THE RECONSTRUCTION OF REGIONAL SYSTEMS OF INNOVATION TO ALLOW THE EVOLUTION OF THE BIOTECHNOLOGY INDUSTRY IN NON-HIGH TECHNOLOGY REGIONS: THE CASE OF THE WESTERN CAPE REGION IN SOUTH AFRICA

by

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DECLARATION

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ABSTRACT

This study investigates the efforts of stakeholders in a regional innovation system (RIS) to reconstruct the system to enable the development of the nascent biotechnology industry in the Western Cape province of South Africa. Various institutions and organisations played a crucial role in effecting these changes. One of the most important changes involved legislation that altered the role that universities play in bridging the gap between research outputs and reaping commercial benefits from such outputs. Following the logic of the regional innovation system, the study focused on the institutional changes, the mechanisms employed to bridge this gap (from creating spin-off firms, and licensing technologies based on university research, to designing programmes to support the development of bio-entrepreneurs). For a comparative perspective from another region that arrived on the biotechnology scene relatively late, the study includes a section on university spin-offs in biotechnology from Hong Kong universities. Since all the efforts to effect the changes to the RIS that would enhance the growth of this promising industry are relatively new, the study faced the usual problems associated with pioneering developments, such as small samples, a complete lack of databases, etc. For this reason, the questionnaire survey and case study methods were used throughout the study. Starting from the general to the specific, the thesis is divided into four complementary parts. Part I comprises the general literature survey and rationale for the study, while Part II narrows the focus to the organisations and mechanisms that connect knowledge creation and knowledge exploitation in the regional context in the Western Cape, South Africa and Hong Kong, China. Part III evaluates early efforts at building a bridge from science to business in the form of bio-entrepreneurship programmes. Part IV takes a micro view, tracking the evolution of biotechnology spin-offs from Western Cape universities, and highlighting the role that

institutional changes played in the genesis, growth and, unfortunately, demise of some biotechnology spin-offs. The last section concludes.

Throughout the study a familiar refrain repeated itself with respect to the challenges faced by new spin-offs, namely the perennial culprits of a lack of appropriate skills, and funding. From our study, bearing in mind the small scale and the danger of generalisations, it would seem as if the reconstruction of the RIS and related changes in the national innovation system (NIS[1]) did not generate the results that the strategy hoped for (at least in the Western Cape, the focus of our study). A beam of light is the relative success achieved with the development and implementation of a bio-entrepreneurship training programme, which laid the foundation to build a more sustainable bridge between the science of biotechnology and the commercial world where the wealth creation opportunities reside.

1 NIS and NSI, and RIS and RSI, respectively, are used interchangeably in the literature.

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LIST OF ABBREVIATIONS

AUTM	Association of University Technology Managers
BRICs	Biotechnology Regional Innovation Centres
CityU	City University
CUHK	Chinese University of Hong Kong
BBBEE	Broad-Based Black Economic Empowered
BioPAD	Biotechnology Partnership for Africa's Development
CA	Chartered Accountant
CBI	Cape Biotech Initiative
CeBER	the Centre for Bioprocess Engineering Research
EcoBio	the East Coast Biotechnology Consortium
ECR-TTO	the Eastern Cape Regional Technology Transfer Office
ICMM	the Institute for the Cellular and Molecular Medicine
IP	Intellectual Property
IPF	Intellectual Property Fund
IWBT	the Institute of Wine Biotechnology
HEIs	Higher Education Institutions
HKUST	Hong Kong University of Science and Technology
MRC	the Medical Research Council
NBS	National Biotechnology Strategy
NGOs	Non-Governmental Organisations
NIPMO	the National Intellectual Property Management Office
NIS	National Innovation Systems
NMMU	Nelson Mandela Metropolitan University

OIL	the Office for Industry Liaison
PolyU	Hong Kong Polytechnic University
PPPs	Public-Private Partnerships
PROs	Public Research Organisations
RCIPS	Research Contracts and Intellectual Property Services
RIS	Regional Innovation Systems
R&D	Research and Development
SBFs	Specialized Biotechnology Firms
SIS	Sectoral Innovation Systems
STEM	Science, Technology, Engineering and Maths
SU	Stellenbosch University
THRIP	the Technology and Human Resources for Industry Programme
TIA	Technology Innovation Agency
TIS	Technological Innovation Systems
TT	Technology Transfer
TTO	Technology Transfer Offices
UCT	University of Cape Town
UHK	University of Hong Kong
USA	United States of America
USOs	University Spin-offs

INTRODUCTION

While knowledge is seen as the most important resource in the knowledge economy in general, biotechnology is distinguished as "one of the most knowledge-driven forms of activity", and referred to as a 'leading example' of an industry based on scientific knowledge (Coenen *et al.*, 2004: 1006). Modern biotechnology has the potential to transform large parts of the global economy and to have a major impact on the way we live. Its birth is usually traced back to the development of the recombinant DNA technique in 1973 and hybridoma technology in 1975. The rapid pace and widespread impact of developments in biotechnology since that time has often been referred to as the biotechnology revolution (Marsh, 2003). There is a large and growing international literature on economic aspects of biotechnology innovation which McKelvey (2001, cited in Marsh 2003: 103) has characterised as “an area of research which attempts to explain how and why the new techniques and knowledge of modern biotechnology can have economic impacts”.

The emergence of biotechnology is expected to have a major impact on regional and national economies not only directly but also indirectly. Furthermore, the production of biotechnology products represents a relatively new and significant growth phenomenon on its own. Over the long run, the growth potential associated with the wider diffusion and the use of biotechnology products and processes, and their convergence with information technologies, nanotechnologies and other applied sciences, is probably even greater. In this sense, biotechnology appears to have the characteristics of a main technology, with the potential to underpin a new techno-economic paradigm (Gertler & Levitte, 2005). It should also be noted that biotechnology is not a singular industry but a set of specific activities and technologies such as biomaterials, DNA makers, genetic engineering, and recombinant DNA among others. These technologies produce not only new products, new processes for existing products, but also new organisms for environmental cleaning and human consumption. Their applications cover different industries such as pharmaceuticals, food and beverages, and chemicals, among others (Niosi and Bas, 2003).

The Regional Innovation System (RIS) concept provides a theoretical framework for analysing the emergence and growth of high-tech industries, i.e. biotechnology. The key thesis suggested here is that the development pattern of regional high-techs is strongly dependent on the structuring of the RIS (Trippl & Todtling, 2007). In the case of biotechnology, for example, strong RISs are located in California (in Los Angeles and San Francisco), Maryland and Washington DC, Massachusetts (Boston), New Jersey (Princeton), New York City, North Carolina (the Triangle Research Park), Pennsylvania and Texas (Niosi and Bas, 2001). Literature shows that concentration of biotech firms in these RISs typically arise around research universities and venture capital locations (Niosi and Banik, 2005).

The biotechnology RIS consists of a basic set of organisations and institutions. According to Niosi and Bas (2003), biotechnology innovation systems have two key organizations; most noticeable among them are research universities, the fountains from which specialised biotechnology firms (SBFs) and their knowledge emerge. Most major biotechnology firms are spin-offs from research universities or from public research organisations. The second key organisations are venture capital firms which provide the seed money, management competencies and credibility in the view of large pharmaceutical and chemical firms (Niosi and Bas, 2003). In the case of biotechnology, developments in the scientific base (which occur in universities, private firms and government laboratories) generally result in relatively quick changes in the stock of human capital, because such organisations have hiring policies that emphasize specific technical and research skills. Thus, biotechnology RIS evolve, because the core scientific knowledge they exploit evolves, but also because firms are able to acquire this knowledge rapidly and effect changes in their organisational routines and technologies (Niosi and Banik, 2005).

It is generally accepted that the regional innovative performance is improved when firms become better innovators by interacting with various supporting organisations and with firms within their region. In this sense, the institutional characteristics of the region, its knowledge infrastructures and knowledge transfer systems, as well as the strategies and performance of firms represent important basic conditions and stimuli for promoting innovation activities (Doloreux & Parto, 2005).

Like other emerging economies, South Africa is also hoping to kick-start its biotechnology industry. To this end, the South African government formulated policies and enacted legislation to create the institutional framework that should help to stimulate this industry. In an attempt to modernise the approach towards the biotech industry to suit a new political and technical environment, South Africa adopted a NIS approach. Specifically, a key policy attempt to build a biotech hub was the Department of Science and Technology's National Biotechnology Strategy (NBS) in 2001. One of the important results of this strategy was the creation of the Biotechnology Regional Innovation Centres (BRICs) (now a component of the Technology Innovation Agency- the TIA) which aimed to develop and commercialise the biotechnology industry. One of the BRICs was Cape Biotech in the Western Cape Province, with the mission "to develop and promote Biotechnology capacity in the Western Cape, which will create significant and sustainable economic and social value for South Africa". Cape Biotech was seen as one of the most important players of the RISs in Western Cape, representing the interests of all stakeholders in the region, including industry, academia, government, finance, the public and all other role players in the field of biotechnology.

1.1. Aim of the study

The key interest of this study is to understand how the RIS in the Western Cape region was reconstructed, in order to allow for the evolution of the biotechnology sector in the region. Various institutions and organisations played a crucial role in effecting these changes. One of the most important changes involved legislation that altered the role that universities play in bridging the gap between research outputs and reaping commercial benefits from such outputs. Following the logic of the regional innovation system, the study focused on the institutional changes, the mechanisms employed to bridge this gap (from creating spin-off firms, and licensing technologies based on university research, to designing programmes to support the development of bio-entrepreneurs).

1.2. Research Questions

There are six interrelated question sets under study in this thesis. Two main and four sub-questions. The first sub-set is concerned with analysing the phenomenon of scientists who created companies as spin-offs. The second sub-set considers scientists' motivations on either creating companies or licensing their technologies. The third sub-set focuses on regional bio-entrepreneurship training. The fourth sub-set is about the biotechnology companies' growth or demise. The first and final main questions cover the questions for reconstructing the RIS. To an extent, these build upon each other. The first sub-set of questions is exploratory in nature and serves to prepare the ground for the second sub-set, which in turn has to be answered before we can say something about the third. Of course, the object of inquiry in the last set of questions already contains its own versions of answers to previous questions set.

The research questions which this thesis seeks to answer are as follows:

QUESTION I: What should be the alternative ways of developing a favourable environment for regional biotechnology concentration to emerge and develop in the knowledge-based economy?

> *QUESTION I.I. What were the key mechanisms used to bring the output of scientists to market, i.e. spinning off or licensing technologies?*
>
> *QUESTION I.II. What motivated academics to create spin-offs or license their technologies and what were the main obstacles they faced?*
>
> *QUESTION I.III. How effective was the first attempts at building a bridge between science and market through bio-entrepreneurship training in the region?*
>
> *QUESTION 1.IV. What happened to the biotechnology spin-offs and start-ups over time and what effect did changes in the institutional and policy environment have on their growth or demise?*

QUESTION II. What are the strong and weak points to promote a biotechnology regional innovation system in the Western Cape?

The following section of this introductory section, which describes research methodology and the structure of the thesis and its delimitations, discusses in detail how the research questions are addressed in the different elements of the thesis.

1.3. Research Methodology

In order to answer the research questions described above, this research specified a multi-method research design which combines both theoretical grounding and empirical data collection (field work).

Compared to developed countries, the South African biotechnology industry is very small and young. Because of the nature of the biotechnology industry in SA, and the lack of a database that allows for quantitative analysis, a qualitative research approach using case studies methodology is believed to be appropriate. This choice of methodology is supported by the relatively small number of the firms created in the region. In this research, the specific goals of the case studies on innovation systems are:

i. to investigate characteristics of innovation systems for biotechnology industry, and
ii. to develop recommendations that enhance the effectiveness of policies to encourage the economic performance of the innovation systems for biotechnology industry in Western Cape region.

Furthermore, since the point of departure is garnering an understanding of a relatively young phenomenon, and the research is a first in several respects. Qualitative research methods allow the pursuit of such understanding even in the face of sparse data. Specifically, the case study permits understanding a phenomenon through its analysis, reconstruction and documenting of participants’ accounts. Moreover, it rests on a qualitative study having an exploratory aspect. Yin (2003: 40) defines a case study as a research design "*that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*". Yin also highlights the importance of having "*multiple source[s] of evidence*" to get a broad comprehension of the observed phenomenon. A case study offers an opportunity to study a particular subject, e.g. one organization, an industry, in depth, or a group of people. This usually involves collecting and analysing information; information that may be both qualitative and quantitative. Thus, in this thesis, different methodological approaches were applied for the different phases of the project. At the beginning of the project and each section’s introduction a context analysis was done. This was achieved by means of secondary research (document and literature survey) focusing on innovation systems, university spin-offs, bio-entrepreneurship and biotechnology industry.

Most of the empirical data was collected through case studies. In part two, section one, the case studies on university spin-offs in Western Cape draw from fieldwork conducted in the Western Cape. The data is collected through questionnaire and interview surveys with important public and private stakeholders. It was managed in two stages, the reason being that a database of spin-offs was not readily available for the Western Cape region and information on spin-offs had to be gathered in the first stage. Conversations were held with knowledgeable people, such as staff members of TTOs of universities. In the second stage a questionnaire was developed and emailed to the companies. Later, representatives of the companies who have responded were interviewed.

In part two, section two, the case studies on biotechnology spin-offs in Hong Kong draw from fieldwork conducted in Hong Kong. An exploratory study by means of a questionnaire survey was conducted in order to understand the performance and innovative status of biotechnology spinoffs in Hong Kong. The survey was managed in two steps. During the first stage, research was carried out to identify how many universities have a TTO, and a five-page email questionnaire was sent to the TTOs. In the second stage, a nine-page questionnaire was developed specifically for the biotechnology spin-off companies. The questionnaire was emailed to those companies identified through the TTO survey; thereafter companies were telephoned and visited to administer the survey. The questionnaire covered, amongst other things, the nature and activities of the company, motivations behind the creation of the company, and the identification of the major problems faced by the company during its life.

In part two, section three, a questionnaire was developed to be completed by the principal researchers who created the technologies. Eleven researchers had responded to the survey of which only eight were willing to participate in our research. The participant number was therefore small, and the research makes no claims of generalisation. A TTO officer interviewed explained that this is not uncommon, since most researchers are reluctant to participate in questionnaire surveys.

In part three, the study procedures included a literature survey, and conducting interviews with the bio-entrepreneurship programme graduates. A case study was undertaken in order to understand the bio-entrepreneurship education context and details in South Africa. Interviews were semi-structured and took 15–40 minutes. All interviews were recorded and transcribed.

In part four, following the initial survey on university spin-offs held, research ventured into the field to establish whether biotechnology spin-offs identified in the survey were still in existence, and whether new ones have been created since. This exploration resulted in ten biotechnology firms being identified. For the purposes of these in-depth case studies, in this research the initial criteria were that the companies should have been created after 2000 (to be comparable), must be active in biotechnology, and particularly in manufacturing, product development or research. To garner the perspective of the supporting agencies in the regional innovation systems, interviews were conducted with senior staff at the company, at the universities' technology transfer offices and the TIA. The interviews yielded a considerable amount of information, which tell a tale of failure that holds important lessons for practitioners and policy makers.

Limitations of the study

The study is based on one province in South Africa, and the number of respondents was relatively small, the research cautions strongly that no generalizations to the rest of the country can be made. The research therefore regards this study as exploratory, but crucial as a source of insight for further research, for example of the biotechnology sector in the rest of the country's regions.

1.4.Structure of the Study

Starting from the general to the specific, the present thesis consists of four complementary parts: five independent papers and a comprehensive introduction (parts 1-4). Whilst each of the respective papers researches one or several aspects of the aforementioned study object, the comprehensive introduction discusses basic concepts. The broad structure is as follows;

i. Part I comprises the general literature survey and rationale for the study
ii. Part II narrows the focus to the organisations and mechanisms that connect knowledge creation and knowledge exploitation in the regional context in the Western Cape, South Africa and Hong Kong, China which consists of three independent papers.[2]
iii. Part III evaluates early efforts at building a bridge from science to business in the form of bio-entrepreneurship programmes which is presented as a research paper

[2] For a comparative perspective from another region that arrived on the biotechnology scene relatively late, the study includes a section on university spin-offs in biotechnology from Hong Kong universities.

iv. Part IV takes a micro view, tracking the evolution of biotechnology spin-offs from Western Cape universities , and highlighting the role that institutional changes played in the genesis, growth and, unfortunately, demise of some biotechnology spin-offs which consists of an independent paper. The last section concludes.

The format of the thesis has three consequences for the structure that are worth addressing here. Firstly, the links between the research questions, as presented above, and the results presented in each section, are less clear than in a traditional thesis. Secondly, since all the efforts to effect the changes to the RIS that would enhance the growth of a promising industry are relatively new, the study faced the usual problems associated with pioneering developments, such as small samples, a complete lack of databases, etc. For this reason, the questionnaire survey and case study methods were used throughout the study. A caveat is therefore sounded throughout, that because of the small samples, the results must be interpreted with care and generalisations cannot be made. Finally, some degree of overlap in content is unavoidable. However, none of the parts treat the same issue with the same depth. The study, furthermore, makes a significant contribution in the insights that it yields in a number of areas where the literature on spin-offs, biotechnology and bio-entrepreneurship training in developing countries is still sparse. The rest of this section, therefore, presents and explains the structure through which part-studies are linked. To begin with, Table 1.1 indicates which research questions each section covers.

Table 1.1: Research questions covered and methodology used by each section

Title	**Research Questions covered**	**Methodology**

Exploring Entrepreneurial Activity at Cape Town and Stellenbosch Universities, South Africa	Q.I, Q.I.I	literature survey, qualitative techniques; case studies, questionnaire and interviews
Academic entrepreneurship in South East Asia: An Exploratory Study of Spin-offs in Biotechnology from Hong Kong Universities	Q.I, Q.I.I, Q.II	literature survey, qualitative techniques; case studies, questionnaire and interviews
Spinning-Off or Licensing? The Case of Academic Technology Transfer at Two South African Universities	Q.I, Q.I.II	literature survey, questionnaire and interviews
Building a bridge between science and business in a regional cluster: Evaluating initial bio-entrepreneurship training efforts in South Africa	Q.I, Q.I.III, Q.II	literature survey, questionnaire and interviews
Where have all the university spin-offs gone? Turbulence in the biotechnology sub-sector of the Western Cape RIS	Q.I, Q.I.IV, Q.II	literature survey, qualitative techniques; case studies and interviews

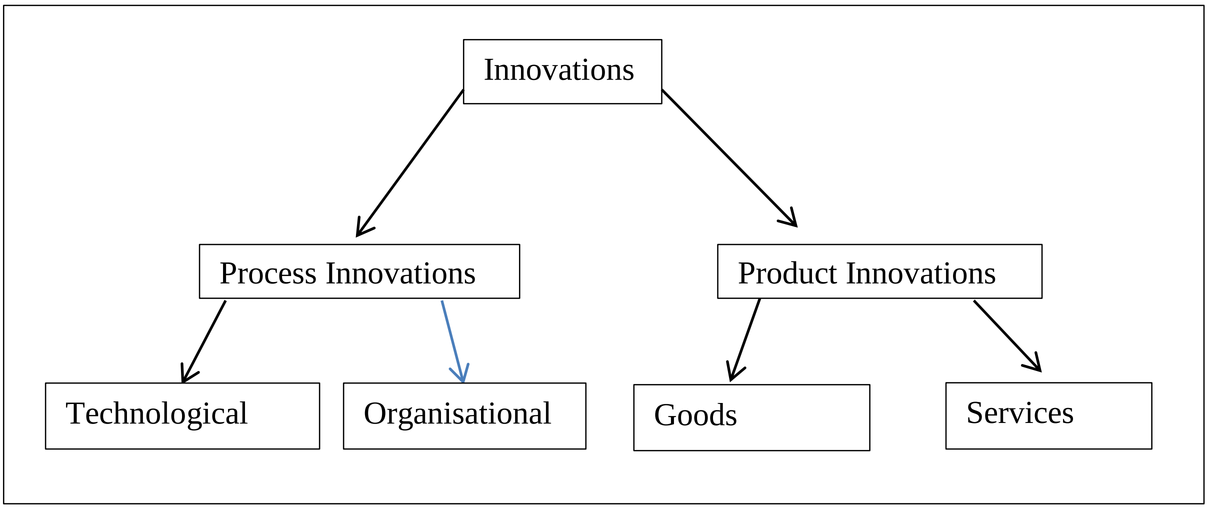
PART I: CONCEPTUALISING ARCHITECTURE

1.1.Innovation

Innovations are new creations of economic significance and usually carried out by firms. They may be brand new, but are generally new combinations of existing elements. It is actually a matter of *what* is produced by firms and *how* is it produced (Edquist, 1997; Edquist, 2001).

The category of innovation is complex and various. Traditionally, it includes process as well as product innovations as indicated below (Edquist, 2001; Kubeczko, Rametsteiner and Weiss, 2006; Cozzens and Kaplinsky, 2009).

Figure 1.1: The category of Innovations



Source: Edquist (2001)

Product innovation refers to radical changes in the output of an enterprise or organisation. Product innovation may be goods or services. It is a matter of *what* is being produced.

Process innovation refers to either technological innovations or innovations in the organisation of an enterprise (Edquist, 1997; Edquist, 2001; Kubeczko, Rametsteiner and Weiss, 2006; Cozzens and Kaplinsky, 2009). It concerns *how* goods and services are produced. Some product innovations are transformed into process innovations in a 'second incarnation' (or 'second appearance'). This concerns only 'investment products' – not products intended for immediate consumption. For example, an industrial robot is a product when it is produced and a process when it is used in the production process.

In this taxonomy, only goods and technological process innovations are considered as innovations of a 'material' kind. On the other hand, organisational process innovations and services are seen as 'intangibles'. It is essential to take the "intangible innovations" into account as well, since their inputs are increasingly important for economic growth and employment. Although product innovations are crucial for changes in the production structure, this must not, however, be interpreted as reducing the importance of process innovations; the latter are necessary for the competitiveness of all firms in all countries, sectors and regions (Edquist, 2001: 6).

After this brief information on "innovation", the next section explains the concept of innovation systems.

1.2.Concepts of innovation systems

In the last decade the concept of "innovation systems" has been used by academics and policy makers around the world (Edquist, 2001; Kubeczko, Rametsteiner and Weiss, 2006; Lundvall, 2007; Bergek, 2007; Liu, 2009). It is worth mentioning here that the innovation systems approach is used here as a conceptual rather than a theoretical framework.

Today it is possible to follow the diffusion of new concepts in time and space by using the internet. Giving 'Google Scholar' the text strings 'innovation system(s)', you may end up with a total of more than 71700 references (this search was done in April 2013). Going through the references scholars can find that most of them are recent researches and that many of them are related to innovation policy efforts while others refer to new contributions in social science (Lundvall, 2007).

Innovation systems comprise a set of different players and institutions that contribute to the development and diffusion of innovations. It is a set of interconnected players who form a system whose performance is determined both by the individual player's performance and also by how they interact with each other as elements of a collective system (Kubeczko, Rametsteiner and Weiss, 2006). Edquist (1997: 14) defined an innovation system as "*all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations.*"

Lundvall (1992: 2) described an innovation system as "*constituted by elements and relationships which interact in the production, diffusion and use of new knowledge.*" In this definition, the knowledge can be interpreted as is exploited for practical, including commercial use (Cooke et al. 1997: 478). Consequently the knowledge created, diffused and used is not always in the form of commercial products or services but can also have practical and social effects. More specifically, knowledge may take the form of new ideas and concepts, new skills, or technological and organisational advances (Seppänen, 2008).

An innovation system is a social and dynamic system (Lundvall 1992: 2). Seppänen (2008) asserts that the system is social because a central activity in the system is learning, which is a social activity. Innovation in the system involves positive feedback and reproduction which makes it a dynamic system. Thus, innovation is not a linear but a recursive process and the system is recursive by nature.

Innovation systems approach has been defined at different levels for different purposes of analysis. Over the last decade there have been several new concepts emphasizing the systemic characteristics of innovation. The most common approaches of innovation system refer to;

- the national, as suggested by Freeman (1987), Lundvall (1992), and Nelson (1993)
- the regional, as used by Cooke (1992) and other scholars;
- the technological, as proposed by Carlsson and Stankiewicz (1991)
- the sectoral, as proposed by Breschi and Malerba (1997)

As suggested by their names, *national and regional innovation systems* (NIS and RIS) refer to innovative activities within national and regional boundaries, respectively. Cooke (1992) notes that the geographical boundaries of RISs are regions within countries or include parts of different countries. Bo Carlsson (Carlsson and Stankiewicz, 1991) with his colleagues introduced the concept *'technological system'* already in the beginning of the nineties which is defined by a particular technology or set of technologies rather than by a geographic region or industry. To avoid confusion with the engineering concept of 'technological system,' the term *'technological innovation system'* is being used here. Franco Malerba and his colleagues (Breschi and Malerba 1997) developed the concept of *'sectoral systems of innovation'* which focuses on various individual sectors or industries, technology fields or product areas (Edquist, 2001; Carlsson, 2006; Lundvall, 2007; Bergek, 2007; Seppänen, 2008).

The delineations about these approaches to innovation systems are different from different perspectives. Therefore, there is no right or wrong way to draw system boundaries and define them in the social and economic context. Most delineations about the national and regional innovation systems are largely determined by organizations and institutions essentially characterized by a certain territorial sphere of influence and interactions. In contrast, sectoral innovation systems may be determined in terms of technology flow in the industries' structure that usually cross geographic boundaries (Gao and van Lente, 2008). However, according to Carlsson and Stankiewicz (1991), actors, interactions and institutions are three basic elements in all innovation systems.

The following section aims to shed light on the existing literature on types of innovation systems. It provides the reader with a theoretical understanding of the innovation concept and how it can be understood in a system perspective.

1.3.Types of Innovation Systems

The use of knowledge, together with innovation and its diffusion, has become key elements of economic growth in the modern world. Continuous innovation is a prerequisite for sustainable competitiveness of both nations and regions (Zhu and Tann, 2005). Innovation is now seen as a socially and territorially embedded process and the regional level has been recognised as being the best context for the development of innovation based learning economies. Regions can be viewed as evolving members of multi-level governance systems and play a key role in coordinating innovation processes (Muscio, 2006).

The last 20 years have seen an increasing acknowledgement in economic and social sciences of the territorial dimension of industrial development and technological innovation. During this period, the literature on innovation has shifted from the national to the regional and local dimensions (Muscio, 2006).

In the next section the innovation systems approach is elaborated from the historical perspective.

1.3.1. National Innovation Systems

Some of the basic ideas behind the concept ’national systems of innovation’ are rooted in Friedrich List’s concept ‘national systems of production’ (List 1841) (Carlsson, 2006; Lundvall, 2007; Lundvall et al., 2009; Pietrobelli and Rabellotti, 2009). His concept ’national systems of production’ took into consideration a wide set of national institutions including those engaged in education and training as well as infrastructures such as networks for transportation of people and commodities. He focused on the development of productive forces rather than on allocation issues.

According to Lundvall (2007) and Lundvall et al. (2009), the first written contribution that used the concept ‘national system of innovation’ is an unpublished OECD paper by Christopher Freeman in 1982, which was on how countries could build knowledge and knowledge infrastructure at the national level with the aim to promote economic development and international competitiveness . The first time the handier ’innovation system’ appears in an Aalborg-publication is in Lundvall (1985) (although without the adjective ‘national’) (Carlsson, 2006; Lundvall, 2007). In this booklet on user-producer interaction and product innovation the concept was used to analyse innovation processes involving firms and knowledge institutions in interaction. A general assumption behind the analysis, that remains central in more recent work on innovation systems, was that innovation and learning are context dependent, interactive processes, rooted in the production structure (Lundvall, 2007).

Again, it was Chris Freeman who brought the modern version of the full concept ‘national innovation system’ into the literature. He did so in 1987 in his seminal book on national innovation systems in Japan (Carlsson, 2006; Lundvall, 2007; Fagerberg and Srholec, 2009;

Liu, 2009; Niosi, 2011). Here the analysis was quite inclusive taking into account the intra- as well as inter-organizational characteristics of firms, corporate governance, the education system and not least the role of government. The following year, when Freeman collaborated with Nelson and Lundvall on technical change and economic theory the outcome was a book, edited by Dosi et al. (1988), with a section with chapters on 'national systems of innovation' (Carlsson, 2006; Lundvall, 2007; Soete, Verspagen and ter Weel, 2010; Niosi, 2011).

