjective knowledge across the country, keeping close and distant members of CRCs informed. CRC meetings, due to the geographical distribution of members, cannot occur as regularly as those within clusters but these are still valuable in the transfer of knowledge between members. Publications such as Australian Biotechnology News and cluster or CRC newsletters are also valuable in keeping the biotechnology community informed on breakthroughs, relevant activities and potential linkages across the country and internationally.

How well is Australia positioned for Biotechnology Competitiveness?

So far, the infrastructure for biotechnology development and the strategies prepared to support this have been discussed. So, how successful is Australia, or will it be, in this field? The historical disadvantages were mentioned and these are critical since biotechnology can have long lead times before commercialization. The lack of government funding and support has resulted in what is known as a 'brain drain' with much of Australia's innovative capacity being expatriated to the USA or Europe. There have been regulatory requirement hurdles such as in the import of biological materials that have made the research and innovation environment less favourable. Venture capitalists are perceived by some to be greedy, insisting upon a five-to tenfold increase in their investment within three to five years (mentioned at the Monash Research Cluster for Biomedicine Research Linkage Seminar 1, 2002). Venture capital, for many biotechnology innovations, would thus only be an option once all the risks had been taken and trials are nearing completion. In addition, the retention of intellectual capital, the perceived competition rather than collaboration between organizations and states and a lack of focus on commercialization has deterred investors. Furthermore, multinationals have been deterred by a lack of incentives (Binning, 2002) and would rather invest in Singapore, China or Japan where manufacturing infrastructure is better developed. Whether Australia should try to emulate the Asian countries to attract multinational manufacturing funding rather than capitalize on its innovativeness and research strengths is debatable, especially since the former require incentives that support the less sustainable 'local technological milieu' model described above.

Despite the limited government support in comparison with other developed countries advancing in the biotechnology field, Australia is an innovative country in comparison with its Asian neighbours, such as Singapore (Binning, 2002), which concentrate more on copying other innovations. However, Australia has little manufacturing infrastructure and labour costs are relatively high.

Australian innovation is in part due to the CRC system, which facilitates knowledge diffusion, and the more recent deliberate attempts to facilitate clustering and the associated socialization of tacit knowledge. Recent commitment by Federal and most state governments to support biotechnology development through the publishing of strategy documents as well as increasing financial and other support bodes well for the future. These inputs, together with Australia's wealth of natural resources, innovative capacity and high standard of living have the potential to make the country a world leader in biotechnology in the near future. Traditional biotechnology should be pursued concurrently with modern 'high tech' biotechnologies as the former are in a better position to yield short- to medium term profits through 'value adding' and could enhance development in 'less favoured regions', while the latter generally have much longer lead times and higher costs and would be based in the larger centres. Overlap between traditional and modern biotechnology, enhancing economies of scale through maximization of expensive capital equipment should be considered and coordination with Asian manufacturing capacity may be another feasible option.

To ensure that opportunities are not wasted, care must be taken to prevent the disbanding of CRCs that may have set unrealistic targets or have long lead times for their projects (impatience could result in a waste of all prior funding just before a breakthrough could potentially have been made). Each cluster's components must support the cluster's core business, while expensive infrastructure should be shared rather than duplicated. In addition to enhancing efficiency, this improves networking. Intellectual capital must be kept in the country by retaining key staff and 'extracting' their tacit knowledge in preparation for their eventual departure. For biotechnology to succeed in Australia, knowledge on desired products and processes, a bridging of the gap between research and commercialization paradigms, and a spirit of cooperation rather than competition should be enhanced. Hollis and Trudinger (2002) stated that, for Australia to make its mark in biotechnology, groups across the country need to cooperate more than they currently are. There is thus a requirement for better networking between governments, academic institutions, potential and existing manufacturers and support organizations (such as patent law and marketing firms) to enhance Australia's competitiveness.

Future biotechnology strategies should identify financially viable projects that can be accommodated by the complementary systems of CRCs and their industrial clusters. New CRCs are constantly emerging as opportunities emerge and this should be encouraged while states should strive to attract and support the infrastructure enabling them to efficiently undertake identified biotechnology projects or their components, as delegated by CRCs.

References

Acharya (1999), *The Emergence and Growth of Biotechnology*, Edward Elgar Publishing Ltd., Cheltenham, UK.

Alcorta, L. and Peres, W. (1998), 'Innovation systems and technological specialisation in Latin America and the Caribbean', *Research Policy*, Vol. 26, pp. 857-81.

Australian Biotechnology Strategy (2000), http://www.botany.unimelb.edu.au/envisci/nick/prop-biotech_nat_strategy.pdf

Baptista, R. and Swann, P. (1998), 'Do firms in clusters innovate more?', *Research Policy*, Vol. 27, pp. 525-40.

Binning, D. (2002), 'Money or nothing: Australia versus Singapore Inc.', *Australian Biotechnology News*, Vol. 1(24), pp. 16-21.

Coehen, R. (1996), 'Challenges of networking in technology assessment', *Technological Forecasting and Social Change*, Vol. 51, pp. 49-54.

Commonwealth Gene Technology Act (2000), Office of the Gene Technology Regulator (OGTR), Canberra.

Correa, C.M. (2000), 'University-enterprise linkages in the area of biotechnology', in R.E. Lopez-Martinez and A. Piccaluga, *Knowledge Flows in National Systems of Innovation*, Edward Elgar Publishers Ltd., Cheltenham, UK, pp. 155-67.