The "national innovation system" concept has since been extensively discussed in both scholarly and policy-analytic work (Freeman 1987; Lundvall 1992 and Nelson 1993). Essentially, these studies describe categories of actors - government, universities, research institutes, and firms - and their interactions with institutions and policies. The National Innovation System concept places stress on the role of institutions in a system within a nation, through their interactions, in supporting the technological development process. It's basically analyses of country-specific factors that influence companies' innovative capabilities (Liu and White, 2001; Edquist, 2001; Carlsson et al., 2002; Sharif, 2006; Fagerberg, Mowery and Verspagen, 2008; Gao and van Lente, 2008; Lenger, 2008).

The national innovation systems concept has been used in a broader sense, which encompasses learning, innovation and competence-building at different levels of aggregation and a narrow sense, which equals innovation to science and technology (Chung, 2002; Fagerberg, Mowery and Verspagen, 2008; Gao and van Lente, 2008; Lundvall et al., 2009). In the broader sense it extends to include all interrelated institutional actors (i.e. social institutions, macroeconomic regulation, financial systems, education, communication infrastructure, market conditions) that create, diffuse, and exploit innovations (Chung, 2002; Gao and van Lente, 2008; Lundvall et al., 2009). Lundvall (1992) defines NIS as;

'A system of innovation ………constituted by elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge… and are either located within or rooted inside the borders of a nation state' (Lundvall 1992: 13).

In the narrow sense, it is aimed at mapping indicators of national specialisation and performance which includes organizations and institutions directly related to searching and exploring technological innovations, such as R&D departments, universities, and public institutes (Chung, 2002; Gao and van Lente, 2008; Lundvall et al., 2009). The narrow definition can be quoted from Freeman (1987), which is

'…The network of institutions in the public and private sectors, whose activities and interactions imitate, import, modify and diffuse new technologies' (Freeman 1987: 1).

Moreover, Nelson and Rosenberg (1993) also give a definition from a narrow sense which they regard as;

'…The set of institutions whose interactions determine the innovation performance of national firms' (Nelson and Rosenberg 1993: 4)

There are many other definitions of NIS. For instance; a national system of innovation defined by Metcalfe (1995) as a "*set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills* *and artefacts, which define new technologies. The element of nationality follows not only from the domain of technology policy but also from elements of shared language and culture which bind the system together, and from the national focus of other policies, laws and regulations which condition the innovative environment (Metcalfe, 1995: 38).”*

Also, Chung (2002: 486) defines NIS as “*a complex of innovation actors and institutions that are directly related to the generation, diffusion, and appropriation of technological innovation and also the interrelationship between innovation actors*.” The major concern in this notion is how we can formulate an effective national setting of major innovation actors and how to animate information flows among them in order to generate and appropriate innovation effectively. The main idea of this approach is that a company’s capability for innovation depends on it being able to interact and coordinate with a variety of external sources of knowledge (competitors, suppliers, scientific organizations, etc.) as well as internally generate knowledge from interdependent sources (like production, marketing or R&D) (Todt *et al*., 2004: 417). In short, national innovation system approach involves socio-institutional adaption, supplier-customer interactive learning, and firm competence and routines, all of which influence the diffusion of the innovation in the national area. (Gao and van Lente, 2008).

The broader perspective is essential as economic growth benefits less from the creation of knowledge *per se* than from its application to the production of new and existing goods and services. An exclusive focus on the creation of new technologies that ignores their exploitation risks overlooking essential cross-national differences in the translation of new knowledge into economic gains (Fagerberg, Mowery and Verspagen, 2008). The effective exploitation of new knowledge or technology is especially important for developing countries such as South Africa, whose contribution to the global pool of new knowledge necessarily is dwarfed by the potential contributions to South African's economic growth from exploitation of this pool.

1.3.2. Regional Innovation Systems

The Regional Innovation System approach emerged at the beginning of the 1990s, focusing on analysing regional economies and economic geography. It has already gained much attention from academics, policy makers and researchers (Doloreux and Parto, 2004; Chung. 2002 and Gao and van Lente, 2008; D'Allura, Galvagno and Li Destri, 2012). Ohmae (1990, cited in Chung, 2002: 486) states that the region has become a focal point of economic activities replacing the nation in the modern economy. In support of this, he argues that regions are more dynamic and reflexive than states in R&D and economic activities. Florida (1998) argues that a region should become a learning region by appreciating the importance of knowledge and that public policy should not only target short-term economic competitiveness, but also the long-term sustainable advantage of regions (Chung, 2002: 487). Furthermore, Breschi and Malerba (1997) argue that the regional innovation activities can stimulate industrial clusters for the whole state, and it can improve the balance of state economic development. Therefore, studying phenomena at regional level is growing in importance as a mode for innovation system research.

In addition, the reason why this concept should be narrowed down is well documented and discussed in Cooke et al. (1997) who argued that a systemic approach to technological change at a national level would be essentially inadequate since most of the interaction in fact takes place at sub-national levels i.e. regional levels. Additionally, Porter (1990, cited in Buesa *et al.* 2006) argued that industries tend to concentrate in specific spaces. Therefore, the Regional Innovation System (RIS) appears as a more relevant, and appropriate approach to the problem.

The concept of RIS has been gaining much attention from policy makers and researchers in the wake of the academic studies on national system of innovation of Freeman (1987) and Lundvall (1992).

The definitions of regional innovation system reduce the scope of innovation study into a region or local area within a nation. Thus, an RIS can be defined as "*a complex of innovation actors and institutions in a region that are directly related with the generation, diffusion, and appropriation of technological innovation and an interrelationship between these innovation actors." (Chung 2002: 487)*

Moreover, the concept of RIS has no commonly accepted definitions. Doloreux and Parto (2004: 3) state it as "*a set of interacting private and public interests, formal institutions and other organizations that function according to organizational and institutional arrangements and relationships conducive to the generation, use and dissemination of knowledge in a region*." The basic argument is that this set of actors produce pervasive and systemic effects that encourage firms within the region to develop specific forms of capital that is derived from social relations, norms, values and interaction within the community in order to reinforce regional innovative capability and competitiveness. In other words, its research focuses on revealing the skills on the local supply in management and technology aspect, the ability of accumulating tacit knowledge, and the capacity of 'knowledge spill-over' in a limited geographical area. By studying RIS, the nations can prevent the problem of unfair geographical concentration of technological and economic capabilities, and develop the national economy as a whole (Chung 2002).

Niosi and Banik (2005) proposed that *Regional Innovation Systems (RISs) are geographical concentrations of interacting organisations (firms, research universities, government laboratories and venture capitalists) designed at the development of a specific technology*. Typically, the concentration of high-tech firms in RISs occurs around research universities and venture capital pools. Labour pools made up of graduates from research universities, knowledge spill-overs from academia to industry, complementary and input markets for university-created technologies, trust and reciprocity, together with reduced transaction costs within the network, has been put forward as explanations for the clustering of key organisations within a particular geographical region (Niosi and Banik, 2005).

Asheim and Coenen (2005, cited in Lenger 2008) defined RIS as, *"the institutional infrastructure supporting innovation within the production structure of a region".* The main focus of the system approach is the interaction within the network of public and private institutions which can be classified as firms, R&D institutes, universities, government agencies and venture capitalists.

Like an NIS, an RIS is composed of three main innovation actor groups: universities, industrial enterprises, and public research organization. Additionally, regional government replaces the central government to effectively direct and coordinate innovation activities in each region. But the actual actors of innovation activities are universities, private enterprises, and public research organizations. These actors make a significant contribution to enhance regional and national technological competitiveness.

In addition to this, the concept of RISs can also be a good tool to formulate SISs, as regions should concentrate specific industrial sectors for the effective development of their regional economies. An RIS comprises of two key components: (1) firms in the regional core clusters and (2) institutions that create an institutional infrastructure. Lundvall in Zhu and Tann (2005: 376) offer a definition that identifying five core elements of an RIS: (1) the internal organization of firms, (2) the inter-firm relationship, (3) the role of the public sector, (4) the institutional set-up of the financial sector, (5) R&D intensity and R&D organizations. All the core elements or key components of an RIS can also be applied to other types of systems that operate at sectoral and technological levels.

According to Cooke (2002a) and Seppänen (2008) the two key subsystems in any functioning regional innovation system are (1) the knowledge application and exploitation and (2) the knowledge generation and diffusion. These subsystems are linked to global, national, and other RISs (Lenger, 2008). "The knowledge application and exploitation sub-system" is formulated by the firms that commercialize the knowledge and their contractors, competitors, collaborators and customers whilst "the knowledge generation and diffusion subsystem" covers universities, research institutes, technology transfer agencies, regional and local governance bodies that support and regulate the innovation policies (Cooke, 2002b; Seppänen, 2008). However, private investors can be the most important players outside basic research in highly innovative regions and metropolitan areas. Also important actors in a regional innovation system include public and private funding organisations and non-firm organisations. Figure 1.2 is an attempt based on the work of Autio (1998, cited in Cooke, 2002a), to present the structure of a regional innovation system.

The organisations of a regional innovation system are associative, meaning there is systemic, i.e. regular, two-way, interchange on matters of importance to innovation. The interactions within and between organisations and sub-systems generate the knowledge flows that drive the evolution of regional innovation system. Linkages between key organisations can be specified in terms of flows of knowledge and information, flows of investment funding, flows of authority and even more informal arrangements such as networks, clubs, and partnerships (Seppänen, 2008).

This research is aimed at the second subsystem in the RIS, namely the universities' roles in the regional innovation systems, from the view of innovation systems which emphasized the importance of knowledge spill-overs from the research activities at universities in the regional knowledge spaces, towards the development of the third role for universities in stimulating regional economic and social development (Gunasekara, 2006). This makes the university an active agent of change, and implies that different competencies and approaches may be needed. Table 1.2 captures the roles of universities in regional innovation systems and summarize the key elements.

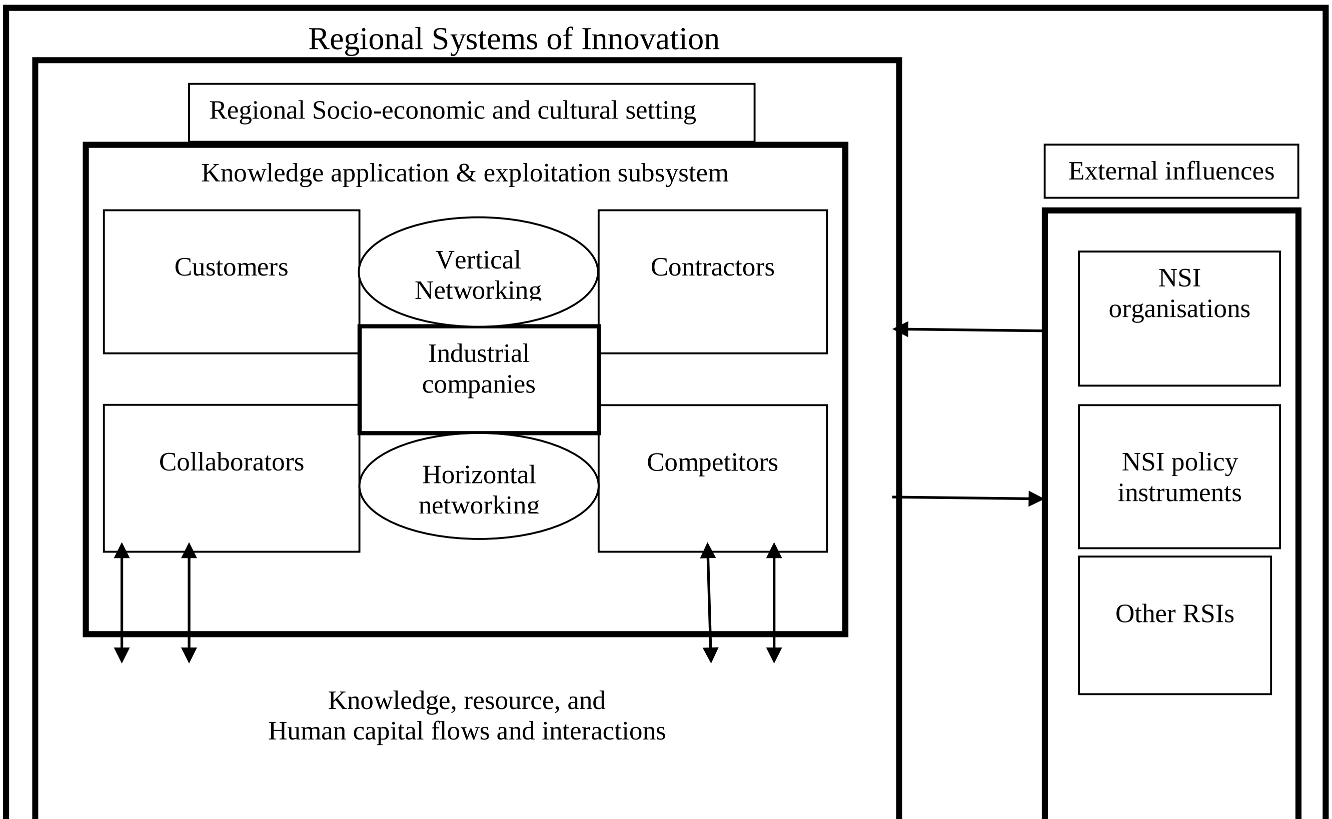
In the context of the third role assigned to (and assumed by) universities, technology transfer is a cardinal focus of policy and research. Universities may seek to transfer technology from the public to the private sector, and therefore reap the benefits of commercialisation through a number of different mechanisms. The transfer of technologies developed in universities and public research organisations (PROs) to the private sector, i.e. "technology transfer" (TT), can be a significant vehicle in national/regional technological innovation and thus, economic growth can be improved (Garduno, 2004). This increased emphasis on TT from universities and research institutions to the industry and the need to develop more "rapid" linkages between science, technology and their utilisation has led to the emergence of a number of entrepreneurial initiatives within academic and research institutions (O'Shea *et al.*, 2004).

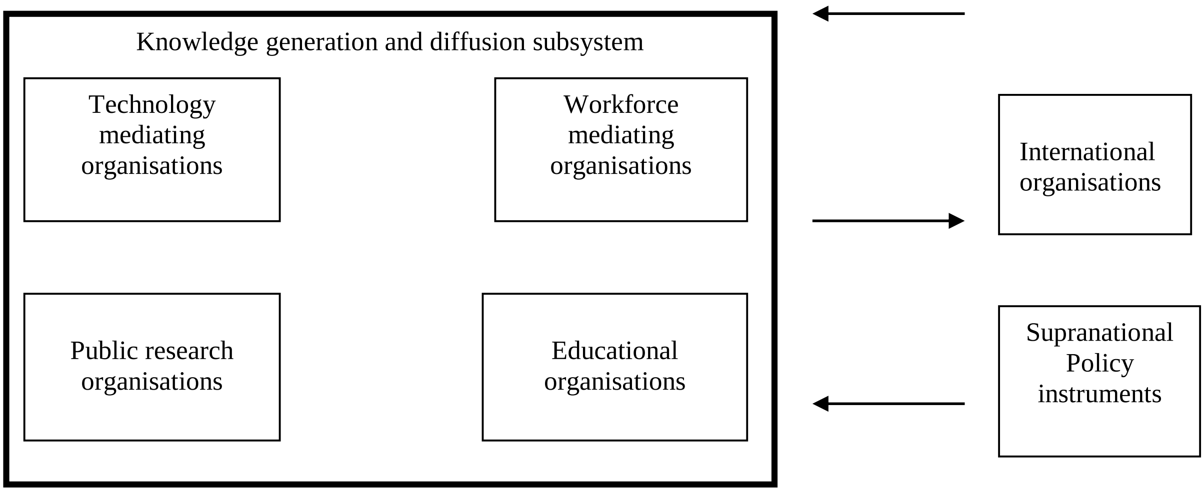
Table 1.2: Analysing universities contribution to the development of RISs

Key Element of RIS	Generative role	Developmental role
Regional agglomeration or clustering of industry	Knowledge capitalization and capital formation projects, centred on firm formation and co-location of new and existing firms near the university.	Entrepreneurial activities, as well as regionally focused teaching and research, not necessarily linked to capital formation projects
Human capital formation	Integration of education and knowledge capitalization activities specifically, firm formation, through teaching incubators. Development of generic, advanced training programs to support firm formation and cross-institutional mobility by organizations and people	Stronger regional focus on student recruitment and graduate retention. Education programs developed to meet regional skills needed Learning processes that are regionally informed
Associative governance	Driver of regional innovation strategy, centred on knowledge capitalization and capital formation projects; by analyzing strengths and weaknesses and bringing together the industry and government to build innovation strategy.	Shaping regional networking and institutional capacity, through staff participation on external bodies; provision of information and analysis to support decision-making and brokering networking between national and international contacts and key regional actors
Regional cultural norms	Tradition of university industry linkages, involving knowledge capitalisation.	Tradition of university industry linkages, involving knowledge capitalization and other research collaborations.

Sources: Gunasekara, 2006

Figure 1.2: Schematic Illustration of the structuring of Regional Innovation Systems





Source: Cooke (2002a)

TT and other topics that relate to technology transfer, such as technology diffusion and dissemination, have become fundamental parts of prevailing research and the technology development policy. TT is a deliberate and planned process (e.g. through licensing, foreign investments, procurement) to disseminate or acquire knowledge, experience and related artefacts (Hameri,1996), and technology transfer offices (TTOs) to facilitate this technological diffusion through the licensing of inventions or intellectual property from university research results to the industry (Siegel *et al.*, 2003; Phan and Siegel, 2006). Siegel *et a.l* (2007:641) viewed TTOs as 'intermediaries' between suppliers of innovations (university researchers) and those who can potentially assist to commercialise them, i.e. firms, entrepreneurs, and venture capitalists. A TTO represents an institutional mechanism created with the purpose of promoting universities' interaction with the industry and the government. The idea of establishment of TTOs is not only the need to improve the effectiveness of university performance, but also boosts the university's income through the transfer of research results to the industry and licensing of technologies (Dos Santos and Rebolledo, 2008). The mission of TTOs is thus to transfer university research results from laboratory to commercial application for society.

1.3.3. Technological Innovation Systems (TIS)

Innovation systems that are assigned to a specific technology or product have been referred to as *technological innovation systems* (TIS) in the literature. The components of a technological innovation system are the actors, networks and institutions contributing to the development, diffusion and application of a particular technology. Carlsson and Stankiewicz (1991) defined a technological system as;

"A dynamic n*etwork of agents interacting in a specific economic/ industrial area under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology" (Carlsson and Stankiewicz, 1991, p. 93*).

TIS analyses a technological field by referring to systemic features, including actors, institutions, (sometimes) technologies and most importantly, all the interrelations between them. The TIS concept has been applied to develop an understanding of innovation processes as related to societal structures such as governments, universities, NGOs, intermediary organisations and the like (Suurs, 2009). A successful innovation system requires the interaction among the actors with different competences. Moreover, the nature of innovation and technology change contain scores of uncertainties and complexities, networks formed by the actors provide other alternatives for firms and other research organizations in governing innovations (Carlsson and Stankiewicz 1991).

1.3.4. Sectoral Innovation Systems (SIS)

The sectoral innovation system approach provides an analytical framework to identify the performance of systems in terms of how well they support innovations in a specific sector. 'Sectoral innovation systems' approach is represented by Breschi and Malerba (1997) ". . . *different industries may have different competitive, interactive and organizational boundaries that are not necessarily national*" (Niosi, 2011).

Breschi and Malerba (1997: 131) define sectoral innovation system as *'the specific clusters of the firms, technologies, and industries involved in the generation and diffusion of new technologies and in the knowledge flows that take place amongst them.*' Sectoral innovation systems are based on the idea that different sectors or industries operate under different technological regimes. These regimes may change over time, making the analysis inherently dynamic, focusing on the competitive relationships among firms by explicitly considering the role of the selection environment (Carlsson et al., 2002; Gao and van Lente, 2008).

A SIS is, therefore, a system comprised mainly of players in one specific sector and interactions between these. Furthermore, the majority of functions of the innovation system are fulfilled by players in the sector. The SIS approach looks at firm and inter-firm level aspects as well as at institutional level aspects both of market and non-market relations and focuses on the differences between types of sectoral innovation systems. The key features of this approach are the differences in and the importance of the knowledge base and the learning process, the role of non-firm organisations and institutions, and the co-evolutionary process changing the sector. The agents within the SIS are individuals and organizations. These organizations may be enterprises and non-firm organizations (such as universities, government agencies. etc.), as well as other individuals or organizations such as consumers, research and development departments or industry associations. Agents are characterized by a specific learning process, competence, structures and behaviour (Breschi and Malerba, 1997). In SIS, for instance, government, as a non-firm organization, may influence a specific technology flow from creation to diffusion through the formulation of technical standards. The technical standards can remove the barriers of interactions among the actors and enhance learning capacities and the technological negotiability (Gao and van Lente, 2008)

The SIS approach of Breschi and Malerba (1997) distinguishes five major types: SIS in traditional sectors, the mechanical industries, the auto industry, the computer mainframe industry and the software industry. SISs in traditional, mature sectors typically often support more process innovations than product innovations. In particular, opportunities are pursued to introduce innovations related to reducing production cost (Kubeczko, Rametsteiner and Weiss, 2006).

Table 1.3 summarizes the different approaches to innovation systems and demonstrates and reveals the key features of the different approaches based on the three basic agents.

Table 1.3: Different "systems of innovation" approaches' summary

	NIS	RIS	TIS/SIS
Main Actors	• Industry • Government • Education and Research organizations	• Universities • Industrial enterprises • public research organization	• Firms • Non-firm organizations • individuals
Institution	• National policies • Laws • National finance supports	• Informal Institutions depending of trust and reliability among the actors	• Standards • Regulations

Interaction	• joint industry activities • R&D collaboration • technology diffusion • personnel mobility	• Inter-firms interactions • External interactions for firms with research organizations • R&D collaboration	• Inter-industry Interactions • Interactions among firms and non-firm organizations

Source: Gao and van Lente, 2008

Having considered an elaborate overview of the literature on innovation systems, two observations remain to be made:

i) The innovation system approach locates this study within the framework of the economics of innovation, which draws on insights from other fields, such as business management and history. The value of this approach will become clear in the rest of the thesis;

ii) For the purposes of this study, the *regional* system of innovation is more suited as a framework for analysis, rather than the *sectoral* system of innovation, given the fluidness of the boundaries of biotechnology in South Africa and the nascent nature of the sector.

PART II: FROM KNOWLEDGE CREATION TO KNOWLEDGE EXPLOITATION

This part of the thesis narrows the focus to the organisations and mechanisms that connect knowledge creation and knowledge exploitation in the regional context in the Western Cape, South Africa and Hong Kong, China. This part consists of three independent sections.

2.1. Exploring Entrepreneurial Activity at Cape Town and Stellenbosch Universities, South Africa[3]

Addressing the first research focus area in part I[4] (which is concerned with analysing the phenomenon of scientists who created companies as spin-offs), this section is devoted to the mechanism of spin-off formation as a means to bring the research output of academic scientists to the market, with the associated expectations of the benefits that such ventures may hold for the inventors, universities and the regional economy. Research starts with spin-offs generally and then narrows the focus to biotechnology spin-offs in subsequent sections.

2.1.1. Introduction

Entrepreneurial activity at universities, especially spin-off formation has emerged as an important mechanism to accelerate transfer of technology and knowledge to the market. Spinning off is a means of technology transfer from a parent organisation that presents a mechanism to create jobs and new wealth (Steffensen *et al.*, 1999). A small but growing number of studies deals with the performance of university spin-offs around the world (O'Shea, 2007) but in South Africa only a handful of studies focused on university spin-offs (Kruss, 2008; Jafta and Uctu, 2009); mostly as part of a broad study on university-industry partnerships, technology transfer mechanisms or academic entrepreneurship (Garduno, 2004; Kruss, 2005; Reichelt, 2007; Grundling and Steynberg, 2008; Kruss *et al.*, 2009). This is partly because of a lack of a comprehensive database of university spin-offs. This study starts on a modest scale, focusing on the universities in the Western Cape region. A dearth of spin-offs at the University of the Western Cape limited the study to a questionnaire and interview survey of spin-offs at Cape Town and Stellenbosch universities. Although this study was conducted

[3]This section was published in a journal. Reference as follow; Jafta R. and R. Uctu, (2013), "Exploring University Spin-offs in the South African context: Entrepreneurial activity at Cape Town and Stellenbosch Universities, *Industry and Higher Education,* Vol. 27, No.2, April 2013, pp. 117-128

[4] It refers to Research Questions' section, p. 4

on a relatively small scale, it is believed that the insights gained from this exploration into the field could prove useful for future research.

This section strives to understand the spin-off phenomenon whereby a new firm is created and formed from parent universities. Specifically, the objectives of this section are to gather information about the historical status of spin-offs and to identify the main characteristics of university spin-offs, which evolved from two South African universities. The research is further interested in the motivations behind the spin off, the relationships with the parent university post spin off, as well as the most important obstacles that the spin offs faced.

In the following section the research elaborates on the definition and importance of university spin-off firms (USOs), where after the research present the methodology and the results of the study. The research then discusses the results and derives lessons and concludes in the final section.

2.1.2. Definition and Importance of University Spin-Offs

There is no single definition of university spin-offs (USOs) that are used consistently in the literature. Spin-offs can be categorised depending on the organisation they originate from, and on the source of the entrepreneur's experience. Spin-offs may originate from different organisations, such as a government R&D organisation, a university or a private firm (Gubeli and Doloreux, 2005).

First, the research assesses the existing definitions of spin-offs in the academic entrepreneurship literature to provide a contextual framework. According to Smilor *et al.*

(1990: 64) a spin-out firm[5] is defined in two ways: (1) the founder was a faculty member, staff member, or student who left the university to start a firm or who started the firm while still affiliated with the university; and/or (2) a technology or technology-based idea developed within the university was used to start the firm. Pirnay *et al.*'s (2003: 356) definition is a "new firm created to exploit commercially some knowledge, technology or research results developed within a university".

Landry *et al.* (2005: 3) see a university spin-off as a new firm that is formed to transfer commercially available scientific and technological knowledge from a parent organisation to the market. According to the authors, two factors of this definition are to be taken into account; firstly, to understand the spin-off phenomenon one has to consider the nature of its parent organisation and, secondly, that the most important decisive factor to create university spin-offs is the production of commercially useful knowledge by researchers. Rasmussen (2006) defines a USO as a new venture initiated in a university setting that is based on technology from a university, whilst Shane (2004) defines a university spin-off as a new firm founded to exploit a piece of intellectual property created in an academic institution (Rasmussen, 2006: 3).

After reviewing the definitions of spin-offs, the research can say that a spin-off involves: a core technology, knowledge or research results developed within a university and transferred into a new firm and the founder member(s) of the firm stay at or transfer from the parent university.

Spin-off firms play a crucial role in the development and commercialisation of new technologies. For example, technology transfer activity performed through licensing of

[5] In this research spin-off firms are also known as "start-up" and "spin-out" firms.

technologies to set up firms and creating spin-offs based on university-developed technologies plays an important role in the USA's technology transfer system (Garduno, 2004). The figures are instructive. According to the Association of University Technology Managers (AUTM), 3,376 spin-offs from American academic institutions were created in the U.S. between 1980 and 2000 (Avnimelech and Feldman, 2011) and have contributed 280,000 jobs to the U.S. economy (O'Shea *et al.*, 2005). In the last decade the university spin-off rate accelerated with an average of more than 500 new start-ups each year, for example, in 2010 alone, 651 university-based start-up firms were started (AUTM, 2010). Another example can be given from Japan. Kondo (2004) explains that government in Japan launched a plan in 2001 to create 1000 university spin-offs in the following three years and has taken various policy measures to promote spin-off creation since then. There are several reasons for the surge in interest in spin-offs:

1) Universities are very important sources of advanced technologies in both developing and developed countries. This is especially the case in the fields of Pasteur-type research, where basic research results can be applicable for commercial use (Kondo, 2004).
2) USOs seem like a relatively cheap way to promote the development of knowledge economies in different places. Policy-makers have been supported in this by research universities who have seen USOs as a means of generating revenue and thus reducing their exposure to external (governmental) interference (Benneworth and Charles, 2004).
3) Spin-offs from universities and government R&D labs are also seen as a bridge between the realm of academic research and industry. They facilitate the exploitation of academic research by allowing a specialised firm to move it into the industrial sector (Byrd, 2002).

4) Universities' technological achievements need to be commercialised in a more rapid fashion to compete in the global market. Time (speed) to market is an important competitiveness factor. A university spin-off is one of the fastest ways to transfer technology to industry (Kondo, 2004).
5) According to Byrd (2002), universities may use spin-off firms as a tool, not only to commercialise a development, but also to give them access to R&D investments. It may also be a more effective way to maximise the return on their investment while, at the same time, enhancing the university's academic and research profile.
6) The technology frontier is wide and key next generation technologies are not easily foreseen. Existing companies cannot investigate all the possibilities. In addition, they are downsizing corporate laboratories to shift their resources to more near-horizon projects (Kondo, 2004).
7) Some USOs are 'high-tech' employers, paying good wages and promoting entrepreneurship, stimulate business support services and infrastructure, which benefit other start-ups (Benneworth and Charles, 2004).
8) USOs build on global technological and client knowledge in developing new networks to access finance, sales and marketing (Benneworth and Charles, 2004).

Given the powerful reasons for spin-off creation, South African universities have followed suit. Such commercialisation of knowledge, technology and research results is facilitated by a new policy framework. The South African government, with its Intellectual Property (IP) Act 2008, encourages commercialisations of IP created in public institutions through the creation of TTOs and other initiatives. The objective of the Intellectual Property from Publicly Financed Research and Development Act, 2008 ("the Act") is to make provision that IP developed from publicly financed research is utilised and commercialised for the benefit of society (Government Gazette, 2008). The Act also aims to:

a. identify commercialisation opportunities
b. encourage and reward human ingenuity and creativity;
c. help grow and develop the private sector, in particular Small and Medium-sized Enterprises (SMEs) and Broad-Based Black Economic Empowered enterprises (BBBEEE)[6];
d. provide for protection of IP prior to publication of research findings; and
e. provide for State "walk-in" rights - where necessary (the State may use the results of publicly financed research and development, in circumstances where IP is required for the country's health, security and emergency interests).

2.1.3. Methodology

First, a literature survey which enabled an understanding of the general concept and importance of spin-offs was carried out. An exploratory study by means of a questionnaire and interview survey was then conducted in order to understand the performance and innovative status of spin-offs. The survey was managed in two steps. Since a database on spin-off firms in South Africa was not readily available[7] for the Western Cape region, information on spin-offs was gathered in the first stage. Conversations were held with knowledgeable people, e.g. staff at university technology transfer offices, to gain information about the existence of spin-offs and to gather advice on the questionnaire being developed. The search for spin-offs took place over the period from 2007-2010 and a total of 53 firms were identified. Based on our field work and interviews, four firms did not fall into the research area; one was sold by the professor who founded it, two were privatised and two are dormant firms. The remaining 44 firms were

[6]This stems from the legacy of inequitable access by the majority of the population to the economy under Apartheid, which has led to a provision for redress in almost all South African legislation.
[7]This is not an unusual phenomenon. Not only in developing countries but in developed countries as well, not obtaining sufficient data in this relatively new branch of enquiry, led researchers to use more qualitative techniques, such as case studies (Rothaermel *et al.*, 2007: 701).

considered suitable to include in our research.

In the second stage, a questionnaire was developed aimed at spin-off founders and/or director(s) of the firms. First of all, the questionnaire was sent by email to the firm, after which the research interviewed, face to face, with the firms that responded to our questionnaire. The questionnaire contained several sections. The first part concerned the description of the firm, in terms of age, size, type of activity, and founders' profiles. The second part of the questionnaire enquired about the motivations behind the spin-off formation, as well as the funding sources and target markets. The third dealt with the identification of the major problems faced by the firm during its life.

Eighteen firms responded to the questionnaire[8]. Only eight firms, however, conceded face-to-face interviews. Since the interviews used the same questionnaire as basis, the research combines the data supplied by the firms who completed it electronically, with the data obtained by putting the questions face to face. In order to protect the privacy of the case study firms, firms from the University of Cape Town are coded from Cape Town I to Cape Town VI and firms from Stellenbosch University are coded from Stellenbosch I to Stellenbosch XII.

2.1.4. Limitations of the study

Since the study is based on one province in South Africa. In addition, the number of respondents relatively small, therefore, the research cautions strongly that no generalisations to spin-offs in the rest of the country can be made. The research considers this an exploratory

[8]The research found that not all the firms were accessible for the following reasons: 1) researcher(s) did not consider their firms to be spin-offs; 2) researcher(s) were unwilling to participate in the study. A TTO officer interviewed explained that this is not uncommon, since most researcher(s) are reluctant to participate in questionnaire surveys.

study, as prelude to a larger scale study of the rest of the country's regions. At this stage, comparisons to spin-offs at other South African regions are therefore not yet possible.

2.1.5. The Results of the Study

The research sought to answer certain key questions. In addition to the usual questions relating to profiles of the firms, the following key questions were posed. What motivated founder(s) to create a spin-off? Do the firms collaborate with other organisations, institutions, or firms? Where did university spin-offs receive assistance from at the time of start-up? What obstacles did they face? In the following sections, the detailed answers are provided.

2.1.5.1.*The Profile of Western Cape USOs*

Definitions of a Spin-Off

Before describing the profile of the USOs that responded, it is important to remark on the variation in the understanding of the concept of a USO. In our search for an appropriate definition of a USO for the South African context, we settled for the relatively simple definition employed by Smilor *et al*.[9] In practice, it turned out that the definition could be more complex. Below, the research lists the more complex definitions of a university spin-off firm that emerged from our study. It was furthermore clear that, in some instances, where the firm definitely fitted the textbook definition of a spin-off, the founders did not consider themselves founders of a spin-off, but rather an independent start-up. This has implications for the measurement of the output of, amongst others, university transfer offices.

[9]Spin-out firms that provide consulting services were also included in the study. Smilor et al. excluded those types of companies in their research.

According to Smilor *et al.*'s simple definition there are two important key points; 1) the core technology of the spin-off firm was transferred from the parent university. 2) the founder and/or key employees of the spin-off was a faculty member, staff member, or student who left the university to start a firm or who started the firm while still affiliated with the university. In our case studies, a more complex definition of a university spin-off was identified:

1. In three instances, the core technology originated from the parent university, but there was much variety with respect to the origin and employment status of founders. For example, for some firms, the founder(s) came from the parent university, and they continue to work for the parent university, while at others, the founders were employed by the parent university or were students there, but now no longer work or study there. In another case, the founders were not from the parent university. Another possibility is that the founders continue to work for the university and the spin-off simultaneously until retirement.
2. In another example, the core technology did not originate from the parent university, but the founder(s) was/were an employee(s) or was/were student(s) of the parent university.
3. In another case where the core technology did not originate from the parent university, nor were the founder(s) employed by the parent university, the spin- off firm used certain resources (such as laboratories) from the parent university.
4. The spin-off firm was created by the parent university (wholly university-owned spin-off firm).

Age and Size

Spin-off activity for these two universities is a relatively recent phenomenon. In the last few years of the previous century, only one spin-off was created before 1990. Following this, in

1990-1994, one company was set up whereas between 1995 and 1999, two companies were created. The number of new firm creation in the form of spin-offs picked up to 5 in the 2000-2004 intervals and almost doubled (nine companies) in the 2005 to 2008 period. Most firms in the survey are therefore relatively young firms.

The firms' size is measured in terms of turnover, employment and R&D expenditure (Table 2.1). As far as turnover is concerned, firm size is not too small (see, for example, Chiesa and Piccaluga, 2000 for comparison). All the firms have got employees, with the biggest concentration of firms falling in the six to ten employee categories. This is not strange for the university spin-off environment. Only four firms have got more than 31 employees. These firms have created more than 405 jobs since inception making some contribution to the reduction in unemployment, which remains a thorny challenge for the country.

Since a core element of the spin-off activity usually involves a new technology or new scientific knowledge, it is helpful to consider how much the new firms spent on R &D. It reveals that all firms invest in R&D. Seven firms' R&D budget is higher than one million Rand (about US$150,000). Only five of them are under the 50,000 Rand (about US$ 7000).

Table 2.1: Firm size: turnover, employment, and R&D expenditure (2008)

Turnover[10] (millions Rand)	Number of companies	Employees	Number of companies	R&D expenditure (Thousands of Rand)	Number of companies
0-10	13	1–5	4	<50	5
11-100	5	6–10	6	50–150	2
		11–20	2	151–300	1
		21–30	2	301–500	2
		31–50	1	501–1000	1
		51–100	3	>1000	7

[10] Some companies mentioned that they haven't sold any products since they are still in development stage and do not have turnover yet.

	Total : 18 companies		Total : 18 companies		Total : 18 companies

Source: Authors survey 2009-2010

Table 2.2: Companies by Type of Activity

Type of activity	Number of Companies
Manufacturing	10
Services	2
Consultancy	2
Research	1
Product-development	1
Services+ Consultancy+ Research+ Product-development	1
Manufacturing+ Services+ Consultancy+ Research+ Product-development	1
	Total : 18 companies

Source: Authors survey 2009-2010

If the type of activity is taken into account (Table 2.2), the spread of R&D spending makes more sense. Most firms (10) in the sample were involved with manufacturing. Only one firm had a policy of selling research results, but it had not done so at the time of the survey, being newly established. Two firms were in service activities; and a further two had multiple activities – that is, they combined manufacturing, service, consultancy, research and product-development.

2.1.5.2.*Who are the Founders and why did they spin off?*

Founders' Profiles

Founders mostly come from the academic environment (university).Two of the USOs were founded with the joint effort of people coming from the academic environment and industrial context (Table 2.3). Seven firms' founders were individuals, while the rest involved teams.. Seven were created by two to three founders. Only one firm had between six and ten founders, while three had four to five founders. This most likely has to do with the nature of the firms' business activity, but is quite similar to the findings for spin-offs in other countries where small and medium-sized enterprises are ubiquitous (see, for example, McQeen and Wallmark, 1982; Smilor *et al.*, 1990; Steffensen *et al.*, 1999; Chiesa and Piccaluga, 2000; Erden and Yurtseven, 2010).

Table 2.3: Founders' Profiles

Founders original activity[11]	No of companies
University	9
Government research centre	1
University and industry	2
Industry	1
University + Industry	3
University + Government research centre + University and industry + Industry	1
	Total: 17 companies

Source: Authors survey 2009-2010

The research asked the respondents to rate their motivations behind the creation of a spin-off firm on a five-point Likert scale where 5 was most important and 1 unimportant. Table 2.4 reflects the outcome. For the majority of firms identifying market opportunities was the most important motivation. In other words, finding an opportunity to commercialize their products was the most important motivation behind the creation of the spin-off firm. Other very important motivations were applying knowledge into practical applications and utilizing the existing knowledge, followed by personal success and to be independent as important. Table 2.5 shows the market at inception and currently. Most firms started with an eye on the international market.

Table 2.4: Motivations behind the Formation of a Spin Off

Motivations-Spin-offs	Average
Identification of market opportunities	4.27
Apply knowledge into practical applications	3.88
Fully utilise existing knowledge	3.44

[11] One company did not fill in the answer as they said "The two founders had finished their PhD's at University and started the company independently i.e. with no University assistance. In my opinion this is not a clear case of a University "Spin off".

Personal success	3.33
To be independent[12]	3.29
Complete the projects	3.27
Aversion for bureaucracy and low risk orientation of the research environment	3.22
Profit making	2.94
Other factors[13]	2.88

Likert scale: 5 = most important, 1= unimportant
Source: Authors survey 2009-2010

Table 2.5: Market at Foundation and at Present

	Geographical market at start-up	Present markets of the spin-off companies[14]
Market	Number of companies	Number of companies
Provincial	5	1
National	5	5
International	8	11
Total	18	17

Source: Authors survey 2009-2010

Funding Sources

Funding for the spin-offs in the sample came mainly from three types of sources, namely government (regional and national funding vehicles), venture capital (primarily from university venture capital funds) and other funds (such as project revenues, operational revenue streams, etc.). In three cases the University of Stellenbosch has provided the majority of the funds (100 %, 90 % and 80% respectively). Only 10% of the funding was received from international foundations (Table 2.6).

Table 2.6: Funding Sources

Category	Source	Percentage of total capital at start-up
Personal Resources (include friends and relatives)	Stellenbosch I	10%
	Stellenbosch II- Directors	20%
	UCT I	20%
	UCT V	40%
	UCT VI	70%
Governments	Stellenbosch III- Cape Biotech	100%
	UCT II- Regional Innovation Centre	100%

[12] One company did not fill this motivation in.
[13] Nine companies did not fill this motivation in.
[14] One firm did not answer this question.

	UCT III- DTI and Cape Biotech	-
	Stellenbosch IV- NRF IF	100%
	Stellenbosch I	10%
	UCT V- WRC, NRF	50%
Bank Loans	Stellenbosch II- Investec	20%
Venture Capital	Stellenbosch V- University	Approx 10%
	Stellenbosch VI- University	Approx 80%
	UCT III - Bioventure	-
	Stellenbosch VII - IDC	95%
	Stellenbosch X- University (facility + interest)	100%
	Stellenbosch I	60%
	Stellenbosch VIII- JDH	100%
	Stellenbosch II- JDH	60%
	UCT I	80%
	Stellenbosch XI- IDC through SPII	-
	UCT VI	20%
International research foundations	Stellenbosch I	10%
Competitive grants	Stellenbosch I	10%
Other	Stellenbosch VI - Operations in 1st year	Approx 20%
	UCT III -Revenue (Sales)	-
	Stellenbosch IX- Client contract	100%
	Stellenbosch V- Comes from projects	Approx 90%
	UCT IV- Vodacom Found	-
	Stellenbosch XI- Consulting projects, Product	-
	sales	10%
	UCT V- Competitions	10%
	UCT VI- Competitions	
	Stellenbosch XII- Research institute funds	90 %
	(University)	10%
	Stellenbosch XII- Employees shares	

Not: UCT: University of Cape Town, Stellenbosch: Stellenbosch University, DTI: Department of Trade and Industry, NRF: National Research Foundation, NRF IF: National Research Foundation Innovation Fund, IDC: Industrial Development Corporation, JDH: John Daniel House Ltd, WRC: Water Research Commission
Source: Authors survey 2009-2010

2.1.5.3.*Major Problems Encountered*

The most significant problems faced by spin-off firms in the Western Cape RIS, South Africa are funding problems and other factors such as getting skilled people, lack of facilities, marketing of the products they developed, and time available to do everything (Table 2.7). Other factors such as patenting, problems among the owners and family commitments do not create significant problems for the firms.

Table 2.7: Major Problems Faced by Spin-Offs [15]

Type of problem faced by spin-offs	Average
Funding	4.00
Others factors (e.g. getting skilled people, lack of facilities, marketing of developed products, time available to do everything)[16]	4.00
Technical problems in development and production	3.35
Distribution	3.17
Estimation of the market demand	3.11
Commercialisation	2.94
Regulatory Compliance	2.64
Relationships with the parent university	2.64
Problems related with the position played in the parent university	2.64
Problems in the management of human resources	2.58
Contractual problems	2.58
Patenting	2.29
Problems among owners	2.17
Family commitments[17]	1.66

Likert scale: 5 = most important, 1= unimportant
Source: Authors survey 2009-2010

2.1.5.4.*Collaboration and Links to Other Organisations*

The results show that, in the case of the Western Cape RIS, it is evident that there is a strong link with the university and spin-off firms; government and spin-off firms. These links include funding, joint projects, sharing inputs and staff. All spin-off firms have collaboration with the universities (except two). Three firms collaborate with both national and international universities and hospitals. Twelve out of eighteen firms have collaboration with the government on different levels and one of the firms collaborates with a foreign government. There is no collaboration with the other spin-off firms except for two firms (Table 2.8).

Table 2.8: Collaboration with Other Organisations

Companies	Government organizations	Research groups/institutes at universities	Other spin-off companies
Stellenbosch I	Yes	Yes Stellenbosch University, South Africa University of Twente, Netherlands University of Grenoble, France Ecole Centrale de Nantes, France	No

[15] One company did not fill in this part of the survey.
[16] Nine companies did not fill this problem in.
[17] Eight companies did not fill this problem in.

		Aachen University of Technology, Germany Kassel University, Germany	
Stellenbosch II	Yes	Yes St Louis Hospital, France Stemlife, Thailand UCT, South Africa	No
Stellenbosch III	Yes	Yes	No
Stellenbosch IV	Yes	Yes	No
Stellenbosch V	Yes Danish government	Yes Stellenbosch University, South Africa Copenhagen University, Denmark	No
Stellenbosch VI	No	Yes	No
Stellenbosch VII	Yes	Yes	No
Stellenbosch VIII	Yes	No	No
Stellenbosch IX	Yes	Yes	No
Stellenbosch X	No	Yes	No
Stellenbosch XI	Yes	Yes	No
Stellenbosch XII	Yes	Yes Stellenbosch University, South Africa University of Ford Hare, South Africa	No
UCT I	No	Yes MRC, South Africa UCT, South Africa	No
UCT II	No	Yes	No
UCT III	Yes	Yes	No
UCT IV	Yes	Yes	Yes
UCT V	Yes WRC COFISA	Yes UCT, South Africa	Yes
UCT VI	No	No	No

Source: Authors survey 2009-2010

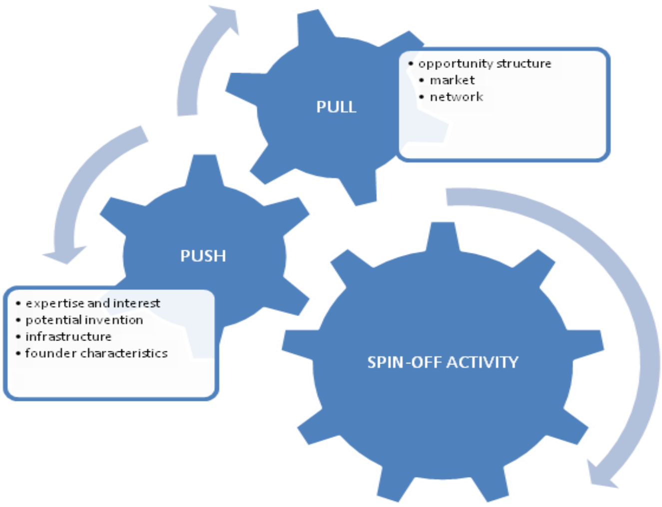
2.1.6. Discussion

In this section, the research remark on the key issues in the study; concentrating on the founders' motivations behind the creation of the firm, the collaboration among the spin-off firms, parent university and government and obstacles that firms faced.

2.1.6.1. *Motivations*

Much empirical work has focused on the factors that will foster the creation of university spin-offs, including institutional support, local context features, and technology characteristics (Fini *et al.*, 2009). On the contrary, the factors that motivate academics at university to venture into spin-off activity have only more recently been the explicit focus of empirical studies. As illustrated in Figure 2.1, these factors are usually framed in terms of pull (demand-side) factors and push (supply-side or production) factors (see, for example, Smilor *et al.*, 1990; Weatherston, 1995; Chiesa and Piccaluga, 2000; Bower, 2003; Meyer, 2006; Rasmussen, 2006; Kroll, 2009; Fini *et al.*, 2009; Morales-Gualdrón *et al.*, 2009; Erden and Yurtseven, 2010).

Figure 2.1: Push and Pull Factors of University Spin-Off Activity



Source: Author' elaboration

The literature also indicates that the motivations cited by academic entrepreneurs are as diverse as the definitions of university spin-offs and the nature of the activities carried out in such firms (Kroll, 2009: 98). If a spin-off is not related to a particular technology, therefore, the driving force may be to apply academic knowledge, for instance, in the supply of consultancy services[18]. The rationale for such decisions consequently requires a consideration of the environment in which they are made (Kroll, 2009). In order to understand spin-off decisions, we need to take account of interactions amongst individuals, organisations, policy measures,

[18]Indeed four of our respondents rate this as an important motivation, while five cited the need to exploit their experience as important.

and the overall environment the entrepreneurs face.

In the case study this research considered, for the majority of firms identifying market opportunities was the most important motivation. This is an interesting finding, since other studies (such as Fini *et al.*, 2009) found that supply-push factors, such as the existence of a potential invention, or the expertise or interest of the founders were most important. From the information supplied, however, the causality is not crystal-clear, i.e. was it possible to identify a market opportunity because some potential technology was already in the making, or did the existence of a market opportunity lead to the emergence of the technology? These are the kinds of questions that are being pursued in the follow-up studies.

Given the importance founders assigned to market opportunities it is interesting to explore what their respective target markets (i.e. geographical market focus) were at the inception, and whether these have altered over time. This is revealed in Table 2.5. It is interesting to note that most firms (eight) have had an international market and five started in national and provincial respectively during their start-up phase. Most firms maintained this focus as currently; eleven firms have an international market, five national and one provincial market focus.

Other very important motivations are: applying knowledge into practical applications and utilizing the existing knowledge, followed by personal success and to be independent as important. This personal success could be interpreted in various ways. From the literature it could mean enhancing one's reputation, strengthening your position in a network of peers rather than success in money terms. Fini *et al.* (2009) for example, found from their survey of the founders of the 47 university spin-offs they studied in the Emilia Romagna region, that Italian academics did not seem to be driven by entrepreneurial attitude (such as personal earnings, employment attainment), but by their expectations of enhancing their academic standing through new opportunities for basic research, accessing research grants, etc. Research based on the motivations behind early spin-offs from MIT (Roberts and Wainer, 1968) found that the primary driver was a desire for autonomy, while McQeen and Wallmark (1982) studying the motivations of entrepreneurs spinning off from Chalmers Institute of Technology found that it was the desire to fulfil their goal of commercialising their technologies rather than generating wealth that motivated the founders.

2.1.6.2. *Collaboration and Link to Other Organisations*

Even though over the last two decades collaboration has turned out to be of the utmost importance in the organisation of R&D in all knowledge-intensive industries (Valentin and Jensen, 2006), relations that develop between a spin-off and its environment during the various stages of its development is something that has only been investigated to a limited extent in the literature (Gubeli and Doloreux, 2005). The innovation systems approach suggests that collaboration is necessary to develop new scientific and technological knowledge for new products and processes (McKelvey, 2004). Gubeli and Doloreux (2005) identified that firms may be interested in collaborative relationships with innovation and production centres, venture capitalists, business angels, banks and other financial organisations seeking high return on investment; and public institutions like government, development agencies, and science parks, innovation centres and incubators interested in starting a process of technological innovation in their regions. As a result of collaboration, firms are saved from isolation (Gubeli and Doloreux, 2005) and can access a pool of skills, equipments and some other opportunities (Byrd, 2002). Collaborative activities with other parties, including universities, research organisations, hospitals, and other spin-off companies, would increase the knowledge capital of researcher(s) in spin-offs. In other words, the knowledge inflow from the relationships formed in such collaboration increases the intellectual capacity of spin-off firms and helps them realise the commercial value of their knowledge stock and research experience (Erden and Yurtseven, 2010). The importance of collaboration is shown in empirical studies, for example, Erden and Yurtseven (2010) found that all the firms (12 spin-off firms from universities in Turkey) in their sample report to have some collaborative relations with other parties. Most firms are motivated to collaborate with other parties to perform research and development activities, to develop new products and to share knowledge and skills. In the case of South Africa, it is evident that there is a strong link with the university and spin-off firms; government and spin-off firms.

It may be argued that location of spin-offs on campus aids collaboration. Current study shows that most of the firms are still located on campus. Six firms[19] are "in" campus, three firms have located in a techno-park and nine firms located nearby the university. Similarly, Erden and Yurtseven (2010) found that almost all the firms in the study opted to locate their business close to universities (eight of the firms reside in techno parks which have been established in university premises by law, three of the firms are hosted in incubation centres that are located within university and only one firm is operating elsewhere). Avnimelech and Feldman (2011) support this trend in their literature survey. For example, investigation of 72 spin-offs from MIT (between 1980 and 1996) revealed that 50% of the spin-offs are located within 20 km of MIT and over 70% are situated less than 100 km from MIT. Another example can be given from Germany, where it was found that 66% of academic spin-offs locate within 50 km from their university. Williams and Majewsky (2002:6), however, argue that while it may make sense for the spin-off to be located near the parent organisation for synergy purposes, it is not

[19] One company was created by the UCT and Cape Peninsula University of Technology (CPUT) staff together and are located on the CPUT Cape Town campus. The company works as a non-profit organisation with experience and understanding of the unique challenges facing the implementation of e-health systems working in the public sector in Africa.

advisable to remain on campus and to access university facilities and infrastructure for free. They argue that getting this access for free, does not allow the firm the opportunity to learn to carry overheads and incorporate it into a realistic cost structure (which it will have to do when it grows larger). Also, the academic atmosphere is often not conducive to the pace of work, flexibility and agility that a spin-off will have to face in a real competitive environment. In addition, housing staff of a spin-off with different conditions of employment together with the other academics may create destructive tensions. One of the biggest drawbacks of remaining on campus is the possibility of being locked-in to the university's administrative processes that are designed for a purpose and work culture that is quite different from that of a business.

Having discussed the motivations behind the firms' creation and collaborations with other parties, the research now turn to the major obstacles which university spin-offs faced.

2.1.6.3.*Major Problems Encountered*

One strand of research in the academic entrepreneurship literature, has concentrated on identifying the factors that enhance and impede the formation and expansion of university spin-offs (Rothaermel *et al.*, 2007: 760). The impeding factors are grouped into those that have to do with information gaps, unrealistic expectations, lack of competencies in founding teams, scarcity of resources (i.e. funding and structural support), and cultural problems. Spilling (2004) also examined some of the barriers to commercialisation such as lack of management experience, networks to resources and role models of forming entrepreneurial teams, availability of services, access to financial resources (i.e. pre-seed, seed capital), conflict between shareholders regarding to the development of the venture. Indeed, in the current survey, the largest difficulty faced by spin-off firms in the Western Cape RIS is funding problems and other factors such as getting skilled people, lack of facilities, marketing of developed products, and time available to do everything. This problem is not unique to South Africa but also prevails in developed countries. Funding for example, seems to be a universal problem: Canadian biotechnological spin-off firms reported difficulties in accessing capital for firm development (Byrd, 2002); Similarly, Japanese spin-off firms found difficulties in obtaining finance, recruiting staff and R&D funding (Kondo, 2004; Kondo and Hasegawa, 2007); Italian spin-off firms experienced difficulties in funding and commercialisation of research (Chiesa and Piccaluga, 2000). Turkish spin-off firms' most important obstacles were insufficient sources of financial capital (Erden and Yurtseven, 2010). The use of personal sources, loans, grants and other sources show that financing is a weak angle of the system in South Africa. The argument is usually when a well-developed venture capital market to provide the seed funding, is lacking, the university should create a venture fund to fill this gap. The empirical evidence so far indicates that universities have not had much success in filling this gap (Fini *et al.*, 2009).

Spilling (2004) found that it is important that academics must have an entrepreneurial orientation to identify potential opportunities for commercialisation and start the process. A lack of management experience may be perceived as a barrier to success. In a case study of Delft University, the Netherlands, (Van Geenhuizen and Soetanto, 2009) it was found that the primary obstacle for the university spin-off was market related (factors such as lack of marketing knowledge, sales skills and customer base). Financial obstacles also played a significant role (cash flow, investment capital, R&D investment), along with management related issues (such as dealing with uncertainty). The authors were not surprised by the market-related problems owing to the fact that spin-off firms evolve from a non-commercial back ground. In order to become profit-generating, different skills and knowledge are required.

2.1.7. Lessons and Conclusion

An objective of this section was to endeavour to define spin-off firms and determine their nature, particularly in a South African context. The focus of the research was spin-offs at the Universities of Stellenbosch and Cape Town, where a study was conducted on firms created by students and/or researchers who have or have had links with these institutions. Some firms were created by post-graduate students, others still by faculty members or by the universities themselves. The study was confined to knowledge and technology transfers from the university to the market irrespective of whether they received university support (from TTOs or otherwise) or not. Part of the results from the research was that some firms were created by individuals, who did not receive support from universities; hence, they did not view themselves as a "spin-off" firm. Therefore, some researchers came to the conclusion that firms supported by TTOs (universities) can be defined as a "spin-off" firm. It was furthermore clear that, in some instances, where the firm definitely fitted the textbook definition of a spin-off, the founders did not consider themselves founders of a spin-off, but rather an independent start-up. This has implications for the measurement of the output of, amongst others, university transfer offices.