De la Rosa, L. and Martin, B.E. (2000), 'The role of the biotechnology and pharmaceutical scientific and productive clusters in the Cuban innovative activity', in R.E. Lopez-Martinez and A. Piccaluga, *Knowledge Flows in National Systems of Innovation*, Edward Elgar Publishers Ltd., Cheltenham, UK, pp. 168-83.

Department of State and Regional Development (2001), *Biotechnology: Strategic Development Plan for Victoria*, Department of State and Regional Development, Science and Technology Division, Melbourne.

Ernst and Young (2001), *Australian Biotechnology Report 2001*. Paragon Printers, Canberra.

Fisher, L.M. (1998), 'Technology transfer at Stanford University', *Harvard Business Review*, Vol. 13, Fourth Quarter, pp. 76-85.

Galvin, P. and Davies, J. (2002), 'Innovativeness in industrial clusters: a theoretical explanation of differences in innovation levels in industry clusters and science parks', *Conference paper presented at the Academy of Management Conference*, Denver, August 2002.

Goldberg, D. (2002a), 'Biotech in South Australia: dancing with the elephants', *Australian Biotechnology News*, Vol. 1(8), p. 28.

Goldberg, D. (2002b), 'Biotech in NSW: United they stand', *Australian Biotechnology News*, Vol 1(5), pp. 30-31.

Herbig, P.A. and Miller, J.C. (1992), 'The United States versus the United Kingdom, Canada, and Australia', *Technological Forecasting and Social Change*, Vol. 41, pp. 423-34.

Hollis, T. (2002), 'Biotech in South Australia: how a 15-minute city bred a biohub', *Australian Biotechnology News*, Volume 1(8), pp. 24-7.

Hollis, T. and Trudinger, M. (2002), 'Biotech in Victoria: smaller players face big issues', *Australian Biotechnology News*, Vol. 1(6), p. 32.

http://www.bioinnovationsa.com.au/template/php.

http://www.botany.unimelb.edu.au/envisci/nick/prop-biotech_nat_strategy.pdf.

http://microtechnologycrc.com/aboutus.html.

http://www.treasury.qld.gov.au/budget/budget99/smartstate/biotech1.html.

Katrak, H. (1998), 'Economic analyses of industrial research institutes in developing countries: The Indian experience', *Research Policy*, Vol. 27, pp. 337-47.

Massey, D. and Wield, D. (1992), 'Science parks: a concept in science, society, and space (a realist tale)', *Environment and Planning*, Vol. 12, pp. 411-22.

Meyer-Kramer, F. and Schmoch, U. (1998), 'Science-based technologies: university-industry interactions in four fields', *Research Policy*, Vol. 27, pp. 835-51.

Mezias, J.M., Grinyer, P. *et al.* (2001), 'Changing collective cognition: A process model for strategic change', *Long Range Planning*, Vol. 34, pp. 71-95.

Mitchell, G.R. (1999), 'Global technology policies for global change', *Technological Forecasting and Social Change*, Vol. 60, pp. 205-14.

Moses, V. and Moses. S. (1995), *Exploiting Biotechnology*, Harwood Academic Publishers, Chur, Switzerland.

National Biotechnology Strategy (2000), Commonwealth Biotechnology Ministerial Council, Canberra.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, New York.

Pearce, J.A. and Robinson, R.B. (1997), *Formulation, Implementation, and Control of Competitive Strategy*, Irwin, Chicago.

Peters, L., Groenewegen, P. *et al.* (1998), 'A comparison of networks between industry and public sector research in materials technology and biotechnology', *Research Policy*, Vol. 27, pp. 255-71.

Riedlinger, M. (2002), 'Cooperative Research Centres going strong in the biosciences', *Today's Life Sciences*, Vol. 14(3), pp. 36-9.

Senker, J. (1998), 'Biotechnology: the external environment' in J. Senker, *Biotechnology and Competitive Advantage*, Edward Elgar Publishing Ltd., Cheltenham, UK, pp. 6-18.

Sherblom, J.P. (1991), 'Ours, theirs, or both? Strategic planning and deal making', in R.D. Ono, *The Business of Biotechnology: From the Bench to the Street*, Butterworth-Heinemann, Boston, pp. 213-24.

Stewart, J.M. (1991), 'Capitalising on new opportunities: Entrepreneurship in biotechnology'. in R.D. Ono, *The Business of Biotechnology: From the Bench to the Street*, Butterworth-Heinemann, Boston, pp. 23-38.

Trudinger, M. (2002), 'The other big Australian' *Australian Biotechnology News*, Vol. 1(25), p.18-20.

Wieandt, A. and Amin, N. (1994), 'Biotechnology: the emerging battlefield for US and Japanese pharmaceutical companies', *Technology Analysis and Strategic Management*, Vol. 6(4), pp. 423-35.

Willoughby, K.W. (1999), 'Strategies for the Local Development of Advanced Technology Industry: Clues from the Case of Biotechnology in New York State', Graduate School of Management, University of Western Australia, Perth.

Young, P. (2002a), 'Biotech in Queensland: beautiful one day, smart the next', *Australian Biotechnology News*, Vol. 1(4), pp. 24-8.

Young, P. (2002b), 'Bioclusters: get it together', *Australian Biotechnology News*, Vol. 1(31), pp. 26-8.