As a result, this research can define the spin-off in South African framework as "*A new firm created to exploit some knowledge, technology or research results conducted at the university by faculty members or students who receive (any kind) of support from the university (the TTO); a new firm created around a university license of intellectual property (founders may be or may not be from university); a firm created by the university itself (wholly university-owned)*".

In summary, what the research have found can be put into two categories, that is, (i) what the field work experience taught and (ii) the insights the research derive from the information garnered by means of questionnaires and personal interviews. Given that it was a small-scale study, the research cautions that the results should be handled with care.

Two insights of a practical nature emerged from the field work:

- Different interpretations of the definition of a spin-off firm exist in the minds of the founders themselves, as well as the people involved in the technology transfer process. This implies that researchers have to be very precise in how they define a spin-off and communicate this clearly to the respondents.
- Universities keep records of spin-offs, but these records do not seem to be updated, i.e. the universities do not closely track the progress of their spin-offs (except in the cases where they have equity). After the field excursion, the research revealed that some of the spin-offs do not exist anymore, and others were discovered that do not appear on the lists.

The research finds that spin-off formation is relatively new for these universities, with very little activity before 1990, accelerating at both universities after 2005, with the largest concentration in manufacturing. The founders originate primarily from universities, with some having held positions in both academia and industry, and a minority purely from industry. The most important reasons cited for spinning off are market opportunities, a desire to exploit knowledge and experience commercially. Like university spin-offs elsewhere, they consider funding to be the most significant problem facing them, followed by other factors (e.g. getting skilled people, lack of facilities, marketing of their products, time available to do everything). This exploratory study provides important lessons and insights that could inform similar research on a larger scale in future.

The next section introduces biotechnology specifically and a comparative narrative of biotechnology spin-off formation in another RIS which came to biotechnology 'bandwagon' relatively late.

2.2. Academic entrepreneurship in South East Asia: An Exploratory Study of Spin-offs in Biotechnology from Hong Kong Universities[20]

2.2.1. Introduction

University research with associated spin-offs is at the heart of knowledge generation in the biotechnology industry. The role of universities all around the world has changed during the past two decades. In particular, universities now have a stronger mandate for promoting technology transfer to enhance a region's economic development (Leung and Mathews, 2006). Universities contribute to the local economy through different channels, such as creating the pre-conditions for regional learning systems, generating technology-based spin-offs, collaborating in R&D with companies, and training scientists, engineers, researchers and other graduates. Adding to these channels, universities contribute through establishing science and technology parks and incubator centres, commercialising research activities and contracting research with companies (Longhi and Keeble, 2000). The advent of biotechnology and its potential benefits for nations sorely in need of economic development, has added urgency to the pursuit of the new role of active conduit between science and market.

The channel on which this section focuses is the creation of a spin-off company that embodies a technology developed at a parent university. This is by no means a new phenomenon in developed countries, especially in the biotechnology industry (Zhang, 2009). There is an

[20]This section was published in a journal. Reference as follow; Uctu, R. and R. Jafta (2012), "Academic entrepreneurship in South East Asia: An Exploratory Study of Spin-offs in Biotechnology from Hong Kong Universities", *Asian Journal of Technology Innovation*, Vol. 20, No. 1, June 2012, 141–154

increasing trend towards spin-off companies in Asia as well, although, only a small number of studies has so far dealt with biotechnology spin-offs from universities in Hong Kong as latecomer in biotechnology. The purpose of this research is to gather information about the history and innovative status of biotechnology spin-off companies from Hong Kong universities in order to understand the dynamics and influence of this phenomenon as knowledge transfer process in biotechnology in Hong Kong better. By using a case study method, the study analyses the local activity as an important step towards understanding the emerging biotechnology industry in latecomers. Although this study was conducted (out of necessity) on a relatively small scale, it is believed that the insights gained from this exploration into the field could prove useful for future research. Many of the issues involved have been analysed in the literature. These include university-industry technology transfer and technology transfer offices (TTO) (Poon and Chan, 2007; Sharif and Baark, 2008), research on the spin-off process by higher education institutions conducted by Leung and Mathews (2006), biotechnology industry in Hong Kong discussed by Poon and Liyanage (2004) and Baark (2005) and biotechnology development in Hong Kong compared to Singapore by Tsui-Auch (2000). The merit of this section, however, lies in the fact that it combines all of these concepts, with a specific focus on university spin-offs in biotechnology.

The rest of the sub-section consists of three parts: in the first, sub-section 2, the concept of spin-offs is defined, located in the context of academic entrepreneurship and then, sub-section 3 discusses the findings of exploratory study on biotechnology spin-off companies in Hong Kong. The section concludes with some lessons learnt and pointers for further research on the growing worldwide spin-off phenomenon (sub-section 4).

2.2.2. The Importance of Spin-Offs

Many universities have become increasingly interested in the creation of a spin-off company as an important tool for the commercialisation of research results (Rasmussen and Borch, 2010; Lee, 2010), but it transpires that there is no universally accepted definition of a spin off. Smilor, et al. (1990: 64) define a spin-off company in two ways: (1) the founder was a faculty member, staff member, or student who left the university to start a company or who started the company while still affiliated with the university; and/or (2) a technology or technology-based idea developed within the university was used to start the company. The effectiveness of this technology transfer method is typically visible in knowledge-intensive sectors such as biotechnology (Chiesa and Piccaluga, 2000; Nezu, 2005).

Policymakers in developed countries are encouraging universities to increase the rate of spin-off formation. The set-up of knowledge-based organisations with original ways of interacting and stimulating academic entrepreneurship is a main contributor to regional economic development (Smith and Bernardy, 2000). Policies to promote university spin-offs have a long history and the results in terms of numbers of new companies created are indicative of success. In the USA, for example, in 2010 alone, 651 university-based start-up companies were started; while a total of 3,657 companies were still operating in 2010 (AUTM, 2010a). Other countries have also followed American practice. In Canada, in 2010, the total number of operational start-ups increased in number from 591 (2009) to 632 (AUTM, 2010b). In UK, 273 new spin-off companies were set up in 2009/10 to exploit intellectual property originating in UK higher education institutions (HEIs). Meanwhile, the total number of university spin-off companies that had been active for three years or more grew steadily, from 746 in 2005/6 to 969 in 2009/10 (www.educationinvestor.co.uk).

There is an increasing trend of spin-off companies in Asia as well (Ngan, 2006). For example, Japan in 1995 created 15 university spin-offs but in 2004 leapt to 195 (Kondo and Hasegawa, 2007). China is also visibly successful in creating high-tech start-ups from universities and research institutes. These start-ups are especially noticeable in Beijing (Kondo, 2003). The World Bank's Report of 2001 on "China and the Knowledge Economy" cited by Nezu (2005) confirms that Beijing University and Tsinghua University created more than 60 spin-offs each in high tech areas. Hong Kong SAR of China has been in the creation of spin-offs for 19 years, starting in the early 1990's. However, there is a limited amount of literature directly dealing with the topic of biotechnology spin-offs from universities in Hong Kong.

2.2.3. Case Studies on Biotechnology University Spin-Offs

2.2.3.1. *Research Methodology*

A variety of secondary sources of information enabled an understanding of the general concept of biotechnology and spin-offs. An exploratory study by means of a questionnaire survey was conducted in order to understand the performance and innovative status of biotechnology spinoffs in Hong Kong. The survey was managed in two steps. During the first stage, research was carried out to identify how many universities have a TTO, and a five-page email questionnaire was sent to the TTOs at five universities in Hong Kong, namely University of Hong Kong (UHK), Chinese University of Hong Kong (CUHK), Hong Kong University of Science and Technology (HKUST), Hong Kong Polytechnic University (PolyU) and City University (CityU). All the universities responded to the questionnaire. TTOs were requested to specify the spin-offs at the university and indicate how many of them are in the biotechnology sector. This process yielded a total of 19 biotechnology companies which seemed to fit the definition of a spin-off.

In the second stage, a nine-page questionnaire was developed specifically for the biotechnology spin-off companies. The questionnaire was emailed to those companies identified through the TTO survey; thereafter companies were telephoned and visited to administer the survey. The questionnaire covered, amongst other things, the nature and activities of the company, motivations behind the creation of the company, and the identification of the major problems faced by the company during its life. During the second stage, field research revealed that two biotechnology companies are not active anymore and three companies are not biotechnology spin-offs. It was evident that one company was not in biotechnology after the completed questionnaires were received, and two others turned out not to be biotechnology companies after the follow-up telephone calls. Two companies had the same director and commercialized and accounted for their products under one company. A further company was identified as not being a biotechnology company after more investigation. In all, our research identified 12 spinoffs related to biotechnology created by Hong Kong universities. Of these, 10 spin-offs were classified in the 'biotechnology' field and two in the 'Chinese medicine' field (Table 2.9). In the next section, the cases of five (41%) biotechnology spin-offs from the universities in Hong Kong are explored[21]. Due to the limited number of companies, no inferences to the other population of spin-offs can be drawn from the primary data and its analysis (Perez and Sanchez, 2003). Companies presented in this section are coded as Company A, Company B, Company C, Company D and Company E.

Table 2.9: Spin-offs from Hong Kong universities[4]

Name of Institutions	No of spin-off companies and joint ventures	Biotechnology spin-off companies and joint ventures

[21] This is not an unusual phenomenon. Even in developed countries obtaining insufficient data in this relatively new branch of enquiry, led researchers to use more qualitative techniques, such as case studies (Rothaermel, et al, 2007: 701).

CityU	23	1
PolyU	18	1
HKUST	29	4
UHK	6	3
CUHK	15	3
Total	91	12

[4] Biotechnology including Chinese medicine
Source: Authors survey and university websites, 2009

2.2.3.2. *Results*

The study has highlighted the profiles of the companies; including the opportunities, obstacles and problems they faced. The survey posts a number of key questions, such as; what are the companies' classifications by type of activity? What are the companies' turnover and R&D budgets? Who is/are the founder(s) and where do they come from? What motivated them to create a spin-off? Do the companies have collaboration with other organisations/institutions/companies? Where did university biotechnology spin-offs receive assistance from at the time of start-up? The detailed answers are provided below.

Definitions of a Spin-off in Hong Kong

The research asked participants to define their companies, before analysing the companies' profiles. In this study the research settled for Smilor et al.'s (1990) simple definition[22] (discussed in Section 2). In the Hong Kong context, this research found that some companies clearly fitted this simple definition but some other companies were more complex and required an expanded definition: (1) The core technology and the founder(s) came from the parent university, and the founder(s) continue to work for the parent university, (2) The core technology of the company was created in the parent university, while the founder(s) were employed by or was/were research student(s) at the parent university, (3) The core technology

[22] Smilor et al.'s (1990) two-dimensional definition. In the aforementioned study, the authors excluded the spin-off firms that provided consulting services. However, those types of companies were included in our research.

of the company originated in the parent university, but the founder(s) was/were not from the parent university and (4) The company was created by the parent university.

The Age and Size

The survey reveals that biotechnology university spin-off activities in Hong Kong have started mostly after 2000. Four companies (Company B, C, D and E) were created after 2000 while Company B, C and D were set up between 2000 and 2005. Company E was set up between 2006 and 2009. Only one company (Company A) was set up before 1990, which was also the oldest biotechnology spin-off company that this survey discovered in Hong Kong.

Table 2.10: Firm size: turnover, employment, and R&D expenditure

	Turnover (Million HK$)	Employees	R&D budget (Thousand HK$)
Company A	11-50	31-50	301-500
Company B	<3	1-5	<150
Company C	4-10	1-5	-
Company D	<3	1-5	1000-5000
Company E	<3	1-5	<150

Source: Authors survey 2009

The firms' size is measured in terms of turnover, employment and R&D spending. The company size is relatively small (Table 2.10). Turnover of three companies is under HK$ 3 million, only company A has more than HK$ 11 million. Companies created after 2000 are still in the development stage, with turnover still relatively low. R&D expenditures are incurred in expectation of future growth in revenues. Companies in the biotechnology sector must spend capital resources on R&D in order to generate more revenues later on (Byrd, 2002). In the Hong Kong case studies, the R&D budget of the companies gives insight into the working of the companies as well. It reveals that only company D (i.e. product-development company) had more than one million HK dollar R&D budget in 2008. Two of them are under the

HK$ 150,000. The R&D budget of Company C was not provided. The companies' size is also reflected in the number of employees. Biotechnology-related companies from universities are small in Hong Kong. Only one company has got more than 31 employees. Four of them have less than six employees. Despite that, our results show that all companies developed commercial products and services (Table 2.11). Two companies developed Chinese medicines, one focused on health care while another two developed biotechnology-related products.

Table 2.11: Commercial products and services developed by the company

	Commercial products and services developed by the company
Company A	1.Five of Chinese Medicines 2.DNA vaccine/in collaboration with others
Company B	1. Gel electrophoresis unit 2. DNA fingerprinting reagent kit
Company C	1. TCM-based products and health foods
Company D	1.CardioDetect H-FABP rapid test 2.CardioCare hs-CRP & infectCheck CRP ELISA kits 3.INfectCheck NeoPT rapid test
Company E	1. Skincare lines: MELI, GENE & SABIO 2. Healthcare lines: GENECARE

Source: Authors survey 2009

Table 2.12: Companies classification by type of activity

Type of activity	Manufacturing-type	Services-type	Consultancy-type	Research-type	Product-development
Company A	O	O	O	-	O
Company B	-	-	-	-	O
Company C	-	O	-	-	-
Company D	-	-	-	-	O
Company E	-	-	-	O	-

Source: Authors survey 2009

When the companies' activity is taken into account (Table 2.12), two companies (B &D) are of the product-development type. Only one company sells research results (Company E) and one company (C) is in services. One company (A) has multiple activities, i.e. combines manufacturing, service, consultancy and product-development.

Table 2.13: Companies collaborating with government organisation(s), research group(s)/institute(s) at universities and other spin-off companies

Collaborations with	Government organizations	Research groups/institutes at universities	Other spin-off companies
Company A	Yes	Yes	Yes
Company B	No	No	No
Company C	No	Yes	No
Company D	Yes	Yes	Yes
Company E	No	No	No

Source: Authors survey 2009

Collaboration has turned out to be of the utmost importance in the organisation of R&D in all knowledge-intensive industries (Valentin and Jensen, 2006), especially in biotechnology. As a result of collaboration, companies could access a pool of skills, lab equipment and some other opportunities. These companies do not normally possess all of the necessary elements to capitalize on new developments at the pace biotechnology demands. For example, a company may have sufficient funding but lack the ideas and expert knowledge another company has (Byrd, 2002). In the case of Hong Kong, it is evident that collaboration between spin-offs and institutions is not strong in all spin-off companies. Only Company A and D had collaboration with the government and other spin-off companies, Company A, C and D had collaboration with the research groups at universities and institutes. Company D is the only one that had collaboration with the research groups at universities and institutes located in Hong Kong, China and other parts of the world (Europe). Company B and E had no collaboration at all (Table 2.13).

One of the most important science and technology indicators of biotechnology companies is the number of patents it creates in different categories. Patents are accepted to be evidence of a country's technological and inventive achievements (Pouris, 2005). Once patented, it is expected that the company will be able to develop the IP into a commercially viable product or use it to improve an existing one. Patents are also considered as a tangible asset, something the company may point to as proof that they are able to capitalize on their R&D (Byrd, 2002). On this note, Byrd (2002) analysed the profile of spin-off firms[23] in the biotechnology sector included in the Biotechnology Use and Development Strategy Survey-1999. Of the 358 core biotech firms found in the manufacturing sector, 123 were core biotechnology spin-off firms (34%). The author also found that Canadian core biotechnology spin-offs hold a total of 1029 existing patents. Rutherford and Fulop (2006) identified for five companies (as case studies) that IP was transferred to each company under licensing agreements, which gave the companies worldwide rights to their respective technologies. In Hong Kong, the companies' intellectual property portfolios revealed of the five companies, three companies have patents (Company A, D and E). Two patents are worldwide and one is a China-based patent.

Who Founded Biotechnology Spin-offs and Why?

In this section the research want to paint a picture of the founders of spin-offs at Hong Kong universities in terms of their affiliation, number at inception, as well as the reasons leading to the creation of a spin-off. The research begins with the founders' affiliations (Table 2.14). It reveals the founders' background.

Table 2.14: Founder(s)' original affiliation

Founders original activity	University	University and industry	Industry
Company A	O	-	-
Company B	O		-
Company C	-	O	-
Company D	O	-	O
Company E	O	-	-

[23] In Byrd's study, a spin-off is described as a new company created to transfer and commercialize inventions and technology developed in universities, firms or laboratories.

Source: Authors survey 2009

The founders of the companies came mostly from the academic environment. One company (D) was established with the joint effort of people coming from the academic environment and industrial context, whilst another company (C) was established by people working in both academia and industry. The next table (Table 2.15) reveals the number of company founders at inception. All the companies were created with joint effort, i.e. have more than one founder. Three were created by two to three founders. One company had four to five founders, while another company had between six to ten founders.

Table 2.15: Number of founder(s)

No of founders	1	2-3	4-5	6-10
Company A	-	O	-	-
Company B	-	-	-	O
Company C	-	-	O	-
Company D	-	O	-	-
Company E	-	O	-	-

Source: Authors survey 2009

A large selection of empirical work has focused on factors that can promote the creation of academic spin-offs, including institutional support, local context features, and technology characteristics (Fini, et al., 2009). However, the factors that motivate academics at university to venture into spin-off activity have only more recently been the explicit focus of empirical studies. These factors are usually framed in terms of *pull (demand-side) determinants* (like market opportunities, applying knowledge into practical applications) and *push (supply-side or production) determinants* (such as being independent or having a profit motive) (see for example Weatherston, 1995; Chiesa and Piccaluga, 2000; Rasmussen, 2006; Kroll, 2008; Fini, et al., 2009; Morales-Gualdrón, et al., 2009).

In addition, the literature also indicates that there is a large variety of motivations behind setting up an academic spin-off (Muller, 2010); and the motivations and aspirations cited by academic entrepreneurs for the foundation of a company are as diverse as the definitions of academic spin-offs and the nature of the activities carried out in such firms (Kroll, 2008; Muller, 2010). That is, if a spin-off is not strictly linked to a particular technology, it is possible that the driving force for the spin-off might be to apply academic knowledge in practice (as in providing consulting services). Understanding the set-up rationale also means taking into account the environment in which these decisions are made and implemented, i.e. 'set-up decisions are decisions driven by human agency and taken by individuals that scan the environment for opportunities.' (Kroll, 2008: 99). In the pre-seed phase, motivations such as opportunity recognition and organisational procedures may be accelerated. People who are mainly driven by the desire to work for themselves might have had the wish to become self-employed at the back of their mind long before. People such as these may therefore recognise the opportunity of exploiting the skills that they acquire, methods they develop or research they conduct (Muller, 2010). Hence, spin-off decisions are to be understood as part of interactions amongst individuals, organisations, policy measures, and the overall environment the entrepreneurs face.

When an entrepreneur decides to set up a company there are various considerations: technological considerations will clearly be at the early stage, requiring proof of concept. On completion, a prototype will need to be developed effectively turning knowledge into a product. The university spin-off is then faced with the issue of market uncertainty, particularly the issue as to whether the product will find acceptability in the market. Consequently, to overcome this problem, the company has to identify the right market application for the technology and to judge the market size (Shane, 2004).

Bearing in mind these insights from the literature, the research asked the founders in our survey what motivated them to create spin-off companies. Respondents were asked to rate their motivations on a Likert scale varying from 1 (not important) to 5 (most important). The results are shown in Table 2.16 and discussed below.

The analysis of the motivations behind the foundation of a spin-off company shows that the major motivation is that the founder(s) wished to apply their knowledge to practical applications, followed by potential market opportunities and profit making.

Table 2.16: Motivation behind the foundation of the spin-off company

Motivations	Average score
Apply knowledge into practical applications	4,8
Identification of market opportunities	4,6
Profit making	4,0
Complete the projects	3,4
Fully utilize existing knowledge	3,4
To be independent	3,2
Aversion for bureaucracy and low risk orientation of the research environment	2,8
Personal success	2,6
Other factors[5]	2,2

Note: 1: Not important, 2: Slightly important, 3: Neutral, 4: Important, 5: Most Important
[5]Two companies did not fill in this motivation in and none of the companies explained what the other factors are.
Source: Authors survey 2009

This is not a surprising result: other studies found similar results. Chiesa and Piccaluga (2000), for example, in their research on Italian spin-offs found that the majority of the firms' motivations (nearly 60%) were pull factors such as identifying market opportunities and applying their knowledge into practical applications. Jafta and Uctu (2009) found similar rankings of motivations for the Western Cape university spin-off firms in South Africa. Kondo (2004) conducted a first survey on the university spin-off companies in Japan and found that the primary motive to found a company is to put inventions to practical use. Making a fortune is mentioned by only a few founders as a primary motive. Kondo and Hasegawa (2007) conducted research on the characteristics of Japanese university spin-off companies by industry, region and founder-type. In their research respondents were asked to rate their motivations in six choices; commercialisation of developed technology, commercialisation of business ideas, asset making, social contribution, own capacity development and others. When faculty members started a spin-off their main motivation was commercialisation of technologies followed by social contribution and commercialisation of business ideas. This result is different in spin-offs created by the students. For them the major motivations were to commercialise business ideas, followed by social contribution and own capacity development. Researchers and technical staff, on the other hand, were motivated by social contributions, followed by commercialisation of business ideas and assets making with the same ratios. Unfortunately, our data for Hong Kong does not allow such a neat matching of founder-type to motivation rankings.

Given the importance founders assigned to market opportunities it is interesting to explore what their respective target markets were at the firms' establishment, and whether these have altered over time.

Table 2.17: Market at foundation and at present

	Geographical market at start-up				Present markets of the spin-off companies			
	Hong Kong	China	S. E. Asia	Others (Europe)	Hong Kong	China	S. E. Asia	Others (Europe)
A	O	O	-	-	O	O	-	-
B	O	-	-	-	O	-	-	-
C	O	-	-	-	O	-	-	-
D	O	O	O	O	O	O	O	O
E	O	O	-	-	O	O	-	-

Source: Authors survey 2009

Table 2.17 reveals the companies geographical target markets. Companies mainly targeted Hong Kong and Mainland China during their start-up phase and their current market still remains the same. Only Company D has focused on Hong Kong, China, other South East Asian countries and international market (especially Europe) since their start-up phase up until 2009.

In all cases, the companies developed commercial products/services (discussed in Table 2.11). This illustrates that they applied their knowledge to practical effect. In terms of marketing their products, the companies had clear market objectives from their inception.

Funding Sources

It is generally accepted that it is important to measure the financial status of biotechnology spin-off companies in order to better estimate the future growth of the sector. For this research's purposes, this funding source information is useful in relation to whether funding was an obstacle to spin-off formation and growth. Spin-off companies need to engage in technical and market development before selling their products or services and need finance to develop their companies. In many cases, companies cannot survive only with their own saving and must acquire finance from external sources like business angels, venture capitalists, and government agencies (Shane, 2004). In case studies in Hong Kong, funding came mostly from personal sources, venture capital and other sources (i.e. angel funds, personal loans) (Table 2.18). A small percentage of the funding was received from international foundations. The use of personal sources, loans and grants show that financing is a weak angle of the system in Hong Kong. This is actually not only for spin-offs but in general for biotechnology companies as it is a relatively new sector and private venture capitalists in Hong Kong have not shown very much interest in biotechnology so far (Lindgren, 2008). This view was supported by one of the participants in this survey. In the interview, the participant opined that venture capitalists in

Hong Kong have not shown much interest in biotechnology because they expect investment return in a short period like investing in Information and Communication Technologies (ICT). Returns on investing in biotechnology are, on the other hand, a long term prospect.

Table 2.18: Sources of funds for start-up

Percentage of total capital at start-up (%)						
Category		Companies				
		A	B	C[24]	D	E
Personal sources (include friends and relatives)		-	-	-	90	-
Governments		-	-	-	10	-
Venture Capital (China-based)		-	-	-	-	100
International research foundations		1	-	-	-	-
Competitive grants		40	-	-	-	-
Other(s)	HK Jockey Club	50	-	-	-	-
	University	10	-	-	-	-
	Personal loan	-	100	-	-	-
	Angel funds (investors)	-	-	~ 45	-	-

Source: Authors survey 2009

Obstacles to success

The literature on biotechnology identifies three crucial elements, commonly called the "three pillars" essential to success for a biotechnology start-up company: (i) effective management, (ii) sufficient capital and (iii) access to new technology that leads to products. All biotechnology companies face difficult managerial challenges in R&D because it is both the most expensive and the most critical aspect of bringing a product to market which requires a complex repertoire of knowledge, skills and talents (including marketing, the basics of Intellectual Property Rights (IPR), early-stage technology finance, and knowledge of scientific,

[24] Only given percentage

regulatory and ethical issues) (Schoemaker and Schoemaker, 1998; Meyers and Hurley, 2008; Malazgirt, 2011). The second pillar, sufficient capital presents a struggle for most biotechnology companies because the processes involved in developing a product is costly and time-consuming. (Schoemaker and Schoemaker, 1998; Malazgirt, 2011). Lastly, every biotechnology company, from its inception, must have a well-defined and well-articulated product focus. The company needs a clear vision to identify the avenues of its future revenue streams. For the biotechnology company it could be a single product to create the foundation for a profitable company. Once chosen, the company need to focus on the development of its chosen product and its underlying technology (Schoemaker and Schoemaker, 1998).

In order to understand the relevance and extent of these major challenges for the companies in survey, the research asked respondents to rate the obstacles they faced on a 5-point Likert scale, where 1 was not important and 5 was most important. The results are illustrated in Table 2.19.

Table 2.19: Major obstacles faced by spin-off companies

Type of problem	Average Score
Estimation of the market demand	4,2
Technical problems in development and production	4,2
Funding	4,0
Relationships with the parent university	4,0
Regulatory Compliance	3,8
Problems related with the position played in the parent university	3,6
Commercialization	3,5
roblems in the management of human resources	3,4
Distribution	3,0
Patenting	2,6
Problems among owners	2,2
Contractual problems	2,2
Others[6]	-

Note: 1: Not important, 2: Slightly important, 3: Neutral, 4: Important, 5: Most Important
[6] None of the companies filled this obstacle in.
Source: Authors' survey 2009

In the current survey, the biggest difficulties faced by biotechnology spin-off companies in Hong Kong are the estimation of market demand and technical problems in development and production, closely followed by funding and relationships with the parent university, regulatory compliance and problems related to the role played in the parent university. Comparing the findings to other studies, it appears that this applies not only in developing countries but also in developed countries. Funding, commercialisation and managerial skills, for example, seem to be a universal problem. Van Geenhuizen and Soetanto (2009) explored a case study of Delft University of Technology in the Netherlands and found that the main difficulties faced by university spin-offs are market-related (marketing knowledge, sales skills, customer base), followed by financial (cash flow, investment capital, R&D investment) and management problems (dealing with uncertainty, management). According to Van Geenhuizen and Soetanto (2009), managerial skills (e.g. market-related problems) are not surprising obstacles since spin-off firms must evolve from a non-commercial environment to become an established, profit-generating firm which implies that a new and different type of knowledge and skill set are required to be successful. Rutherford and Fulop (2006) found similar lack of expertise in Australian biotechnology start-ups. The authors stated that business awareness of science is low and scientists lack entrepreneurial skills to commercialise their research. To overcome these problems, the authors suggested to train and equip scientists with the necessary commercialisation and managerial skills. Byrd (2002) found that the major problem faced by Canadian biotechnology spin-off companies is access to the capital to develop the company. Similarly, Kondo (2004) found that a major difficulty at start-up for Japanese companies was access to finance, followed by staff recruiting. Likewise, Kondo and Hasegawa (2007) found the major difficulty is recruiting R&D staff, followed by the lack of R&D funds. Chiesa and Piccaluga (2000) also found that some of the major problems Italian spin-off companies faced was funding and commercialisation of the research results. Perez and Sanchez (2003) studied ten companies spun-out from the University of Aragon in Spain and identified that the major obstacles spin-offs confronted are the small market size and lack of financial sources during the first year of their activity. Although the rankings vary, it is evident that the top three to four obstacles elsewhere are similar to the ones listed in Table 2.19.

Overall, although spin-off creation from Hong Kong universities in biotechnology is a relatively new phenomenon, it seems as if the motivations for creating them, and the obstacles they face, are not significantly different from the experiences of spin-off companies elsewhere.

2.2.4. Conclusion

This section surveyed university technology transfer offices and firms in order to gather information about the history and innovative status of biotechnology spin-off companies from universities to contribute to the understanding of this phenomenon as knowledge transfer process in Hong Kong. The research analysed the local activity as an important step towards understanding the emerging biotechnology industry in latecomers. Based on the case study, research could say that there is an increasing awareness of academic entrepreneurship in the form of creating university spin-offs in Hong Kong, but not yet for the biotechnology sector, where spin-offs are relatively few. This is actually not only for spin-offs but in general biotechnology is comparatively new and private venture capitalists have also not shown very much interest in biotechnology so far (Lindgren, 2008).

One of the main results of this study is that the definition of biotechnology spin-offs for some companies clearly fitted the textbook definition but some others were more complex and required an expanded definition. In one case, for instance, the founders were not from the university while in another case; the company was created by the university itself.

The study has also highlighted the profiles of the companies; opportunities, reasons for foundation, obstacles and major problems faced by biotechnology spin-offs. In summary, the results suggest that biotechnology university spin-off firms in Hong Kong;

- are relatively small in size and young (less than ten years in existence),
- operate more often in biotechnology product and process industries rather than services;
- developed commercial products and services,
- collaborate seldom with other organisations, with two exceptions,
- are aware of IP protection,
- are mostly formed by university staff,
- are created with joint effort, i.e. have more than one founder,
- are motivated to create spin-offs in order to apply knowledge to practical applications and utilise market opportunities,
- experience problems with estimating the market demand, technical problems in development and production and difficulties with financing, as the most important inhibitors to success.

Although this study was conducted on a relatively small scale, it is believed that the insights gained from this exploration into the field could prove useful for future research. This section contributed to the understanding of the *rationale* for and the nature of biotechnology spin-offs from Hong Kong universities. The research also generated a few interesting questions to pursue in further research, namely:

i) it would be useful to track the survival strategies and / or growth paths of these firms over time; and (this idea is pursued in the pen-ultimate section for biotechnology spin-offs at Western Cape universities, South Africa).

ii) related to the first question, investigate the role that patents play in the success of these spin-offs, and finally

iii) compare the motivations of academics who were in a position to spin-off, but did not, to better understand the pull and push factors in spin-off creation. (This idea is pursued for academic scientists at universities in the Western Cape RIS in the next section).

2.3. Spinning-Off or Licensing? The Case of Academic Technology Transfer at Two South African Universities[25]

When universities embark on technology transfer to the private sector in order to reap the benefits of commercialisation, they have a number of different mechanisms at their disposal. This section focuses on the option of Intellectual Property (IP) licensing of technologies from universities. In particular, the study asked why academics that are in a position to create a spin-off, based on the commercial value of their invention, would rather opt for licensing. This question was pursued in the context of the universities' rationale for technology transfer, the nature and performance of their technology transfer institutions, and the motivations behind the academics' decisions. Although the research have previously introduced the concept of technology transfer and discussed it briefly, the research give a more extensive exposition here, as prelude to the description of TTO activities at the two universities. This case study focuses on two of South Africa's oldest research-led universities, based in the Western Cape region.

2.3.1. Introduction

[25] This section was accepted to a journal for publication. Reference is as follow; Uctu, R. and Jafta, R. (forthcoming, 2014), "Spinning-Off or Licensing? The Case of Academic Technology Transfer at Two South African Universities", *Industry and Higher Education*.

When universities embark on technology transfer to the private sector to reap the benefits of commercialisation, different mechanisms are available. The most common ways are creating spin-off companies and licensing technologies. Several authors have assessed the determinants and outcomes of faculty involvement in technology commercialisation, such as the tendency of academics to patent and disclose inventions, co-author with industry scientists, and create companies (Siegel *et al.*, 2007), while others have examined the characteristics of the knowledge transferred through licensing, evaluation of Technology Transfer Offices (TTOs) productivity and the role of incentives in licensing performance (Conti *et al.*, 2007). However, only a few studies have focused on the factors underlying the choice researchers make, i.e. whether technology should be licensed or commercialised by creating a spin-off company.

With the aid of case study methods, focusing on technology transfer activities at South Africa's two oldest and premier research-led universities (University of Cape Town (UCT) and Stellenbosch University (SU)), the following questions were addressed in this section:

1. What is the rationale for technology transfer at the two universities?
2. What progress with regard to technology transfer has been made at these universities?
3. What motivates researchers to license their inventions?
4. Why would researchers in a position to create a spin-off, i.e. those who have a technology with commercial potential, choose not to do so?

The answers to these questions will contribute valuable insights primarily for TTOs, university management, and policymakers in South Africa and similar developing countries. The purpose and scope of this section is therefore not aimed at settling debates in the context of technology transfer mechanisms.

The remainder of this section is structured into seven sub-sections. Sub-section 2 gives a brief survey of the literature on technology transfer from universities to the public, while sub-section

3 deals with the role of technology transfer offices. Sub-section 4 contains the technology transfer activities at the two universities. In sub-section 5 the purpose and scope of the study is described and the data and methodology used are explained and then the results are presented. In sub-section 6 the main discussion is undertaken and the conclusions are highlighted in sub-section 7.

2.3.2. The Importance of Technology Transfer from Universities

In this section, the research first examines the meaning of technology transfers (TTs); the research then considers the purpose of TTs and finally, explains the methods of technology transfers.

There is no internationally accepted definition of technology transfer. Synder *et al.* (2003: 3) define technology transfer as "the application and sharing of scientific knowledge between researchers and research organisations (including laboratories, universities, industry, research institutes, local and state governments and third party intermediaries (e.g. venture capitalists and management companies)". According to Dos Santos and Rebolledo (2008), technology transfer is made in different ways (e.g. oral communications, the physical transfer of a tangible research result or through the IP licensing). Supporting this point of view, Parker and Zilberman (1993, cited by Dos Santos and Rebolledo; 2008: 280) state that "technology transfer is any process by which basic understanding, information, and innovations transfer from a research institution (e.g. a university, an institute or a governmental laboratory) to individual or firms in the private and quasi-private sectors". Also taking into account TT as a process, Thursby and Thursby (2002) observe that technology transfer is a production process occurring in three stages:

(i) the first-stage of development is the invention disclosure which is filed by faculty members when they believe that their research results have commercial potential;

(ii) the second-stage is patent applications by TTOs for those disclosures they believe can be patented and licensed;

(iii) the final-stage is obtaining licensing.

Friedman and Silberman (2003:18) identify TT as "a process whereby invention or intellectual property from academic research is licensed or conveyed through use rights to a for-profit entity and finally commercialised". This process involves several steps as can be seen in figure 2.2.

According to Fernandez (2007) universities perform two main societal functions: educating students and conducting research[26]. Over time, a third function has been added that today generates much interest: since the enactment of the Bayh-Dole Act[27] in the United States of America (US) in 1980, the promotion and commercialisation of universities' research results has been a focus of attention. In other words, transfer of technologies arising from university research, to industry, through patenting, licensing and creating companies, has come to be seen as a third function.

The most common ways of transferring technologies are through the licensing of technologies and the creation of spin-off companies. The research first considers the definition of licensing from the literature.

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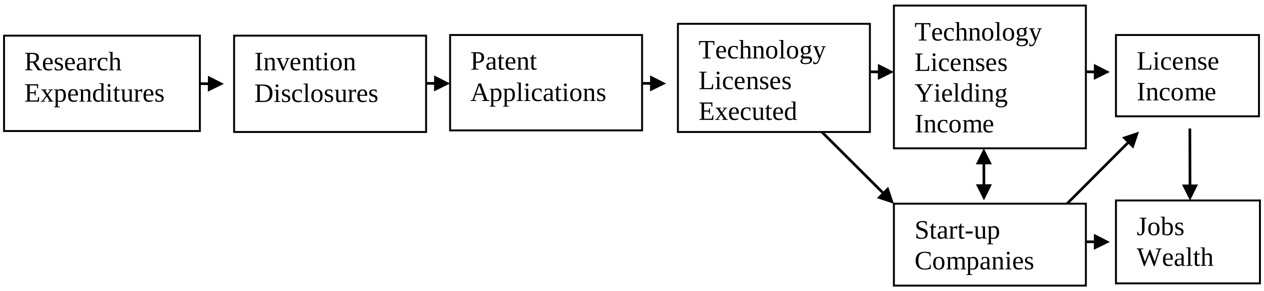
[26] In developing countries such as South Africa, community engagement is considered another contribution that universities make.

[27] The Bayh-Dole Act of 1980, which helped to set up the field of technology transfer in the United States, made commercialisation easier by clearing the way for universities to claim legal rights to innovations developed by their faculties using federal funding.

Figure 2.2: The process of university technology transfer



Source: adapted from Friedman and Silberman (2003)

Lee and Win (2004: 435) define licensing as “the transfer of less-than-ownership rights in intellectual property to a third party, to permit the third party to use intellectual property”. It can be exclusive or non-exclusive and is mostly preferred by small business. Bercovitz and Feldman (2006: 178) describe a university licensing which provides the right for companies and others to use intellectual property in the codified form of either patents or trademarks. According to them, “contractual licensing agreements involve selling a company the rights to use a university’s inventions in return for revenue, in the form of upfront fees” and the regular payments of royalties.

Secondly, the research assesses the existing definitions of spin-offs in the literature to provide a contextual framework as there is no single definition of university spin-offs in the literature. Bercovitz and Feldman (2006: 179) point to various possible definitions for “university spinoffs” (USOs): "firms formed by the university, faculty or staff; firms formed around a university license of intellectual property; startup firms that have joint research projects with the university; and firms started by students or post-doctorate students around research conducted at the university". Pirnay *et al.*’s (2003: 356) definition of USOs is “new firms created to exploit commercially some knowledge, technology or research results developed within a university”. Landry *et al.* (2005: 3) see a university spin-off as a new firm that is formed to transfer commercially available scientific and technological knowledge from a parent organisation to the market. University spin-off activity is seen as a means to transform local economies and a mechanism which provides a way to capture the benefits of proximity to research universities (Bercovitz and Feldman, 2006). Summarising the essence of these definitions, the research can say that a spin-off involves; a technology, knowledge or research result developed within the university and then transferred into a new venture. Furthermore, the founder(s) either stay at or transfer from the university to the new venture as well.

Recognising the importance of technology transfer, many countries, including South Africa have introduced legislation to facilitate this process, including the creation of institutional mechanisms to drive technology transfer. One such mechanism is the technology transfer office, the role of which the research discusses next.

2.3.3. The Role of Technology Transfer Offices

Technology transfer offices (TTOs) are expected to play an active role between the universities, faculty members and industry. Siegel *et al.* (2007:641) see TTOs as 'intermediaries' between suppliers of innovations (university researchers) and those who can potentially assist to commercialise them, i.e. firms, entrepreneurs, and venture capitalists. Dos Santos and Rebolledo (2008: 279) in similar vein define TTOs as 'institutional mechanisms created with the aim of promoting universities' interaction with industry and government. TTOs perform a systematic survey of existing research and knowledge within the universities while encouraging researchers/students to commercialise their technological opportunities in their research and disclose their discoveries to the TTO. The latter promotes the technologies they identify as having market value to potential users (Cartaxo and Godinho, 2011). Young (2005) lists four primary reasons for establishing university TTOs as identified by the Association of University Technology Managers (AUTM):

- facilitating the commercialisation of research results for the public good
- rewarding, retaining, and recruiting high-quality researchers
- developing closer ties with industry
- generating income for further research and education, and, thus, promoting economic growth.

The TTOs are established not only to improve the effectiveness of university performance, but also to augment the university income through the transfer of research results through different mechanisms (e.g. setting up a company, licensing technologies). The activities of TTOs have important economic and policy implications, since technology licensing and spin-offs can result in additional revenue for the university, employment opportunities for university-based researchers and graduate students, and local economic and technological spill-over through the stimulation of additional Research and Development (R&D) investment and job creation (Siegel *et al.*, 2007: 641). The benefits from university technology transfer can be quite significant. For instance, in the USA, annual licensing revenue generated by US universities and research institutions rose from about $160 million in 1991 to $1.4 billion in 2005. By 2011, this figure had grown to $2.5 billion (AUTM Licensing Survey, 2012[28]). In 2011 alone, 671 start-up companies were started; while a total of 3927 start-up companies were still operating at the end of the financial year 2011 (AUTM Licensing Survey, 2012).

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[28] The 2011 survey was sent to 305 U.S. institutions (234 universities and colleges, 65 hospitals and research institutions, two national laboratories, and four third-party technology investment firms). Of these 305 U.S. institutions, 186 responded to the survey. The respondents included 157 universities, 28 hospitals and research institutes, and one third-party technology investment firm.

Almost all research universities in the US have established TTOs to commercialise their IP. The success of US technology transfer has attracted interest from universities and research institutes all around the world. TTOs have been set up in many countries other than the US: developed countries such as Germany, the United Kingdom, and developing countries such as the Republic of China, South Africa, and many others have changed their laws and policies, modelling them after US practices, the Bayh-Dole Act, to allow universities and faculty members to manage and transfer intellectual property (IP) to the market (Nelsen 2007). However, TTOs are relatively new at South African universities and research institutions, and are not yet found in all universities and research institutions. Some efforts were made to promote TT activities as early as the 1980s; but TTOs were established at a few institutions only during the late 1990s (Wolson, 2007). The South African Government introduced the Intellectual Property Rights from Publicly Financed Research and Development Act 51 of 2008 ("the Act") to promote the patenting of publicly funded research (So *et al.*, 2008). The objectives of "the Act" are *inter alia* to encourage commercialisations of IP created in public institutions through the creation of Technology Transfer Offices; to create the National Intellectual Property Management Office (NIPMO) and an Intellectual Property Fund (IPF) (Government Gazette, 2008). Some higher education institutions have recently set up offices and other institutions without TTOs are in the process of setting them up. Currently 18 universities and Public Research Organisations (PROs) have established TTOs. Adding to this, one regional Technology Transfer Office was also set up in the Eastern Cape Province to assist universities to manage their commercialisations[29]. The Act also aims to:

[29] The Eastern Cape Regional Technology Transfer Office (ECR-TTO) was formed by all four Eastern Cape universities (University of Fort Hare, Rhodes University, University of Walter Sisulu and Nelson Mandela Metropolitan University (NMMU)) under a Memorandum of Agreement. The ECR-TTO assists institutions to manage and commercialize their Intellectual Property, particularly as Universities of Fort Hare, Rhodes and Walter Sisulu do not have fully-fledged Technology Transfer Offices. The NMMU's TTO is the Department of Innovation Support & Technology Transfer. The ECR-TTO is funded by the National Intellectual Property Management Office.

a. identify commercialisation opportunities;
b. encourage and reward human ingenuity and creativity;
c. assist, grow and develop the private sector, particularly Small and Medium Enterprises and Broad-Based Black Economic Empowered (BBBEE) enterprises[30];
d. provide for protection of IP prior to publication of research findings; and
e. provide for State "walk-in" rights - where necessary (the State may use the results of publicly financed research and development, in circumstances where IP is required for the country's health, security and emergency interests).

As can be seen from the aims, there are many similarities to the US Bayh-Dole Act. However, there are conditions in the South African IP Act of 2008 that are unique, such as the preference for licensing to BBBEE companies.

2.3.4. Technology Transfer at Two South African Universities

South African higher education institutions and research organisations are growing to appreciate the value of intellectual property (IP), which is evident in the establishment the TTOs, but the capacity to manage IP varies considerably across institutions; with the Council for Scientific and Industrial Research, Medical Research Council, Universities of Cape Town, Stellenbosch, Pretoria, Witwatersrand and North-West having relatively well-established and resourced TTOs while, some other institutions may have a single person who, in addition to other responsibilities, is expected to oversee the institution's entire IP management portfolio and its transfer to the market (Gumbi, 2010).

[30]This stems from the legacy of inequitable access by the majority of the population to the economy under Apartheid, which has led to a provision for redress in almost all South African legislation.

Significant research output is a logical requirement for technology transfer to happen. Two universities that have a long record of experience of technology transfer activity are the research-oriented universities of Stellenbosch and Cape Town in the Western Cape, South Africa. In the next sections, the research elaborate on the progress that these two institutions have made regarding technology transfer with the aim of benefiting the university, industry, the inventors, and the broader society.

2.3.4.1. *University of Cape Town: Research Contracts and Intellectual Property Services*

The University of Cape Town (UCT) is the oldest university in South Africa, that places a strong emphasis on technology transfer activity. The University's success in the area of innovation and technology transfer is confirmed by its performance, in the Most Innovative Higher Education Institution competition 2008, run by the Innovation Fund (an instrument of the Department of Science and Technology). UCT received a certificate of recognition for coming second overall, and won the Best Case Study category as well as the category for Best Improvement in Technology Transfer Capacity. The latter is measured by assessing the overall improvement in capacity and effectiveness of the commercialisation office to facilitate the commercialisation process (www.innovus.co.za; Innovation at UCT, 2010).

The technology transfer office of UCT has seen many incarnations. it started as the Office for Industry Liaison (OIL) in 1999; then in 2002 UCT Innovation was established and renamed Research Contracts and Intellectual Property Services (RCIPS) in 2007 (www.sarimaconference.co.za). The Office's role is to receive disclosures of inventions, evaluate their commercial merit, and protect the intellectual property and in collaboration with the inventors, market and license the technology, or create spin-off companies (Innovation at UCT, 2010). It also supports UCT's research activities by centrally managing, authorising and negotiating research contracts entered into with a wide variety of funders. RCIPS seeks to stimulate the growth of the South African economy by fostering small business development and/or the creation of jobs through the commercialisation and implementation of UCT's intellectual property, transforming society and leading to social and commercial benefit[31].

In Table 2.20 to Table 2.23 we present UCT's commercial activities and performance with respect to patents, disclosures, licensing, revenues and spin-offs. The disclosures received, provisional patent applications filed and total number of patent applications since 2004 are presented in Table 2.20. One hundred and forty three (143) disclosures have been made to the Office over the period 2004 to 2010.

There has been an increase in the number of disclosures received and patent applications filed. The number of patents granted has also increased. Whereas two were granted in 2004, by 2010, it had grown to 36. This has been as a result of RCIPS moving from a passive service mode into a more proactive mode of exploration for new IP and raising awareness of patenting and IP in the different departments (Innovation at UCT, 2010).

Table 2.20: Annual UCT Patent Portfolio Statistics

	2004	2005	2006	2007	2008	2009	2010
Disclosures	20	20	7	9	31	25	31
Patent Applications Filed	26	26	23	50	64	46	57
National Phase Patents Granted	2	9	6	3	10*	47*	36
Application Details;							
Provisional	8	12	4	5	27	9	-
PCT	3	5	9	3	3	20	-
National (including Divisional, excluding Regional)	10	7	6	36	28	10	-
Regional	5	2	4	6	6	6	-

* Includes country validations following European patent grant
Source: UCT Innovation 2010 and RCIPS 2011

31 www.uct.ac.za

Fifty-one license and assignment agreements relating to UCT intellectual property have been entered into over the period of 2001 to 2010 (Table 2.21).

Table 2.21: License Agreements Relating to UCT Intellectual Property

Year	Disclosures	Number of License Agreements
2001	-	1
2002	-	1
2003	-	8
2004	20	9
2005	20	4
2006	7	3
2007	9	3
2008	31	8
2009	25	6
2010	31	8
Total	143	51

-: the research could not find the data for these years
Source: UCT Innovation 2010 and RCIPS 2011

UCT's revenue and income derived from commercialisation of its IP is presented in Table 2.22[32].

Table 2.22: IP Commercialisation Revenues (Rand)

Year	Licensing (R)	Sale of IP (R)	Profit UCT Companies (R)	Total (R)
2001	0	87,143	0	87,143
2002	0	107,952	0	107,952
2003	0	0	0	0
2004	13,905	0	0	13,905
2005	1,728	0	0	1,728
2006	70,058	0	0	70,058
2007	49,815	0	0	49,815
2008	170,266	150,000	0	320,266
2009	136,494	0	693,630[a]	830,124
2010	3,500,000	0	400,000	3,900,000
Total	3,942,266	345,095	1,093,630	5,380,991

[a] This company is currently being incubated within UCT and is as a 'ring-fenced' operation. This is an unaudited figure.
Source: UCT Innovation 2010 and RCIPS 2011

[32] The value of equity held in companies has not been included in the table and many of these companies being early start-ups have yet to declare dividends.

A total of five spin-off companies have been formed, based on UCT IP (Table 2.23). According to Innovation at UCT (2010) three further companies would spin out in 2010 and another is being incubated within the university whilst it establishes itself in the market and proves its viability. UCT has also recently acquired shares in a medical device start-up which will work closely with the university in order to develop their IP further, due to strong synergies with the university.

Table 2.23: Spin-Off Companies from UCT[33]

Year	Number of company set up
2004	2
2005	-
2006	2
2007	-
2008	-
2009	1
Total	5

Source: UCT Innovation 2010

2.3.4.2.*Stellenbosch University: 'Innovus Tegnologie Oordrag' (Pty) Ltd*

Stellenbosch University (SU) has a well-established structure for technology transfer activity. Stellenbosch University regards the commercialisation of its Intellectual Property and knowledge as part of its responsibility in the area of community interaction. The University mission shows it clearly; "The raison d'être of the Stellenbosch University is to create and sustain, in commitment to the academic ideal of excellent scholarly and scientific practice, an environment within which knowledge can be discovered, can be shared, and can be applied to the benefit of the community"[34]. The University's success in the area of innovation and technology transfer is underscored by its performance in the Technology and Human Resources

[33] Numbers provided by TTO only.
[34] www.sun.ac.za

for Industry Programme (THRIP).[35] In 2005, Stellenbosch University won the Department of Science and Technology award as the Most Technologically Innovative Higher Education Institution (Reichelt, 2007) and in 2008, the University, received a certificate of recognition for coming third overall in the Most Innovative Higher Education Institution competition (www.innovus.co.za). The institution has developed administrative structures to support its commercialisation and technology transfer activities and has also created a favourable environment for researchers in terms of intellectual property rights (Reichelt, 2007).

The University had two arms for the commercialisation of its research. First, the University had an intellectual property office (InnovUS) under the Executive Director: Finance and Operations. The "Office for Intellectual Property" was set up in 1999 as TTO of Stellenbosch University and renamed InnovUS in 2004 (Nel, 2009). InnovUS was responsible to facilitate the exploitation of intellectual property derived from faculty members and students. InnovUS handled all of the normal technology transfer related duties one might expect: review of invention disclosures, intellectual property, mining, and review of intellectual property clauses in research contracts, technology marketing, and license negotiation and management (Garduno, 2004). Second, the university established a wholly-owned private company called Unistel Group Holding Ltd. (UGH) that functioned along with InnovUS in commercialisation of technology and IP from university research through start-up companies.

In 2009 the structure of TTO was changed and the new company, InnovUS Tegnologie Oordrag (Pty) Ltd., replaced Unistel Group Holdings (Pty) Ltd and also encompasses the innovation and commercialisation infrastructure of the past. According to Nel (2009) the core responsibilities of InnovUS Tegnologie Oordrag (Pty) Ltd. are;

[35] An incentive scheme of the department of Trade and Industry (www.dti.gov.za), which matches every R1 in research funding secured from industry to encourage innovation and skills development.

1. to apply SU technology to the benefit of society,
2. to serve faculties and to increase awareness of technology transfer among faculty, researchers and students,
3. to maximise third stream income for SU through commercialising IP,
4. to promote value creation within and growth of the SU portfolio of spin off companies,
5. to raise the profile of SU as top performing university in order to attract top researchers.

Successful university technology transfer offices must have clear policies regarding the protection and exploitation of intellectual property developed by university faculty members, staff and students (Reichelt, 2007). Stellenbosch University has a detailed policy regarding the exploitation of intellectual property. The policy[36] includes detailed steps e.g. the IP ownership issues including staff, students, visiting lecturers and researchers (including post-docs), outside organizations, sponsors, funders and the government; exploitation of IP through licensing and new business formations (start-ups) and allocation of income derived from commercialisation of intellectual property.

In Table 2.24, Table 2.25 and Table 2.26 the research present the performance of InnovUS with respect to patents, disclosures, licensing, royalty incomes and spin-off companies created.

Table 2.24 shows that technology transfer activity in terms of disclosures has increased significantly since the beginning of the decade, to total 269 (2001-2011). Invention disclosures increased from 12 in 2001 to 62 in 2009 and then decreased to 45 in 2010. The table also indicates that final patented technologies increased locally, in Europe, the USA and other parts of the world.

[36] The policy can be downloaded from the website (www.innovus.co.za).

Table 2.24: Patent Status of Innovus Tegnologie Oordrag (Pty) Ltd

Year	Disclosure	Provisional Patent	PCT	South Africa	Europe	USA	Other
2001	12	7	0	2	0	0	0
2002	12	10	1	1	0	0	0
2003	14	14	0	1	0	0	0
2004	9	13	2	5	0	0	1
2005	8	6	2	1	1	0	1
2006	8	9	1	1	0	0	0
2007	43	19	1	2	0	1	4
2008	36	21	5	0	0	1	0
2009	62	24	9	5	2	2	6
2010	45	19	14	9	3	3	10
2011	20	8	5	1	1	0	4
Total	269	150	40	28	7	7	26

Note: Other (New Zealand, India, Canada, China, Japan, Australia, Russia, Brazil and Singapore)
Source: Innovus Tegnologie Oordrag (Pty) Ltd

Table 2.25: Licensing-Related Performance Indicators of Innovus Tegnologie Oordrag (Pty) Ltd

Year	Disclosures	Licence Agreements	Royalty Income (Rand)
2003	14	0	315,456.55
2004	9	1	512,678.34
2005	8	0	578,514.91
2006	8	2	313,071.13
2007	43	0	653,981.54
2008	36	6*	1,378,305.04**
2009	62	6*	896,800.92
2010	45	2	5,085,065.74
2011[1]	20	1	4,862,219.01
Total	245	18	14,596,093.18

*5 Licences signed plus one Memorandum of Understanding (MoU), **R566 757 in Escrow (per agreement with licensee) until milestones achieved.
[1] Up to date.
Source: Innovus Tegnologie Oordrag (Pty) Ltd

Table 2.25 presents the commercial activity of InnovUS. Whereas 40 patents were generated between 2001 and 2011 (Table 2.24), 18 licenses were allocated between 2003 and 2011. Royalty income from licensing agreements increased from R315,456 in 2003 to R 4,862,219 in 2011 and total income (2001 to 2011) totalled more than 14,5 million Rand (around US$2,085,174).

Table 2.26: Spin-Off Companies Created[37]

Year	Number of company set up
1999	1
2000	1
2001	-
2002	1
2003	-
2004	-
2005	-
2006	1
2007	2
2008	-
2009	1
Total	7

Source: Innovus Tegnologie Oordrag (Pty) Ltd

The TTOs records (presented in Table 2.26) indicate slow progress in the creation of spin-off companies. It is, however, important to note, that these are solely entities that were created under the auspices of the TTO. Independent spin-off activity is not recorded here.

2.3.5. Case Study: Spinning-Off or Licensing?

The TTO normally receives suggestions from scientists whether a project is marketable through licensing or spin-off creation. Later, the firms that are interested in such new projects consider the prospects, which could be a proof of concept or a complete prototype, or R&D still in embryonic stage that needs further development.

In the context of this chain of decision-making, previous research, which examined academic entrepreneurial activities focusing on spin-off creation at Cape Town and Stellenbosch universities (Jafta and Uctu, 2009) resulted in interesting questions arising, such as why academic researchers who are in a position to create a spin-off choose not to do so and, what motivates researchers to license their technologies? This section therefore aims to explore

[37] Numbers provided by TTO only.

these questions.

2.3.5.1. *Methodology*

As a first step, the research had to establish whether technologies for licensing were available at the two universities in the study, and to identify the academics in possession of research results that could lead to technologies that can be licensed.

Twenty-seven technologies ready for licensing from Stellenbosch and eight from UCT were identified in 2010[38]. After follow-up visits and contacts with the TTOs, the research found that five technologies had been terminated, one technology had been assigned to a spin-off company and another one was used to establish a company. The research excluded these technologies from the research, so that the total technologies being investigated were 20 from Stellenbosch and eight from UCT.

Following the investigation, a questionnaire was developed to be completed by the principal researchers who created the technologies. The research started e-mailing in mid-2010 for the first time, with a follow-up later in 2010. By the end of September 2010, eleven researchers had responded to the survey of which only eight were willing to participate in research. The participant number is therefore small. A TTO officer interviewed explained that this is not uncommon, since most researchers are reluctant to participate in questionnaire surveys. Due to the small number of technologies studied, no claim of generality to other populations of

[38] Technologies were gathered from the Tektique's web site (www.tektique.co.za) which is a collaboration of South Africa's leading universities, the Medical Research Council (MRC) and their technology transfer offices. Tektique is funded by the Department of Science and Technology through the Innovation Fund. This web platform was created to offer third party organisations and industry more insight into and access to the IP and patents available from South African universities and science councils, and thereby ensuring greater ability to commercialise technology and patents stemming from publicly financed research and development.

technologies or researchers can be made from the primary data and their analysis, but it is believed the insights gained here are valuable in constructing larger research projects in future The questionnaire included questions requesting information on the profile of the researchers, as well as the technologies. For the two crucial questions the research were exploring, namely the motivations to license and the factors influencing the decision to license rather than create a spin-off, the research used a five-point Likert scale where 5 was most important and 1 unimportant. Technologies are coded from A to H.

2.3.5.2.*Limitations of the study*

Since the study is based on one province in South Africa, and since there is only a small number of respondents, no generalisations to academic technology transfers (spin-offs and/or licensing technologies) in the rest of the country can be made. This particular section can be considered to be an exploratory study, as prelude to a larger scale study of the rest of the country's regions. At this stage, comparisons to academic technology transfers (spin-offs and/or licensing technologies) at other South African regions are therefore not yet possible.

2.3.5.3.*The Results of Case Studies*

Three of the technologies studied originated from the engineering faculty (technology B, C and D), two from science (technology A and G), one from health science (technology H), one from agricultural science (technology F) and one technology from two faculties (technology E) (Engineering and Health Sciences jointly). It was revealed in the survey that three technologies fall in the biotechnology sector, four technologies in other sectors (Precision Engineering, Wood in Wine, Biomedical Engineering and Medical Devices) and one technology combined biotechnology, nanotechnology and green technology (Table 2.27).

Table 2.27: Sectors

	Bio	PE	Nano	GT	WiW	BE	MD
Technology A	O	-	-	-	-	-	-
Technology B	-	-	-	-	-	O	-
Technology C	-	-	-	-	-	-	O
Technology D	-	O	-	-	-	-	-
Technology E	O	-	-	-	-	-	-
Technology F	-	-	-	-	O	-	-
Technology G	O	-	O	O	-	-	-
Technology H	O	-	-	-	-	-	-

Bio: Biotechnology, PE: Precision Engineering, Nano: Nanotechnology, GT: Green Technology WiW: Wood in Wine, BE: Biomedical Engineering, MD: Medical Devices
Source: Authors survey 2010

It was found that all the technologies were the product of collaboration. Four technologies were created by two to three researchers (technologies B, D, F and G). Three technologies were created by four to five researchers (technologies A, E and H) and one technology had between six to ten researchers (technology C). Patents indicate evidence of a country's technological and inventive achievements (Pouris, 2005). Of the eight technologies, four had worldwide patents (technologies A, C, F and G), one was a South Africa-based patent (technology B) and three patents were provisional (technologies D, E and H).

Respondents were asked to rate their motivations for licensing the technology on a Likert scale varying from 1 (not important) to 5 (most important). Results are presented in table 2.28. The analysis of the motivations behind the licensing of the technology shows that the major motivations are that the researcher(s) wished to apply their knowledge to practical applications, followed by wishing to fully utilize existing knowledge, and finally, the desire to pursue profit. Other motivations were that licensing is a common strategy within the industry sector; it is a niche technology and personal success.

Table 2.28: Motivations

Motivations	Average score

Apply knowledge to practical applications	4.2
Fully utilise existing knowledge	3.8
Profit making	3.8
Licensing is a common strategy within the industry sector	3.7
It is a niche technology	3.6
Personal success	3.6
Final step to complete existing project(s)	3.4
The technology is near market and requires little further development and investment	3.3
Building an industrial network	3.0
The technology fits an existing company's IP/product portfolio	2.8
A company is linked with the research either as a sponsor or interested observer	1.8
Others factor(s)	-

Likert scale: 5 = most important, 1= unimportant
Source: Authors survey 2010

Lastly, researchers were asked to rate the factors affecting their decision not to create a spin-off company (Table 2.29). The most cited reason was funding, followed by commercialisation, distribution and estimation of market demand. In the discussion in section 6, the research places these results in context, both with respect to authors' expectations and findings in similar studies in the literature.

Table 2.29: Factors affecting the Decision not to set up a Company

Factors[1]	Average score
Funding	4.7
Commercialisation	4.2
Distribution (product and/or services)	4.2
Estimation of the market demand	3.7
Leaving the academic position	3.2
Regulatory compliance	3.1
Family commitment(s)	2.8
Problems in human resources	2.7
Technical problems in development and production	2.5
Relationships with the parent university	1.8
Problems among owner(s) of the technology	1.2
Others factor(s)	-

Likert scale: 5 = most important, 1= unimportant
[1] one participant did not complete this part of the questionnaire
Source: Authors survey 2010

2.3.6. Discussion

2.3.6.1.*Motivations*

What would motivate a university scientist to license a technology, rather than simply making their research results available through publications, conference participation or exhibitions? The analysis of the motivations behind the licensing of the technology shows that the major motivation is that the researcher(s) wishes to apply knowledge to practical applications, followed by a desire to fully utilise existing knowledge, and to pursue profit. Other motivations were: "licensing is a common strategy within the industry sector"; "it is a niche technology" and "personal success." One participant mentioned that his university does not have the knowledge and capability to create a successful spin-off company in a particular niche market. According to the participant, the easiest way to make a profit is through licensing.

Of course, the motivations would differ depending on the stakeholders' perspective. Siegel *et al.* (2003) present the motivation for technology transfer from university to industry from the perspectives of scientists, technology transfer offices and firms/entrepreneurs in five research universities in two regions of the US (Table 2.30).

A primary motive of scientists is recognition within the scientific community (e.g. publications in journals and research grants). University scientists may also be motivated by personal financial gain and/or a desire to secure additional funding for graduate students and laboratory equipment. The primary motive of the TTO is to protect and market the university's intellectual property.

Table 2.30: Motivations & Actions of Stakeholders in TT

Stakeholders	Actions	Primary motives	Secondary motives	Perspective
University scientists	Discover of new knowledge	recognition within the scientific community e.g. publications,	financial gain and a desire to secure additional research	scientific

		grants (especially if untenured)	funding (mainly for graduate students and lab equipment)	
TTO	works with faculty members and firms/ entrepreneurs to structure deals	protect and market the university's intellectual property	facilitate technological diffusion and secure additional research funding	bureaucratic
Firm/ entrepreneur	commercializes new technology	financial gain	maintain control of proprietary technologies	entrepreneurial

Source: Siegel et al., 2003

Secondary motives include securing additional research funding for the university (through royalties and licensing fees, sponsored research agreements) (Siegel *et al.*, 2003) and facilitating technology diffusion. Firms and entrepreneurs also express great concern about ''time to market,'' since the ultimate benefits from product and process innovation depend on commercialising the product or perfecting the new production process before competitors do (Siegel *et al.*, 2003).

Zuniga and Guellec (2009) carried out a business survey on the licensing-out of patents in Europe and Japan. The aim was to investigate the intensity of licensing to affiliated and non-affiliated companies, its evolution, and the characteristics, motivations and obstacles met by companies already licensing or willing to license. The authors found that for both European and Japanese companies, the first motivation to license patents to third parties is "earning revenue". This supports the notion that financial gain is a strong motivation for both private companies and academics. To sum up, especially from the perspective of scientists' motivations, this section's findings are similar to that cited from the literature.

2.3.6.2.*Factors Affecting the Decision Not To Set Up a Company*

One of the questions faced by technology transfer managers and inventors is whether to license a technology or to create a start-up firm to commercialise it. According to Cervantes (2003), the answer to this question, depends on the nature of the technology to be transferred, the market for such a technology, the skills set of the staff, researchers involved in the invention, access to venture capital, and the institution's mission. Certain platform technologies with a wide range of applications may be commercialised via a start-up company for example, while others may be licensed to larger firms with the business capacity to develop the invention further and integrate it into its R&D and business strategy.

Participants were asked in the survey the reasons why they chose not to create a spin-off. The biggest reason put forward was lack of funding, followed by commercialisation, distribution and estimation of market demand. Jafta and Uctu (2009) found support for the significant role played by funding in this decision in earlier research on spin-offs. In previous research, the authors examined the major problems that spin-off companies encountered at two South African universities and found that apart from funding, factors such as finding skilled people, lack of facilities, marketing of developed products, and time constraints all played a part in deterring the creation of spin-offs. Furthermore, Kamariah et al. (2011) and Nelsen (2007) argue that university-generated technologies are often still in embryonic stage and will require substantial investment in time, money and skills to develop something to take to market. The funding requirement for an academic researcher to start a spin-off may be daunting, whereas a license holds a promise of less risk and an income stream.

The same question was asked to the TTO officers. According to one of the TTO officers there are two main reasons; first of all, most of the inventors/researchers are not entrepreneurs and are not willing to leave the academic world (according to the IP policy, if a university researcher sets up a company, they should leave the university’s employment). Further reasons given were that researchers enjoyed doing research and publishing their work. Licensing, moreover, afforded an opportunity to earn money from technologies. According to one TTO officer, on the other hand, new generations (younger researchers) are more passionate about creating companies than licensing the technologies. Secondly, funding is a problem. When one wishes to create a company, s/he, at least, must secure 5 years' money to get back the result (start earning money). For these reasons most of the researchers come to the decision to license their technologies.

As can be seen from the case studies and the universities' technology transfer activities, researchers tend to license their technologies rather than creating companies. If the objective is to create more companies, both universities should change their incentive system. For example, K.U. Leuven Research and Development (a Belgian TTO) has generated over 90 companies since 1972, having a combined total turnover of over 400 million euro and employing more than 3,500 people (for more info, http://lrd.kuleuven.be/en/spinoff/creation). One of the main reasons for being successful is that TTO's incentive system. In the case of spin-offs, individual researchers could receive up to 40% of the intellectual property shares; and can invest financially in the spin-off company created (Vendrell-Herrero, 2008).

These findings and observations have implications for IP policy and practice at universities, especially in relation to incentive structures aimed at encouraging technology transfer and commercialisation.

2.3.7. Concluding Remarks

The technology transfer from universities to the market has historically been dominated by the practice of licensing, while other literature shows that in the UK in particular, successful universities lean more towards the development of spin-off companies (Vendrell-Herrero, 2008). In the last few years, therefore, deciding whether to license or create a spin-off has become a relevant question for researchers, scientists and TTO managers.

When the TTO receives a profitable invention, one quandary is how to commercialise it, i.e., a license or spin-off. Some researchers argue (for example Shane and Stuart, 2002; Locket et al., 2003) that spin-offs are a better solution to commercialise the invention where the patent system is less effective, therefore, the TTO's experience and legal support are very important in such decision.

In this section, the researcher was curious about the role of technology transfer at two Western Cape universities, and in particular, what would motivate academic researchers to license their technologies, as opposed to creating a spin-off company. Furthermore, the researcher was interested in finding out the reasons for their decision. These questions were pursued in the context of the activities and rationale of university technology transfer offices, including an overview of the performance of these offices at the two universities. This overview allowed researcher to discern a pattern regarding the spin-off and licensing behaviour for the period, with licensing being favoured over spin-offs. Against this backdrop, the case studies provided useful further insights.

This research is based on a very small sample and can therefore not be generalised. It is however, significant to note that findings with respect to the motivations for licensing and the factors influencing the decision to license rather than spin-off are not that different from the existing literature.

Funding (or the lack thereof) still plays a significant role in creating spin-offs (as if they do not have funds to create spin-off, licensing their technologies is a better option), and so does the desire to put knowledge to practical use. The latter motivation bodes well for a country sorely in need of innovations that will address socio-economic challenges and spur economic growth.

Throughout the preceding sections, reference was made to the importance of skills, education and training in the context of academic entrepreneurship and technology transfer, and the particular expertise required to achieve success in biotechnology start-ups. The research now turns to an assessment of the pioneering efforts to address this need in the Western Cape RIS.

PART III: STRENGTHENING CAPACITY FOR BIOTECHNOLOGY

This part of the thesis is novel as it evaluates early efforts in South Africa to equip bio-entrepreneurs with the skills necessary to build a bridge between the science of biotechnology and the commercialisation of knowledge and ideas in this field in the form of bio-entrepreneurship programmes which is presented as a section here.

3. Building a bridge between science and business in a regional cluster: evaluating initial bio-entrepreneurship training efforts in South Africa[39]

3.1.Introduction and background

Biotechnology is seen as a major growth industry and a significant contributor to economic growth in many countries. Consequently, national governments across the globe take it seriously (Hine and Kapeleris, 2006) as evidenced by the fact that they have invested billions of dollars into strategies to enhance biotechnology research, development and commercialisation (Collet and Wyatt, 2005).

In the development of regional biotechnology industries, small-to-medium size enterprises (SMEs) will be the driving force with start-up companies figuring predominantly in bringing biotechnology products and processes to the global marketplace. New ventures such as biotechnology start-up companies or projects in established SMEs require champions with a sound knowledge of the relevant science and a familiarity with the business principles relating to product innovation, market development and venture capital (Collet and Wyatt, 2005). One of the most important factors needed to develop a biotechnology industry in a region is the existence of an entrepreneurial culture. This refers to the fact that scientists should look not only at the scientific side of research, but also at the commercial exploitation of their results (Chiesa and Chiaroni, 2005). The commercialisation of research is essential to the development

[39]This section was published in a journal. Reference as follow; Uctu, R. and R. Jafta (2013), "Bio-entrepreneurship as bridge between science and business in a regional cluster: South Africa's first attempts", *Science and Public Policy*, July 2013, doi:10.1093/scipol/sct049, pp. 1-15.

of a local biotechnology industry and there is a critical need for graduates able to drive this process (Collet and Wyatt, 2005). Many countries operate bio-entrepreneurship training programmes to generate appropriately skilled people to grow the biotechnology industry (Meyers and Hurley, 2008), and thus to create "bio-entrepreneurs" in their countries. This is an emerging trend in the world and the bio-entrepreneurship training field is still in the fluid phase in which many players are in the process of developing programmes, and no dominant design or success story has yet emerged.

Empirical literature on bio-entrepreneurship training in developing countries is still sparse. Studies on the entrepreneurial activities in biotechnology have focused mainly on the USA, UK and other developed countries. This section is novel in that it assesses the first structured attempts in South Africa to equip scientists with the skills necessary to build a bridge between the science of biotechnology and the commercialisation of knowledge and ideas in this field. The research present a case study on the bio-entrepreneurship training programme implemented at Cape Biotech, which was one of the Biotechnology Regional Innovation Centres[40] and now part of the Technology Innovation Agency (the TIA)[41]. The bio-entrepreneurship training programme is targeting scientists who have feasible business ideas (no business registered yet) and scientists who have already registered their start-up, but lack business skills. The main objective of the programme is to support and facilitate the

[40]The South African Department of Science and Technology (DST) introduced the National Biotechnology Strategy (NBS) in 2001 to modernize the government's biotechnology institutions and to develop the biotechnology industry given a changing political and technical environment. An important product of the NBS was the formation of biotechnology regional innovation centres (BRICs) in 2002 to develop and commercialise the biotechnology industry. These are Cape Biotech Initiative in Western Cape, the East Coast Biotechnology Consortium (EcoBio, operating under the trade name of LIFElab) in Kwazulu Natal and Biotechnology Partnership for Africa's Development (BioPAD) in Gauteng province.

[41]The Department of Science and Technology (DST) has recently established a new public institution, the TIA, which is a single public agency that was formed from a merger of seven DST-funded organisations, namely, BRICs (Lifelab, Biopad and Cape Biotech), Plantbio, Tshumisano, Innovation fund and Amts (Advanced Manufacturing Technology Strategy). BRICs (Lifelab, Biopad, and Cape Biotech) no longer exist and are now a component of the Technology Innovation Agency (TIA).

development of business skills necessary for sustainable biotechnology ventures, as well as the development of bio-entrepreneurs and future business managers in South Africa. The programme is evaluated against its objectives from the perspectives of the participants. In addition, it gives a measure of the effectiveness of the programme in terms of the number of bio-enterprises created. This evaluation was done against the backdrop of the participants' understanding of bio-entrepreneurship, their views on the prospects for South Africa's biotechnology industry, and their assessment of the strengths and weaknesses of this industry in the Western Cape.

The rest of the section is structured as follows: first there is a survey of literature on bioscience entrepreneurship followed by a detailed case study of the Cape Biotech bio-entrepreneurship programme. The last section concludes the section.

3.2.Overview of the literature on Bio-entrepreneurship

It is accepted that small entrepreneurial businesses in high-technology industries have contributed to job creation, technological innovation, knowledge, technology transfer and regional development (Muller *et al.,* 2004). Particularly, in the context of biotechnology, Persidis (1996) in Hine and Kapeleris (2006) describes bio-entrepreneurship as wealth creation that comes from life science discoveries in the laboratory and that are applied in the commercial market. Meyers (2008) describes it as a process of creating value from life science innovations. For authors' purposes, the research describes bio-entrepreneurship as the form of entrepreneurship in which a bio-entrepreneur identifies a business idea from the field of biotechnology and seeks to commercialise the idea by setting up a new business. In another words, it is simply *the creation of biotech enterprises.* Bio-entrepreneurs tend to have different characteristics than those needed in the traditional context as is shown in Table 3.1 below.

Table 3.1: Traditional Entrepreneurs and Bio-entrepreneurs

	Traditional Entrepreneurs	Bio-entrepreneurs
Background	Business	Scientific
Education	MBA	Life science (Masters, PhDs) and/or MBA
Age	Younger	Relatively Older
Objectives	Involved only with development and marketing of the product	In addition, also have an in depth knowledge of the product itself.

Source: http://www.rishibiotech.com/bioentrepreneurship

One of the greatest challenges for researchers is converting scientific discoveries and innovations into successful companies. The literature on biotechnology identifies three crucial elements, commonly called the “three pillars”, essential for the success of a biotechnology start-up company: (i) managerial skills, (ii) sufficient capital and (iii) access to new technology that leads to products. The "start-up" phase of biotechnology companies is essentially a "valley of death" that has to be crossed by bio-entrepreneurs who often lack the experience and expertise necessary to convert their ideas into commercial products suitable for public consumption. Most biotechnology companies face difficult managerial challenges in R&D because it is costly and often the most critical aspect of bringing a product to market. Even when biotechnology start-ups source R&D externally, particular skills are required to incorporate the R&D results and align it with company strategy and objectives. Biotechnology research is often more complex than traditional pharmaceuticals because researchers may not know for years what forms their products will take after they begin their research. It needs careful management and strategy. In addition to these significant obstacles, management at a biotech start-up company face additional challenges such finding the correct balance between cutting-edge scientific research and commercialisation opportunities. Resolving the economic and commercial challenges faced when developing a new product requires a different set of skills from conducting research on technology and its application. One of the important components is that the management team must ensure various means to encourage scientific staff to work on the one or two products that will lead the company to its success. Often, a scientific team has a wide range of potential products; however, they often lack the resources to simultaneously exploit several products commercially. In contrast, big pharmaceutical companies enjoy the luxury of having the means of experimenting with a wide range of technologies and products in order to find that one blockbuster, whereas the start-ups must be selective due to their circumstances. Management also faces the exciting but daunting task of bridging the gap between the scientific and business side of a company. In addition they also need to decide which direction would be most beneficial for the entire company (Malazgirt, 2011). Biotechnology companies therefore require cross-disciplinary knowledge, skills and talents (including marketing, the basics of Intellectual Property Rights (IPR), early-stage technology finance, and knowledge of scientific, regulatory and ethical issues) (Schoemaker and Schoemaker, 1998; Meyers and Hurley, 2008; York *et al.*, 2009; Malazgirt, 2011). In addition to these requirements, bio-entrepreneurs should have special communication, emotional and social intelligence skills, such as self-awareness, self-control, and social awareness (Meyers and Hurley, 2008). These authors also argue that the demand for talent is not only a problem in developing countries but an international problem. In the case of the Singapore cluster, the biggest problem has been identified as a continued shortage of entrepreneurial scientists and managers. It is in this area that the Singapore government meets its greatest challenge – it is difficult to inculcate creativity and the entrepreneurial spirit. These qualities are difficult to impose, even on a willing populace (Arroyo, 2005: 54). Volery *et al.* (2007) showed that Switzerland has several key challenges in management of young biotechnology companies, which include managing funding, planning strategies, marketing and sales, IP and administration. Nosella *et al.* (2006) cited Italy, where managerial skills at university start-ups are lacking in the scientific staff at universities. Rutherford and Fulop (2006) found a similar lack of expertise in Australian biotechnology start-ups. They observed that business awareness of science is low and scientists lack the entrepreneurial skills to commercialise their research. To overcome these problems, Rutherford and Fulop (2006) and Nosella *et al.* (2006) suggested training and equipping scientists with the necessary commercialisation and managerial skills and to get assistance from TTOs for organisational and financial support. Nosella *et al.* (2006) for Italy suggested a joint scientific and managerial competency with founders comprising a team of academic scientists and industry managers.

Chiesa and Chiaroni (2005) highlight the following practices that are used to help the diffusion of the bio-entrepreneurial culture among researchers in nations and specifically in regions:

i) Setting up managerial courses for science and technology graduates. Scientists often fail to evaluate the commercial possibilities of the research results correctly. In addition, they lack the necessary managerial competences to define company strategy in the long term. Teaching managerial courses to life science graduates, even at a low level of specialisation, may make them 'familiar' with the managerial approach and may help them to understand and better evaluate external support by 'professional' managers;

ii) Offering MBA and related courses dedicated to biotechnology. The characteristics of business models of biotech companies are such as to require 'tailored' managerial solutions, that may also be made available to scientists;

iii) Encouraging entrepreneurial experiences among researchers. For instance, making it possible for academics to try the entrepreneurial adventure with the option, in case of failure, to go back to their previous academic position;

iv) Creating competition for research grants. Competition for research grants may be introduced at national and regional level, by ranking universities and public research centres by looking at their scientific outputs and also at their attitudes to the commercial exploitation of such outputs. This way of evaluating scientific activity, by adding the perspective of commercial exploitation, achieves the twofold objective of rewarding leading centres and forcing them to improve their exploitation mechanisms.

The research now moves from bio-entrepreneurship *per se* to *bio-entrepreneurship education* in developed and developing countries, with the latter focusing mostly on developments in the South African NIS.

3.2.1. Bio-entrepreneurship Education in Developed countries

University-trained biotechnology graduates may generally possess a solid knowledge-base but often lack real world business insight and are often not entrepreneurially inclined, preferring instead to pursue careers focused on science. As such, the average biotechnology science graduate is generally not suited to or capable of operating in the commercialisation environment between research and the market that is the focus of start-ups and established SMEs (Collet and Wyatt, 2005). Many universities have realised this problem. Hence, there has been growth in the number of bio-entrepreneurship programmes in the world that provide bio-business education. According to Meyers and Hurley (2008) bio-entrepreneurship programmes are designed to teach the knowledge, talents and attitudes required by entrepreneurs who are interested in biotechnology commercialisation. The USA, European Countries, Scandinavian countries, Canada and Australia are some of the countries that have created bio-entrepreneurship programmes in their higher institutions. All of these new entrepreneurial programmes are reshaping the graduate education of scientists and engineers and creating new entrepreneurs in biotechnology. Table 3.2 indicates some selected dual-degree graduate programmes in biotech and business for illustration purposes.

Table 3.2: Selected dual-degree master's programmes in business and biotech

University	Location	Degree	Year Started

Johns Hopkins	Baltimore, Maryland, the USA	MS/MBA	2000
University of Pennsylvania	Philadelphia, the USA	MB/MBA	2003
Macquarie University	New South Wales, Australia	MB/Master of Commerce in Business	2004
University of Calgary	Alberta, Canada	MBT/MBA	2004
University of Florida	Gainesville, the USA	MS/MBA	1993
RMIT University	Melbourne, Australia	MBB (Masters of Biotech/Business)	2001

Source: Waltz (2005), [i]MB, MBT, Master of Biotechnology

3.2.2. Bio-entrepreneurship Education in South Africa

Most of the bio-entrepreneurship programmes and activities have been established in developed countries, whereas little is known about bio-entrepreneurship education programmes offered in developing countries, with a few exceptions, such as the exploratory study on bio-entrepreneurship in Kenya by McEnrue (2011). McEnrue (2011:4) confirms the paucity of data and research on bio-entrepreneurship in developing countries, especially in Sub-Saharan African countries. The concept of "bio-entrepreneurship" is still comparatively new in these countries. In South Africa only a few institutions and private companies have recently created bio-entrepreneurship programmes. In Gauteng and the Western Cape these programmes are mainly run by public institutions.

Table 3.3 below shows these programmes, in chronological order.

Table 3.3: Bio-entrepreneurship course and programme created in Western Cape and Gauteng regions

Name	Location	Year	Brief Description

Biotechnology in the Workplace- FABI, University of Pretoria	Gauteng region	2006	The BSc-Honours in Biotechnology which is an inter-departmental programme between Biochemistry, Genetics, Microbiology, Plant Pathology and Plant Science departments. They developed a new course called *Biotechnology in the Workplace (BTW)* has been introduced for students in their fourth year (i.e the first post-baccalaureate year). The course was established with the help of the Case Western Reserve University and was taught as part of the Molecular and Cell Biology module. The course helps students to understand the basic concepts of bio-entrepreneurship in South Africa and introduces some managerial and business skills that are needed by bio-entrepreneurs including entrepreneurship, intellectual property, marketing, financial aspects and start-up ventures for the biotechnology industry.
The Certificate in Bio-entrepreneurship-University of Pretoria	Gauteng region	2008	After the creation of the TIA, the Certificate in Bio-entrepreneurship at University of Pretoria, joined the Certificate in Bio-entrepreneurship, the first level, presented by the Technology Innovation Agency.
The Cape Biotech Bio-entrepreneurship programme	Western Cape region	2008	This programme was the first bio-entrepreneurship programme in the Western Cape region. After the creation of the TIA, the Cape Biotech Bio-entrepreneurship programme joined the Certificate in Bio-entrepreneurship, the first level, presented by the Technology Innovation Agency.
The E-learning Certificate Programme	Country wide	2010	It's in a choice of three specialised Bio-Entrepreneurship Courses administered by Xcell Bioconsulting, a private company, and presented in association with the Graduate School of Business, the University of Cape Town, is accessible country wide. Successful candidates may participate in the Advanced Certificate in Bio-entrepreneurship of TIA presented by the University of Basel and, if selected, may proceed to a week-long Bio-entrepreneurship Summer School, held in Switzerland.
The Certificate in Bio-entrepreneurship presented by the Technology Innovation Agency[42]	Gauteng and Western Cape region	2010	This is a three level programme of which the first level is the Certificate in Bio-entrepreneurship presented by the University of Pretoria in Pretoria and Cape Town. The second level is the Advanced Certificate in Bio-entrepreneurship presented by the University of Basel and the third level sees selected candidates proceed to a week-long Summer School held in Switzerland.
Bio-entrepreneurship programme	Western Cape region	2012	This initiative is administered jointly by three Western Cape universities namely the University of Western Cape, University of Cape Town and Cape Peninsula University of Technology. Graduates of this programme are accepted as participants to the first level Entrepreneurship programme presented by TIA and they may participate in the Advanced Certificate in Bio-entrepreneurship presented by the University of Basel and, if selected, may proceed to a week-long Bio-entrepreneurship Summer School, held in

[42] Programme changed to a 3 tier programme co-sponsored by Swiss

			Switzerland[43].
The Gauteng Accelerator Programme-Biosciences (GAP - Biosciences)	Gauteng region	2012	Programme started in collaboration with Emory University in Atlanta, Georgia. GAP Biosciences is a comprehensive, nine-month programme that includes educational programmes and a business plan competition, designed to accelerate the establishment of biosciences-based companies that will be both profitable and contribute to Gauteng's socio-economic development.

Source: Authors own construction, 2013

Since the University of Pretoria in the Gauteng Province played a pioneering role in setting up bio-entrepreneurship programmes, it seems appropriate to expound in more detail on their efforts, before proceeding to the pioneering work in the Western Cape RIS, the focus of this research. Kunert *et al.* (2008) mention the BSc-Honours in Biotechnology which is an inter-departmental programme between Biochemistry, Genetics, Microbiology, Plant Pathology and Plant Science departments. They developed a new course called *Biotechnology in the Workplace* which helps students to understand the basic concepts of bio-entrepreneurship in South Africa. The course was established with the help of the Case Western Reserve University and was taught as part of the Molecular and Cell Biology module. The course introduces some managerial and business skills that are needed by bio-entrepreneurs including entrepreneurship, intellectual property, marketing, financial aspects and start-up ventures for the biotechnology industry. Pepper (2009) mentions another bio-entrepreneurship course (*Certificate in Bio-entrepreneurship*) which was set up and presented by the Institute for the Cellular and Molecular Medicine (ICMM) at the University of Pretoria[44]. The course covers scientific and managerial skills ranging from biotechnology overview to marketing. Other modules are health biotech (Drug development and clinical trials, TB diagnostic, Stem cells), GMOs and biosafety, biotech business management and biotech from a Department of Science

[43] A personal interview with the manager at Cape Biotech, 07 November 2012

[44] Information gathered from a workshop. PhD candidate attended Human Capacity Development for Biotechnology Workshop at Innovation Hub, Pretoria, South Africa (supported by Cape Biotech), 30 November 2009

and Technology perspective (incl. Technology Innovation Agency), business incubation, intellectual property, licensing (incl. NIPMO-the National Intellectual Property Management Office, the biotech funding environment, biotech business models (and business plan), leadership, bioethics and bio-law and an idea-to-product module.

Learning outcomes of this course are[45];

1 to understand the nature of biotechnology with a focus on red (health) and green (agricultural) biotechnology,
2 to understand the funding policy environments as they relate to biotech
3 to explore different biotech business models and to acquire the fundamentals of biotech business management,
4 to understand the requirements of a biotech business plan in particular from the perspective of prospective funders
5 to be able to manage issues in intellectual property and licensing as they pertain to biotech
6 to understand the nature of business incubation and its place in the biotech value chain
7 to develop fundamental notions with regard to marketing in the biotech space and
8 to understand the complexity of the interface between stakeholders
9 to be able to take an idea to market.

The research now turns to the bio-entrepreneurship programme in the Western Cape RIS.

3.3. Bio-entrepreneurship education: an empirical study of the first steps in the Western Cape RIS

[45] information gathered from www.up.ac.za

3.3.1. Description of the Bio-entrepreneurship programme and its origins

Biotechnology is accepted as a driving force for South African economic growth in the field of health care, life sciences and agriculture. In 2001, South Africa introduced a key policy document, the National Biotechnology Strategy (NBS), to build a biotech hub. The South African government allocated R450 million (around US$58 million) in public funding for biotech development (Al-Bader et al., 2009; Louet, 2006) between 2004 and 2007. The aim of this strategy was to stimulate the development of biotechnology skills, capacities and tools in South Africa (Gastrow; 2008). The NBS drew some important conclusions from a review of the management of biotechnology activities of other countries:

- A dedicated agency was needed to champion biotech and manage relevant activities to ensure coherence between programmes
- Strong Science & Technology capabilities must be build, targeting human resource development
- Investment must focus on the commercial products and processes locally and internationally (Wolson, 2005).

Government attempted to close the gap between research activities and commercialisation by encouraging Public-Private Partnerships (PPPs) between local and international actors and creating the Biotechnology Regional Innovation Centres (BRICs) (Cloete *et al.*, 2006).

BRICs served as vehicles for facilitating and supporting biotechnology innovation and commercialisation. Three biotechnology innovation centres were created, namely, Cape Biotech Initiative (CBI) in Western Cape, the East Coast Biotechnology Consortium (EcoBio, operating under the trade name of LIFElab) in Kwazulu Natal and Biotechnology Partnership for Africa’s Development (BioPAD) in Gauteng province (Table 3.4). The BRICs have different focus areas: Cape Biotech and LIFElab focus on human health biotechnology research and development while BioPAD concentrates on several areas, including biotechnology research and development in agriculture, mining, and environmental applications.

Table 3.4: Biotechnology Regional Innovation Centres (BRICs) in South Africa

BRICs	Location	Aims
Cape Biotech	Black River Business Park, Cape Town	Industry stimulation and capacity creation, and disseminating and managing government funds by investment in promising projects in human health
LIFElab	East Coast region	The two primary program areas are human health and bio-processing
BioPAD	The Innovation Hub Science Park, Pretoria	The application of biotech to industrial growth through process and product development, mining competitiveness and environmental rehabilitation or prevention of adverse environmental effects

Source: Akermann and Kermanni, 2006a

Cape Biotech is one of several trusts created to boost this initiative. Cape Biotech Initiative was incorporated as a Section-21 Company in 2002 (Pouris, 2008) with a vision to facilitate and invest in the development of a biotech economy, by focusing on five selected areas. These included point of care diagnostics, nutraceuticals from biotechnology processes, combination and conjugate vaccines, drug delivery and high throughput bio-prospecting (DST, 2006). The Initiative won the tender to establish a R150 million (approximately USA$ 20 million) incubator in terms of the National Biotechnology Strategy (www.capegateway.gov.za). Through regionally focused projects, the Cape Biotech acts as a centre for the development of a range of businesses and new product offerings, as well as having the capacity to support these. With an interest in capacity creation, portfolio and knowledge management, Cape Biotech is therefore a cluster development initiative in addition to a funding body (www.blueprintbiotechlab.co.za). Cape Biotech in essence, has three major roles: industry stimulation through capacity creation; management of government funds by investing in promising projects; and co-ordination of business support networks. Its functions include investment, networking, bio-economy intelligence, marketing and capacity development (www.fdimagazine.com).

To exploit the potential of the biotechnology industry in South Africa, there is a need for entrepreneurial scientists who should have both research and management skills and also an understanding of scientific, regulatory and ethical issues. Entrepreneurs able to develop the industry and build bridges between the science of biotechnology and the commercialisation thereof are needed. By developing new competencies through education, biotechnology entrepreneurship can promote new biotechnology creations (Kunert *et al.*, 2008; Kunert *et al.*, 2012).

Kunert *et al.* (2008, 2012) found that there are three major restrictions to the development of an active and competitive bio-entrepreneurship environment in South Africa.

1. First, the small number of researchers involved in biotechnology who may have potential as a bio-entrepreneur. There are fewer researchers in South Africa compared to developed countries which negatively impacts the availability of sufficient and adequate technical expertise and skills required for biotechnology start-up companies. This skill shortage continues even though South Africa has several excellent biotechnology research groups and centres, where research is driven by well-trained and experienced staff. This shortage also shows up in the relatively low number of patent and scientific publications in the biotechnology field. An encouraging element is that these publications demonstrate the potential capacity to develop a local biotechnology industry in South Africa.
2. Secondly, new graduates in biotechnology lack the skills to stimulate the industry. Reason is quite clear; graduate students receive sufficient research training in

preparation for a future academic career, but few educational programs provide training in entrepreneurial skills for these students. Graduates have little knowledge about biotechnology entrepreneurship and innovation when they graduate. Further, they often have not received extensive training in collection of information required to solve problems, critical review of information, and techniques to search for new solutions. This creates a major problem for companies interested in finding new ideas with potential for commercial success. This lack of skills is also due to both the existing shortage of well-trained faculty in biotechnology in academic institutions and also the disinterest of many faculties in bio-entrepreneurship and commercialisation. Since graduates frequently receive a very narrow specialised training in these institutions, they are further poorly equipped to adapt to rapid changes in technology, which is a necessity for biotechnology. Adding to this, as a result, in South Africa up to 75% of PhD graduates remain in higher education institutions, government research organisations or public service. Thus, relatively few post-graduate students consider industry as a future career.

3. Because of limited local opportunities in industrial positions and the less than favourable environment for start-ups, South Africa loses many well-trained students to other countries. Unfortunately, the current climate for the development of a biotechnology industry and bio-entrepreneurship in particular is also not very favourable. A rather complicated funding system, which is less favourable for start-ups, limits the prospects of even the most innovative individuals.

To set up a successful biotechnology industry and support bio-entrepreneurship in South Africa, biotechnology graduates should be encouraged to obtain interdisciplinary training. Therefore, one of the aims of the Cape Biotech is to develop bio-entrepreneurial skills and promote the growth of a bio-entrepreneurial culture within existing companies and research institutions. For this purpose, Cape Biotech created business skills development programmes, namely the Bio-entrepreneur programme, Bio-mentor programme and Higher Education Institutions Entrepreneurial Programme. The details are below.

Bio-entrepreneur programme: The main objective of this programme is to support and facilitate the development of business skills necessary for sustainable biotechnology ventures in the Western Cape. CBI aims to involve participants such as CEOs and/or GMs of biotech start-ups, second-line management, and aspiring biotech entrepreneurs. The objectives of this programme are;

- to build and augment the business skills of participants in the context of their own business ventures through:
  - ➢ Delivery of business theory and concepts
  - ➢ Transfer of tacit knowledge and experience between course conveners and the participants
  - ➢ Application of the learning to real business situations
- to equip participants with the skills to improve the robustness of their business ventures
- to support the development of bio-entrepreneurs and future business managers

In 2008 and 2009 the programmes were run by four venture capitalists. Their backgrounds are respectively Chartered Accountant (CA), Geologist, IT expert and one had a medical background (physiotherapy), but all four were entrepreneurs. The programme was outsourced and the same type of programme has been running for more than five years now, in a part of ICT cluster in Cape Town. The content of the Bio-entrepreneur programme is:

- 14 practical hands-on group lecture sessions over 28 weeks covering various business and financial topics. Business modules are value proposition, market and customer segmentation, business model, practical operations strategy, pricing, marketing, sales, negotiation, people management and preparing a business plan. In the financial module; analysis and interpretation of financial statements, budget, forecast and performance measurement, growth, working capital and cash flow management and valuations and exits have been taught.

- Assignments for practical application of the theory
- Monthly mentorship sessions with individual mentors.

Selection criteria for the *Bio-entrepreneur programme*s differed from the first one (2008) to the second one (2009)[46]. For the first programme, a few people from Cape Biotech were admitted and the companies in which money had been invested were asked to each send one member of their personnel. The idea was simply to fill the venues. When the programme proved successful and positive feedback was received, people became interested in attending the programme, and companies began to approach the manager at Cape Biotech. Apart from the different selection criteria, changes were also made to the modules offered before the second programme. The manager at Cape Biotech also pointed out that after receiving feedback from the people, a 3rd programme would start in April 2010 and by November 2009 four applications had already been received[47].

Bio-mentor programme: The participants in this programme are the graduates of the bio-entrepreneur programme, biotechnology business managers and bio-entrepreneurs. The main aim of this programme is to provide a forum for identifying and addressing issues that affect biotechnology companies and to support networking and cluster development. Other objectives of the programme are:

[46] A personal interview with the manager at Cape Biotech, 18 November 2009.
[47] This was the time when the field work was done, 15 February 2010.

- To up-skill bio-entrepreneurs through interaction with experienced business leaders
- To provide a forum for networking between biotechnology business managers & technology developers
- To provide a forum for leveraging synergies for win-win business collaborations and clustering.

HEI Entrepreneurial programme: The main purpose of this programme is to raise awareness of the technology commercialisation process required to develop and take an innovative idea to market and of the crucial inter-disciplinary nature of the process. Other objectives of these programmes are:

- To understand the key concepts and options in commercialising hi-tech technologies in the biotechnology sector
- To understand how to assess technologies for their commercial potential
- To understand the steps that technologies go through in the journey from the laboratory to the marketplace.
- To have a working knowledge of the business plan process
- To explore the roles that intellectual property protection and licensing play in the commercialisation process.

Cape Biotech aimed to reach graduate students, post-graduate students, and post-doctoral fellows interested in innovation - taking their inventive research outcomes to the marketplace and/or those interested in a career in biotechnology business development or in joining a start-up company. The Manager of Human Capital Development of Cape Biotech stated[48] that activities were started at the University of Cape Town for the first time in 2009, but there were no formal courses at other universities.

[48] A personal interview with the manager at Cape Biotech, 18 November 2009.

This study focuses on the bio-entrepreneur programme, in particular.

3.3.2. Research Purpose and Methodology

Given that this training programme represents the first structured attempt at enhancing the entrepreneurship skills of scientists, this research:

1. evaluates the programme against its own objectives from the perspectives of the programme graduates primarily to give feedback to Cape Biotech and other relevant agencies to fulfil an expressed need to improve and expand the programme; specifically, the objectives are
   - to build and augment the business skills of participants in the context of their own business ventures through:
     - Delivery of business theory and concepts
     - Transfer of tacit knowledge and experience between course conveners and the participants
     - Application of the learning to real business situations
   - to equip participants with the skills to improve the robustness of their business ventures
   - to support the development of bio-entrepreneurs and future business managers
2. deriving from these objectives, we discern a measure of the effectiveness of the programme in terms of the number of enterprises that have been created by participants, but cannot yet say something about the growth and longevity of the enterprises.

The study procedures included conducting a literature survey via internet and library research, and conducting interviews with the Cape Biotech bio-entrepreneurship programme graduates.

A case study was undertaken in order to understand the bio-entrepreneurship education context and details in South Africa. In the paper two consecutive Cape Biotech bio-entrepreneurship programmes are analysed. In 2008 the programme was operated successfully and seven students graduated, followed by sixteen graduates in 2009.

A total of 28 graduates and a manager at Cape Biotech were included in this research. Interviews were conducted based on a questionnaire, aimed at evaluating the programmes and gaining useful feedback to inform further efforts at bio-entrepreneurship training. Twelve questions were prepared for the manager at Cape Biotech and ten for the graduates. Interviews were semi-structured and took 15 to 40 minutes. All interviews were recorded and transcribed. We received responses from three of the twelve 2008 graduates (25%) and twelve of the sixteen 2009 graduates (75%). If we include the manager this means that there were 16 responses overall (57.1%).

3.3.3. Research Results

3.3.3.1. Historical context of the bio-entrepreneur programme

The programmes that are the subject of this study were preceded by an earlier attempt in 2007. During this first bio-entrepreneur programme, Cape Biotech entered into a partnership with a British-based company. The aim of this programme was to transfer essential bio-business skills to university scientists, promising entrepreneurs and early-stage companies in an industrial environment. The two-year programme was intended to consist of industrial seminars, workshops, MBA courses and electives and business skill courses. The programme was intended to be taught by leading academics, industrialists and entrepreneurs from the Cape, Cambridge, Munich, Boston, San Diego and San Francisco biotech clusters. The hope was that the course would lead to at least ten students graduating from this programme every year (Akermann and Kermani; 2006a). The Bio-entrepreneurship Programme, 2007 was launched at Cape Biotech, but was unfortunately not a success. We asked the manager at Cape Biotech the reasons for being unsuccessful and she responded "*I was not in Cape Biotech then but what I know is that the programme 2007 was replaced with another programme called "The Hellfire programme" and the people who were involved in this programme were very young and went back to the corporate sector. This programme is not an entrepreneurship programme, it is mostly about intrapreneurship.*" The Hellfire internship programme is explained in their website[49] as a first of its kind in the South African life sciences sector, and is aimed at addressing skills development, job creation, increase entrepreneurship and life-science innovation and technology which can be transferred from a research basis to the marketplace. Hellfire is sponsored by Acorn Technologies[50] and the Godisa Trust (now SEDA Technology Programme - STP). Since the first programme did not take off, and its replacement is not an entrepreneurship programme, we will henceforth consider the 2008 bio-entrepreneurship programme the *first programme* and the 2009 programme the *second programme*. The first programme started in November 2008 and was completed in April 2009. The second programme started after this and graduation took place in November 2009. The duration of the Bio-entrepreneurship Programmes was 28 weeks. The 2008 bio-entrepreneurship programme produced 19 graduates in different categories. There were seven attendance certificates (those whom did not complete all the modules), seven graduates and five graduation certificates with special recognition (top graduates). In this section the focus will be on the graduates and graduation certificates with special recognition only and interviews with them will be reported. The 2009 bio-entrepreneurship programme produced 16 graduates. The manager at Cape

[49] www.hellfire.org.za
[50] Acorn Technologies had merged with Cape Biotech (Al-Bader et al., 2009).

Biotech believed that these programmes were successful because they were presented by people who were already in the industry and because it is not a theoretical course. The people who presented the programme are actually venture capitalists and they know the ins and outs of the business plan and industry. One of the outcomes of the 2009 programme is that a new company will be created by one of the graduates. In the next section the profiles of the participants are presented.

3.3.3.2. Profiles of participants

Table 3.5 below presents the general profile of participants including their gender, age, degree obtained, field, university and their current positions.

Meyers and Hurley (2008) discuss in their research that some trends are reshaping the future graduate-level education in bio-entrepreneurship programmes and one of them is the low participation of women and minorities in science, technology, engineering and maths (STEM).

Littlehales (2006) points out that many specialised academic training, seminar and mentoring programmes in the USA are slowly beginning to focus on equipping female bio-entrepreneurs. This is not only a problem in developing countries but also developed countries. Littlehales also explains that especially in the biotechnology industry there are only a handful of successful women bio-entrepreneurs.

Table 3.5: Profile of participants in the bio-entrepreneurship programmes

Year		2008	2009
Number of graduates from programme		12	16
Number of participants in this study		3	12
Gender	Female	2	6
	Male	1	6
	Total	*3*	*12*
Age[1]	20-30	-	5
	31-40	2	5

	41-50	1	1
	Total	*3*	*11*
Education	BSc in Plant Biotechnology	-	1
	BSc in Biotechnology	-	1
	BSc (Honours) in Biochemistry	1	-
	BSc (Honours) in Pharmacology	-	1
	BSc (Honours) in Immunology	-	1
	MSc in Bio-medical Engineering	1	1
	MSc in Bioinformatics	-	1
	MSc in Immunology	-	1
	PhD in Medical Bio-chemistry	-	1
	PhD in Microbiology	1	-
	PhD in Plant Biotechnology	-	1
	PhD in Neuroscience	-	1
	PhD in Molecular Biology	-	1
	MB ChB in Medicine	-	1
	Total	*3*	*12*
University[2]	Stellenbosch University (SU)	1	3
	University of Cape Town (UCT)	1	6
	University of Pretoria (UP)	-	2
	University of Edinburgh	-	1
	Total	*2*	*12*
Position	Honours student	-	1
	Post-doc fellow	-	1
	Director of a company	-	2
	CEO of a company	-	1
	Project manager of a company	-	2
	Business Unit manager of a company	-	1
	Technical Assistant at a company	-	1
	Intern at a Public Research Organisation	-	1
	Self-employed	-	1
	Serial Entrepreneur	-	1
	Manager of Medical Devices at one of the BRICs	1	-
	Head of Quality Control at an Institute (PPP)	1	-
	Researcher at one of HEIs	1	-
	Total	*3*	*12*

[1,2]One participant did not answer this question.
Source: Authors construction based on data obtained through interviews, 2010

That is why universities and some institutions now run special entrepreneurship programmes for females to increase the number of scientists with special managerial skills. In the case of the study, of the 15 participants, eight (53.3%) were female and seven were male graduates. The results of Pepper's research (2009) support the trend of increased female participation. He indicates that in the bio-entrepreneurship course organised by ICMM at the University of Pretoria 10 female, and 18 male participants responded.

The age of the participants is also shown in Table 3.5. Most of them are in the young age group. The average age is 33.64. Out of 14 participants, 12 are between 20 and 40 years of age, with five of them under 30 and seven in the 30 to 40 age group. Only two participants were over 40. Pepper (2009) found that the average age of participants in the UP bio-entrepreneurship course was 33.85. This seems to indicate that the majority of participants in bio-entrepreneurship courses offered in South Africa are fairly young.

The minimum degree obtained by any participant was a BSc (two people). Three people had obtained BSc Honours, four MSc, five PhD and one MBChB. As was mentioned at the beginning of the section many entrepreneurs in the biotechnology field have doctor's degrees. As can be seen from the table, 35.7% of the participants had achieved a PhD in the biotechnology field.

Following the emergence of genetic engineering and cell fusion, biotechnology applications have become diverse, with a range of biotechnology companies becoming involved in the businesses of biopharmaceuticals, biochips, bioinformatics, cell culture, medical diagnostics, medical devices, food and agricultural and environmental products (Poon and Liyanage, 2004). Some programmes are designed for narrow market niches like biologics while others focus on attracting a wider audience with more diverse backgrounds (Meyers and Hurley, 2008). Participants in this study had degrees in various disciplines, such as Plant Biotechnology, Biochemistry, Pharmacology, Immunology, Bio-medical Engineering, Bioinformatics, Medical Bio-chemistry, Microbiology, Neuroscience and Molecular Biology. Having different backgrounds brings different perspectives to the classroom and advantage can be taken of these talents in networking sessions.

The results show that most of the participants received their degrees from UCT (50%) followed by Stellenbosch (28.5%) and the University of Pretoria (14.2%), and one participant had a degree from the University of Edinburgh. The research also shows that most graduates already filled positions in different institutions. That is what Cape Biotech aimed at when they set the programme up. Targeted audiences were CEOs and/or GMs of biotech start-ups, second-line management, and aspiring biotech entrepreneurs.

3.3.3.3. Understanding of bio-entrepreneurship

In this section, the participants were asked to define the concept bio-entrepreneur. A bio-entrepreneur is one who looks for commercial value in the technologies that he/she applies in conducting research in the field of biotechnology. Most participants define a bio-entrepreneur as *"a person who has a scientific/medical background and finds a way to convert a biotechnology application from an academic idea to a commercially viable product or service by finding a suitable market and who is passionate about becoming an entrepreneur with starting his/her own business and making money"*. In addition to this, some participants also believe that an entrepreneur can also be interested in expanding companies. A keyword analysis of the respondents' definitions produced three recurring elements of the definition:

- Personality traits or personal attributes ('go-getter's mentality', 'having guts', not for the faint-hearted', people with 'lots of ideas and energy')
- Features distinguishing *bio*-entrepreneurship from other entrepreneurship;
- Obstacles such as scale of start-up costs and the length of commitment to the venture before significant returns are generated.

3.3.3.4. Views on biotechnology prospects

3.3.3.4.1. Global competitiveness

Since biotechnology is viewed as a global source of future growth, the respondents were prompted on their views regarding South Africa's biotechnology prospects. According to the participants South Africa is still far behind the EU and the USA in biotechnology. Sixty per cent of the participants agreed that South African biotech is still very small and in the infancy stage. The participants advanced various reasons for this assessment: that South Africa is situated at the foot of Africa and not close to Europe; the mind-set here is different. People often think that South African products are simply not good enough, not of high quality and also that it is very expensive to export them and to work around the foreign regulations like EU regulations. Back (2009) points out that international marketing is complicated and that there are differences in the regulatory environments in the USA and other countries. In the context of global markets, the manager at Cape Biotech emphasises that bio-entrepreneurs in South Africa need to be familiar with these regulations. Therefore, international bio-entrepreneurship has to be taught by experts.

Participants came to the conclusion that South Africa still has some problems that need to be solved in order to be in the global league, namely:

1. People need to work in a team but in South Africa people work in solo conditions, where people hold on to their 'own little IP and struggle to create a value chain from the lab to the market'.
2. More funds are needed. 'If you do not have the finances you can hardly compete with the amount of venture capital in biotechnology in the US. People rather put their money

in the bank to gain higher return on the investments at the moment rather than later in biotech. As far as the growth rate of companies is concerned, you will get your investment's return eventually. The lead time in biotechnology matters, obviously because in takes 10 years to actually get your products commercialised. People require a quick turnaround time in terms of how they want their money back. If people can just get into the high growth phase so that there is a market'.

3. Marketing is important.
4. There is a need to attract some overseas investors to invest in South Africa.
5. There is a need to look at India and Brazil as our competitors and to learn from them.
6. South Africa has the potential to capitalise on our indigenous heritage. The main concern is that South Africans are 'oblivious to capitalising on IP'.
7. Venture capital, which really does not exist in SA. 'SA VC likes to make safe bets which are a contradiction in terms'.
8. It was also pointed out that in the South African context, government has recognized the biotechnology industry and has put money into it. Yet, it is believed that South Africa is at the moment very diversified ('all over the place') in terms of biotechnology. If South Africa focused on unique products and field, it will not be so hard to find a place in international market. Two participants suggest that SA Biotech needs to have a clearer and constructive investment approach and more focused field'.

The participants, however, also identified opportunities; even though the biotech sector is very small, they believe South Africa has a lot of opportunity and scope to participate globally. The opportunities that were identified by the participants include:

1. Exploration and application of the available 'indigenous plants and indigenous ideas'.

2. South Africa has specific needs; being a leader in Africa. There is a big need for food in Africa, and South Africa is in the position to address that need. This is a great opportunity for South Africans.
3. South Africa has many unique problems to deal with that can possibly only be solved from the South African angle. South Africa has a ‘competitive advantage in terms of the prevalence of diseases like HIV and TB and overseas biotechnology companies can test their diagnostic kits and their drugs here’.
4. South Africa has a comparative advantage due to its immense biodiversity’.

3.3.3.4.2. Strengths and weaknesses of the Western Cape biotechnology industry

In the table below (Table 3.6) the strength and weaknesses of the Western Cape biotechnology are shown. Knowing the participants’ views on the strengths and weaknesses helps to identify elements in the bio-entrepreneurship programmes that address these weaknesses (and to reveal gaps). The important strengths as identified by the participants include; having Cape Biotech in the Western Cape; a strong network; people are open to innovation; the location of Cape Town, the well-known and friendly city, research universities like UCT and Stellenbosch and the prevalence of diseases like HIV and TB.

They identify lack of funding as one of the main weaknesses, followed by lack of data; less bio-business; lack of collaboration; being far away from other centres, lack of academic mind-set; lack of bio-incubators and bio-science parks, lack of coordination and a lack of trained, skilled people.

Table 3.6: Strengths and Weaknesses of the Western Cape Biotech Industry

Strengths of the Western Cape Biotechnology Industry	1. Having Cape Biotech is important. The government shows a lot of commitment, towards bio-technology, especially for the BRICs, 2. The Western Cape has a good network and a relatively strong community compared to the rest of the regions in the country. People create networks through structures like

	Cape Biotech and the activities they organise or through personal contact with former classmates and colleagues. Because the industry is so small, people know each other, 3. People are open to innovation, 4. Location. Certainly the allure of Cape Town as a destination both for South Africans and foreigners is great. Everyone knows where Cape Town is and this adds credibility to companies based in Cape Town, 5. The Western Cape is in an ideal situation to become a hub, 6. Many overseas people explore and invest in the Western Cape (i.e. Kapa Biosystem), 7. Friendly-life environment, 8. International airport/harbour, 9. Biodiversity, 10. Good science departments at the universities, 11. Having many people suffering from TB and HIV so that tests can be done.
Weaknesses of the Western Cape Biotechnology Industry	1. There is never enough money, lack of funding, 2. Not commercial enough like in Johannesburg and Pretoria, 3. A lack of data bases 4. Lack of collaboration amongst the institutions, 5. Far away from international Biotech hubs such as Boston (USA) and Europe etc where money is available, 6. Scientists do not know how to run businesses, 7. The unsuitable mind-set of the local academics, 8. The lack of science parks and incubators specifically focused on biotechnology. 9. Little coordination. There are few bridges between the universities and the industries and between the companies themselves, 10. Lack of trained and skilled people. Lack of education is also a weakness (especially skills) not only in the WC but also in SA as a whole, 11. Young industry, with limited infrastructure/facilities to support aspiring Biotech entrepreneurs, 12. There are limited multi-mentorship programmes and also sharing the success stories, 13. Difficult to get information, advice and access to the necessary skills locally.

Source: Authors survey 2010

3.3.3.5. Bio-entrepreneurship programme

3.3.3.5.1. Expectations and perceptions of the programme

3.3.3.5.1.1. Before enrolment

The research asked graduates what their expectations were before enrolment, in order to see whether these were met, and whether their perceptions of the programme had changed upon completion. Three participants did not have any expectations before the enrolment. Others participants' expectations were;

- to find out more about the various aspects of business environment (e.g., marketing and all the related terminology and various aspects of finance and all the different levels in business start-up and set up), entrepreneurship in biotech space and the growth of South African biotech,
- to know more about how to write a business plan
- to be able to launch a business with a better understanding of what is required to launch a successful biotech company
- to receive more training in the financial side of running a business
- to look at science from a business point of view, to bury "the doctor approach " a little bit and take a business approach,
- to participate in networking.

One participant especially stated that s/he was very confused about whether s/he wanted to follow an academic career or to look more closely at the biotech industry. S/he attended the course to better her/his understanding of entrepreneurship and business. As a result s/he does not want to be in business but s/he said that if an opportunity presented itself in future s/he would be equipped to take advantage of it.

Another participant said s/he would be taught valuable skills and lessons during the programme, and then be teaching others, transferring this knowledge to others that can benefit from her/his attending the programme.

When one looks at what bio-entrepreneurship requires, it is an extensive repertoire of knowledge, skills and attitudes which are listed by Meyers and Hurley (2008) such as knowledge of the legal environment (like understanding basic IP and licensing terms, and being able to interpret a term sheet), marketing, international bio-entrepreneurship (e.g. understand the regulatory environment in international markets), new product development (e.g. understanding how to manage an R&D portfolio), business development and planning (e.g. being able to write an innovative business development plan), manufacturing, finance, leading bioscience ventures (e.g. being able to demonstrate managerial skills and leadership ability like team building, project management, budgeting, negotiation and inspiring the employees), clinical trials and validation, communication skills, technology development, management and commercialisation (e.g. understanding the basic technology transfer setting between industry, academia and government and different technology transfer mechanisms like in and out licensing, spin-out etc), emotional and social intelligence skills (such as self-control and social awareness). It is insightful to note that most of the participants' expectations were about understanding the various aspects of the business environment (marketing and the financial side of the business). We assumed that this is because most of the participants are already in business; they are CEOs, directors or second line managers.

3.3.3.5.1.2. After completion

Participants' articulation of expectations was different after completing the programme. One participant compared the programme with European bio-entrepreneurship programmes that she had attended before and found that the bio-entrepreneurship programme that was offered in South Africa lacked scientific contents and was more focused on entrepreneurship and that presenters did not have a bio-science background. That is a crucial point when one looks at the programme offered here. Because of the time limit, presenters are not able to teach all subjects in depth. Programmes mostly covered the business and financial modules. Business modules include: value proposition, market and customer segmentation, business models, practical operations strategy, pricing, marketing, sales, negotiation, people management and preparing a business plan. The financial modules include: analysis and interpretation of financial statements, budget, forecast and performance measurement, growth, working capital and cash flow management and valuations and exits. The modules did not cover the other knowledge, skills and attitudes as listed by Meyers and Hurley (2008) in their paper and mentioned in an earlier section of this section.

Some participants pointed out that they have learned more about the biotechnology environment and bio-entrepreneurial activities in Western Cape and also the role government played in creating a favourable environment. As a scientist it was also valuable to know the business side (marketing, finance etc...) and being able to create a business plan. It was also helpful to know what investors look at when they invest in bio-business.

Two participants' expectations were to be independent in terms of being able to start businesses and having the correct tools to go about it.

Some others were interested in networking and seeing what kind of channels there are and how to go about running a company. For an entrepreneur to run a company, it is necessary to understand what needs to be done. And the programme taught it.

3.3.3.5.2 Motivation for choice of bio-entrepreneurship programme

Closely linked to the expectations of the programme, are the reasons why a participant would choose this programme over other options. We asked the interviewees what motivated them to enrol in this programme rather than studying for an MBA. Most of the participants indicated that the reason why they did not study for an MBA was that an MBA is expensive, a huge investment financially, a broad and intense course, that it requires lots of dedications and time and lastly that an MBA teaches the typical structures and dogmas in corporate business, and does not focus on innovative and entrepreneurial teachings that challenge the status quo.

The reasons why they participated in this course were that it was cheaper, a very good introductory course and relatively quick. A person running a business, did not have to be absent from his/her business for a long time. The course was practical, not an in-depth course, it was more focused and touched on a lot that the MBA course does. This course allowed a person to get a feel for the whole environment, the assignments required were helpful, networking was very good and participants could learn from one another. Because each person came from a different background of the biotechnology sector, one did not only learn from the presenters, but from the other participants as well[51].

In addition, some participants mentioned that the time frame was nice, and the hours were flexible. It was not an intensive course but at least it opened their eyes to many issues. There was no other programme available that focused on what was really a niche market. It seemed like a mini-MBA that was applied to the biotech industry.

One of the participants was about to apply to do an MBA, another one was already doing MBA and two are planning to do it in the future.

3.3.3.5.3. Strengths and weaknesses of programme

Table 3.7 shows the strong and weak points of the programme according to the participants. Seven participants especially highlighted how lecturers were good and knowledgeable. Six

[51] Some of the reasons given by participants in this paragraph could not have been known beforehand which could be served as motivation, and should be viewed as ex-post justifications.

participants also liked the mentorship programme and mentioned that this added value to the course. Other important strong points of the programme were networking and interaction with each other. Seven participants opined on this topic. They also mentioned that they found the topics and concepts useful.

Five participants criticised the length of the programme and felt that more case studies could have been done. One participant, unlike the others, feels that presenters do not take the scientists perspective and says "*Presenters are in IT technology and that type of industry, they have businesses but they do not have knowledge of biotechnology. If you do a bio-entrepreneurship course you need to relate with it*". Another weak point of the programme was touched on by two participants, namely that every participant were not at the same level: "*The weak point, not everyone attending the course is on the same page. Not all of them have the same business experience; some are just setting up, some are at the idea phase, and some are already running a successful business. It makes it harder to extract value for everybody at the same lecture. You can set up levels: beginner, intermediate, experienced levels or otherwise start-up phase, already running phase and already successful business phase. That would be beneficial.*"

"*No way of determining skill level / quality of attendee. It would help if there were some sort of grading for the programme that is recognised. It helps when approaching investors etc, they can find out if you were proficient in the programme or were just a spectator. You had some people who were already in business for a long time and people who have not been into business so there could be two different classes for experienced and inexperienced students.*" One participant touched on an important point, saying; "*Practically I think only a handful of people were really going to become bio-entrepreneurs and start their own businesses. The rest* *of us were just trying to learn more about what to do if any opportunity came around*". Three participants did not identify any specific weak points.

3.3.3.5.4. Explicit benefits

According to the interviewees the bio-entrepreneurship programme was highly beneficial for almost every participant. Crispeels *et al.* (2009) argue that in the biotechnology industry one individual cannot set up and run a biotech company. There is a need for "an entrepreneurial team" to grow a successful company. One participant also thinks that it is more beneficial and productive when people work as a team. At the end of the programme two participants found it very beneficial but decided not to go into business rather to work in a team and in academia. But they stated that they now understand the bio-entrepreneurial environment and business much better.

Others found it highly beneficial. Answers were also in broad sense in line with the nature of their work environment. Some participants think that it opened their eyes to see as a manager what to deal with in the future. Some believed it seemed beneficial, and that they will see the result when the business starts making money, whereas others found it beneficial and plan to use what they've learned in future. Networking and meeting other people was another stated benefit of the programme. One participant stated how important it was for her "*our company is fairly well established unlike many of those where the other participants come from. As we have many separate departments where people are more specialised, a lot of the information was more theoretical and not directly related to what I do on a daily basis. However, in order to do the assignments I had to speak to people internally and now have a much better understanding of how the company operates"*.

Table 3.7: Praise and criticism of the course

Strong points	**1.** *Content of the course:* The course was well-balanced. All the topics were applicable, thought-provoking and at an appropriate level. The introduction of financial topics was a good idea. **2.** *The participants:* It was good to mix with people from different backgrounds. Participants could learn from each other. **3.** *The presenters:* The presenters were good, passionate and knowledgeable. Many of them were experienced businessmen. **4.** *Mentors:* It was helpful to have mentors. **5.** *Assignments:* The assignments were helpful. One participant says that writing the assignment forced him to interview workers in his own company and that he now has a much better idea of how his own company works. **6.** *Involvement:* The involvement of the government and the private sector was a good idea. **7.** *Networking:* The course created opportunities for networking
Weak points	**1.** *Contents of the course:* Certain topics were not of interest to all the participants. It was argued that the course should be longer. **2.** *The participants:* The knowledge levels of participants differed. Participants should qualify to attend. The businesses of entrepreneurs were at different stages. There should be different courses for example for beginners or those at the start-up stage and for those more experienced. **3.** *The presenters:* Some presenters came from the IT sector. They had too little knowledge of biotechnology. Some lectures were very theoretical. There is a need for more practical help for example regarding administration. **4.** *Mentors:* There should be more time for mentors and participants to meet. **5.** *Assignments:* The financial budgeting assignment was too difficult. There was too little feedback on assignments.

Source: Authors survey 2010

3.3.3.5.5. Relevance for current work environment

The participants were asked whether they use the knowledge they gained from the programme. Fifty-three per cent of the participants said that they did, 20% said that they used some aspects and 26.6% said that that they did not use it at the moment, but would later.

Participants who use their new knowledge use it for business plans, negotiations, reading balance sheets, working with people, budgeting and understanding statements. For instance one participant says that he applies the knowledge "*more on the operations and finance side where it is very helpful. As I have no interaction with external customers, the modules on Marketing, Pricing, Sales, etc. were not directly applicable to what I do*".

The participants, who do not use the knowledge, do not do so because of the fact that the positions that they currently hold, do not require such knowledge.

3.3.3.5.6. Recommendation to others

The participants were asked whether they would recommend this course to others. All participants agreed that they would recommend it to others. Some of them especially highlighted the reason why they would. It is;

- A good course to take especially if a person is not sure if he/she would like to enter the business environment.
- A good course from the networking point of view
- A good course for people who are involved in setting up new ventures and who need a sense of direction and sound business advice

In sum, it is fair to conclude that most of the participants' expectations were met, with a few exceptions, as set out above.

To complete this assessment, the research matches the objectives of the bio-entrepreneurship programme with the participants' observations about the programme. The programme had three broad objectives:

- to build and augment the business skills of participants in the context of their own business ventures through:
  - ➢ Delivery of business theory and concepts
  - ➢ Transfer of tacit knowledge and experience between course conveners and the participants
  - ➢ Application of the learning to real business situations

Judging from the observations of the participants, the majority implied that this objective was largely met. Constructive criticism related to the duration of the programme, the backgrounds of the facilitators, and the diversity in terms of level of experience of the participants.

Although these were minority views, they provided useful suggestions for improvement, which the research highlights again in the concluding section.

- to equip participants with the skills to improve the robustness of their business ventures.

The programme developers did not provide clarity on how success in achieving this objective is to be measured, and the results are likely to emerge only over time, following implementation of the new knowledge. Indications are, however, that the participants believed that they would reap the benefits in their businesses.

- to support the development of bio-entrepreneurs and future business managers.

Although the support was given, the reflections of the participants indicate that only a few of them really wanted to be bio-entrepreneurs, but that the course was useful in giving them the exposure to come to the conclusion that this was not the avenue they wanted to pursue. Although this result is to be expected in a new initiative, it sends a strong message about the selection criteria.

Lastly, when considering the effectiveness of the programme in terms of the number of enterprises created, we do not see a rapid progression from 2008, where out of 12 graduates, two had existing companies, and four (33,3%) created new companies after graduation, to 2009, where out of 16 participants, five had existing companies and four (25%) created new enterprises after graduation[52].

[52] TIA, personal communication, 9 April 2013

3.4. Conclusion and policy recommendations

In the context of general policy measures aimed at improving economic growth and creating jobs, South African policy makers view new growth sectors, such as biotechnology as an important means of contributing to the achievement of these objectives. Like other countries pursuing the benefits of biotechnology as a growth industry, South Africa faces a shortage of entrepreneurial skills that would bridge the gap between science outputs and marketable bio-products. To address this need, Cape Biotech, now a component of TIA, has implemented a bio-entrepreneurship programme which was one of the first structured attempts in South Africa, to specifically equip scientists with adequate knowledge and skills to build a bridge between the science of biotechnology and the commercialisation of knowledge and ideas in this particular field. This bio-entrepreneurship training programme has been constructed to expose participants to theoretical and practical learning on entrepreneurship and management skills that span science and commerce. The programme was an integrated cross-faculty programme, with multiple background participants, stimulating teamwork, networking and learning from each other throughout the courses to shape the individuals and teams. These aspects have been shown to determining factors for the future success of young innovative biotechnology companies.

This study assessed the programme in terms of its objectives and against the expectations of the participants, as well as their views on the strengths and weaknesses of the programme and its implementation. The results allow us to draw out recommendations specifically pertaining to the programme, as well as general policy implications for agencies such as the TIA, as well as policy makers.

Although the participants viewed the programme as largely successful, certain key aspects emerged that, when addressed, could improve the effectiveness and efficiency of the initiative, and could also inform design of other initiatives:

- Finding the balance between biotechnology and commercial expertise and experience in compiling the course content and selecting the facilitators;
- Fine-tuning the time-allocation for the course content, so as to balance scope and depth of the learning materials;
- Revisiting the selection criteria for participants. One respondent suggested devising beginners, intermediate, and advanced categories or levels for start-up phase, growth phase and already successful business participants, which seems like a workable idea.
- Lastly, the participants expressed a need for the qualification to be graded specifically, so that it represents a signal to the market, e.g. potential investors, about the participant, e.g. active and committed participant, or spectator. This could be an important distinguishing factor in an environment where funds are scarce and investors risk averse.

From the literature as well as our case study emerged a number of issues that policymakers and the relevant agencies and institutions should consider to determine the way forward for the development of the biotechnology sector and bio-entrepreneurship in particular:

- A recurring theme is the question whether bio-entrepreneurship training should be incorporated in the undergraduate training of scientists, or added post-graduation;
  Related to the issue above, is the need to create awareness of biotechnology and the opportunities it holds for entrepreneurship at school, college and university level; Policy makers ought to consider whether in order to develop an awareness of biotechnology enterprise and biotechnology entrepreneurial spirit, such aspects should be incorporated into the school and college curriculum.

- Aspirant entrepreneurs are often faced with a lack of useful information and a scant network of resources, including skilled staff;

  The TIA could play a facilitating role in providing various informational services relating to promotion of entrepreneurship and acting as a network agency of the support system of academic institutions and Research & Development (R&D) organizations to foster entrepreneurship, and creating awareness among academics, government bodies and industry.
- Although the National Biotechnology Strategy identified the need for a dedicated agency to champion the biotechnology sector, no such agencies exist; also not to promote bio-entrepreneurship. Aspects relevant to entrepreneurship policy can be found across a broad spectrum of ministries and agencies, ranging from education to trade and immigration (Audretsch, 2013). We recommend that the DST and TIA revisit the idea of a dedicated agency to champion biotech and manage the relevant activities to ensure coherence and efficiency in programmes designed to support the sector.

The research conclude that the bio-entrepreneurship education 'engineers' at Cape Biotech had laid a solid foundation to build a bridge between science and business in the Western Cape, on which the rest of the structure can now be build.

PART IV: EVOLUTION OF BIOTECHNOLOGY SPIN-OFFS-A MICRO VIEW

This part of the thesis takes a micro view, tracking the evolution of biotechnology spin-offs from Western Cape universities, and highlighting the role that institutional changes played in the genesis, growth and, unfortunately, demise of some biotechnology spin-offs.

4. Where have all the university spin-offs gone? Turbulence in the biotechnology sub-sector of the Western Cape RIS[53]

4.1.Introduction

Throughout this study, research has focused on the third role of universities in the RIS, i.e. their efforts to bridge the gap between science and market by means of technology transfer efforts. Over the course of the study, lasting several years, the research painstakingly put together a database of university spin-offs, and sought to understand the founders' motivations for spinning off or licensing technologies, as well as the challenges faced by academic scientists venturing into the world of commerce. In this section the research is posing the question 'what happened to the university spin-offs and start-ups since their inception?', i.e. the research trace their trajectory from genesis to growth, or sadly, their demise. The research pursues this question with two broad notions in mind:

a) The essential pillars that underpins growth in biotechnology spin-offs and start-ups (effective management, sufficient capital, and access to technology);
b) The role of institutions and other actors in the RIS, aimed at supporting innovation.

The research for this thesis was initially designed to complete the study with an investigation of the growth stories of the biotechnology spin-offs from the universities in the study. When it became evident that several of the firms targeted for this in-depth story, were no longer in existence, a more important question became 'why did they fail?'. In the search for answers to this question, a tale of turbulence in the sector, and particularly in the environment in which they were to innovate and grow, emerged. Turbulence, in the literature on economics of

[53] This section is submitted to a journal. Reference as follow; Jafta, R. and Uctu, R. (2014), "Turbulence in the biotechnology sub-sector of the Western Cape Regional Innovation System", submitted to *South African Journal of Science.*

innovation, refers to entry and exit of firms in an industry or sector (Klepper, 1996; Malerba and Orsenigo, 1996; Bosma and Nieuwenhuijsen, 2000; Baptista and Karagoz, 2006). In general terms, turbulence also refers to discontinuities and changes that occur in the environment in which the firm operates, especially the institutions in the NIS or RIS that have or are supposed to have supportive linkages to the firms. We use the concept of turbulence here in both senses.

The merit of this section lies in the fact that it draws together many of the useful insights from previous sections and the literature, and with the aid of the case studies, show how a complex series of internal (to the firms) and external factors (in the RIS) combined to lead to the failure of the biotechnology spin-offs.

The rest of the section is structured as follows. After expanding on the three central requirements (the so-called 'pillars') for success in biotechnology commercialisation, the research proceed to the case studies, discussing the methodology and providing the broad information on the ten biotechnology firms that were initially targeted for in depth study, where after we present the case studies. The research derive lessons and policy implications in the discussion section and conclude in the last section.

4.2.The Three Pillars of Successful Biotechnology Commercialisation

According to the literature, there are three structural elements which are called the "three pillars" that are essential to gain success for a biotechnology start-up company: (i) effective management, (ii) sufficient capital and (iii) access to new technology that leads to products (Schoemaker and Schoemaker, 1998; Meyers and Hurley, 2008; Malazgirt, 2011). Effective management is not always a strong point for dedicated scientists who produce technologies.

Effectively bringing in the necessary know-how is essential to succeed. A start-up further needs access to good technology and associated patents in order to produce revenue. Finally, finding adequate capital is often a challenge for scientists who do not have a financial background (Malazgirt, 2011). This section describes how South African start-up companies (un)managed the three pillars. The following section gives brief information about each pillar.

4.2.1. Effective Management

Managerial talents are one of the most fundamental challenges and the weakest pillar in most biotechnology companies. R&D poses difficult managerial challenges because it is the most critical aspect of bringing a product to market and it is costly. Hence, biotechnology firms need a complex range of knowledge, skills and talents (Schoemaker and Schoemaker, 1998; Durai *et al.*, 2006; Volery *et al.*, 2007; Meyers and Hurley, 2008; Malazgirt, 2011). York *et al.* (2009) state that such a bio-entrepreneur should have cross-disciplinary knowledge and talents including marketing, the basics of Intellectual Property Rights (IPR), early-stage technology finance, and knowledge of scientific, regulatory and ethical issues. In addition to these requirements, bio-entrepreneurs should have special communication, emotional and social intelligence skills like self-awareness, self-control, and social awareness (Meyers and Hurley, 2008). This feature, having technical and commercial skills, is mostly found in biotechnology companies where the biotechnology start-up companies have a dual decision team, with an executive manager (CEO) and a scientific manager (CSO) (Bureth *et al.*, 2010).

Researching the economic and commercial challenges in the development of a new product requires an entirely different set of skills from conducting research on technology and its applications. A successful management team must find a way to ensure that the scientific staffs are working on the one or two products that will ensure company success. Often, a scientific group has a large set of potential products, but lacks the resources to exploit more than one or two commercially at any given time. Big pharmaceutical companies have the luxury of experimenting with many technologies and products to find that one blockbuster whereas the start-ups must be selective. Management is faced with the exciting, but difficult, task of being the bridge between the scientific and business sides of a company, and to decide which direction the entire company should take (Malazgirt, 2011).

Finding appropriate talent is an international problem. A recent report describing the Singapore cluster, for example, noted that their biggest problem is its continued shortage of entrepreneurial scientists and managers (Meyers and Hurley, 2008). Volery *et al.* (2007) revealed in their research that Switzerland has several key challenges in management of young biotechnology companies, which include managing funding, planning strategies, marketing and sales, IP and administration. Nosella *et al.* (2006) gave another example from Italy. Managerial skills at university start-ups are mostly lacking in the scientific staff working at the university. Rutherford and Fulop (2006) found a similar lack of expertise in Australian biotechnology start-ups. The authors observed that business awareness of science is low and scientists lack the entrepreneurial skills to commercialise their research. To overcome these problems, Rutherford and Fulop (2006) and Nosella *et al.* (2006) suggested respectively to train and equip scientists with the necessary commercialisation and managerial skills and to get assistance from TTOs in terms of organisational and financial support. Nosella *et al.* (2006) suggested another solution that can solve the problem in Italy which is a joint scientific and managerial competency where the founders could be a team of both academic scientists and industry managers.

4.2.2. Sufficient Capital

Capital forms the second pillar of any biotechnology company's struggle, because the processes involved in developing a product in this field cannot be simply developed in an entrepreneur's garage with a few friends, after hours. At the early stages, a biotechnology company can never have too much of this resource. Biotechnology is capital intensive and in many cases requires huge amounts of funding for many years (Schoemaker and Schoemaker, 1998; Durai *et al.*, 2006; Volery *et al.*, 2007; Malazgirt, 2011). According to some experts, it typically takes approximately US$1 billion, in addition to ten years of research and clinical trials, to release a drug to the international market. Over 200 new treatments and vaccines have run this gauntlet in recent years, including products to treat cancer, diabetes, AIDS, and other autoimmune disorders (Malazgirt, 2011). Therefore, bio-entrepreneurs must spend considerable energies on cultivating financial resources for their young companies (Schoemaker and Schoemaker, 1998). Konde (2012) echo this finding, stating that early stage biotechnology start-up investing is a resource-intensive business, where every entrepreneur needs to build partnerships with local and global investors, and with corporations and government entities, hoping to gain enough runway to validate their business model, create value and become cash flow positive, before they look for additional funding (Konde, 2012).

This is a big problem in developing countries as well as developed countries. Byrd (2002) found that the major problem faced by Canadian biotechnology spin-off companies is access to the capital to develop the company. One of the biggest challenges faced by biotechnology start-ups in Singapore is getting sufficient funding to keep them going. In the high-risk early stage start-ups, companies mostly rely on angel investors (Thanabalasingam, 2012). This is also the case for India. The Indian biotech firms mainly rely on private equity (PE) and venture capital (VC) funds. In recent years, Indian start-up biotech companies have been left vulnerable by the decline in early stage funding, as private investors move to later-stage investment strategies, due to the closed exit market and a lack of money to invest in new and risky projects (Konde, 2012).

In both developed and developing countries, governments are the most important funders of the biotechnology sector. In South Africa, a developing country, government support is more important than private investments. Financing for biotechnology in South Africa is strongly government-led, with the BRICs (part of the TIA now) s instruments. However, compared to other countries, South Africa is still falling behind in this level of finance. The research returns to the South African situation in the case study analysis.

4.2.3. Access to the Technology

In the mid-1970s, the emergence of technologies based on recombinant DNA and monoclonal antibody breakthroughs, which evolved from the revolutionary work of scientific partnerships such as that of Cohen and Boyer, and Kohler and Milstein, established the foundations for the biotechnology industry. This is the third pillar upon which every company must be built. Today, most biotechnology companies still look first to university for sources of new technology. Universities provide a particularly fertile ground for harvesting such discoveries, the importance of which cannot be underestimated. The Bayh–Dole Act, and similar legislation that encourages academic institutions to license discoveries that emanate from federally (government) funded research, will most likely continue to fuel the biotechnology revolution (Schoemaker and Schoemaker, 1998).

Every biotechnology company, from its inception, must have a well-defined and well-articulated product focus. Whether directed toward a specific technology or toward a disease area, the company needs a clear vision of its basis for future revenues (Schoemaker and

Schoemaker, 1998). Biotechnology start-ups can only concentrate on one or two avenues of research, yet they are statistically no more successful than big pharmaceutical companies at developing a successful drug or other biotechnological process. According to current industry standards, approximately 8 out of 10 medicines will fail during clinical trials. For a biotechnology start-up, a 20% chance of success is a major hurdle. Larger companies can finance additional research with existing successful products, but it is difficult for a biotechnology start-up to stay afloat with other products (Malazgirt, 2011). The great challenge for any bio-entrepreneur in this time of ubiquitous opportunities is to maintain a rigorous focus on the chosen product and its underlying technology (Schoemaker and Schoemaker, 1998).

Maintaining patents is another fundamental challenge for biotechnology start-up companies. The reason is that patents for a biotechnology process can be much more difficult to understand than patents in other fields (Malazgirt, 2011).

Having explained the key requirements for successful biotechnology commercialisation, the research can now proceed to the empirical work, where the research will apply these insights in the South African cases.

4.3. Case study: the evolution of biotechnology spin-offs and start-ups

4.3.1. Methodology

Following a literature survey and the initial survey on university spin-offs (Uctu and Jafta, 2009), reported in Part II, the research ventured into the field to establish whether biotechnology spin-offs identified in the survey were still in existence, and whether new ones have been created since. This exploration resulted in ten biotechnology firms being identified, two from the University of the Western Cape, four from the University of Cape Town and four from the University of Stellenbosch.

For the purposes of these in-depth case studies, the research initially set the criteria that the companies should have been created after 2000 (to be comparable), must be active in biotechnology, and particularly in manufacturing, product development or research. The research therefore excluded service-type and consultancy firms (four) and one firm that was created in 1997 and closed down in 2007. Five companies fitted the criteria. However, when the research continued the investigation, the research found that more companies had gone under than survived. The more important question to pursue, became 'why the failure?. Two of the companies that failed, were willing to participate in the in-depth interviews. One was from UCT and one from the University of Stellenbosch. To garner the perspective of the supporting agencies in the RIS, the research arranged and conducted interviews with senior staff at the universities' technology transfer offices[54] and the Technology Innovation Agency. The interviews yielded a considerable amount of information, which, as the research will show in our analysis, tell a tale of failure that hold important lessons for practitioners and policy makers.

In the next section, the research elaborates on the company histories. The companies are coded Company A and B.

4.3.2. Overview of biotechnology spin-off companies

[54] Unfortunately, the TTO at UCT was only willing to confirm that Company B was no longer operational and the founder of the company refused to give any information beyond what is in the public domain.

4.3.2.1.Company A

Company A, was a University of Stellenbosch spin-off company, which at the time of its establishment, represented and opportunity to realise the commercial potential by bringing to market the technologies developed, and capitalising on the research proficiency and extensive knowledge generated at the Institute of Wine Biotechnology(IWBT) at Stellenbosch University (Stellenbosch University, 2005, Rippenaar, 2006, Moore, 2008). This company was officially launched in 2005. It was a biotechnology-based start up with the aim of establishing a sustainable product and technology development process that would combine the research output and intellectual property generated by the IWBT with sound commercialisation and marketing practices (Stellenbosch University, 2005; Moore, 2008; Innovus, 2012; www.wynboer.co.za).

To pursue this pioneering initiative, the IWBT appointed a team of five researchers to work solely on Company A projects, and a Project Manager to guide the commercialisation and business needs of the venture in 2005. The research staff members at the IWBT assisted the team, each contributing their expertise and knowledge to the Company A projects. There was a Project Leader who is a full Professor in a department at Stellenbosch University (Stellenbosch University, 2005).

The company focused on the areas of genetic enhancement technologies, conventional development of unique yeast and bacterial strains, and development of quality control niche service offerings (chemical and microbiological) to the wine industry. Their projects were designed to generate a large number of hybrid and/or recombinant wine yeast strains. Research aimed, amongst others to develop yeast strains that are able to enrich wines with antioxidants and nutritional supplements. Company A also wanted make the fermentation process more efficient through the production of yeast strains with enhanced levels of key fermentation enzymes, and reducing the reliance on sulphur dioxide during the fermentation process. (Stellenbosch University, 2005; Moore, 2008, Innovus, 2012; www.wynboer.co.za), these research and technology developments were believed to hold an important strategic advantage for the South African wine industry in the global market. Company A sought to actively commercialise the novel technologies at the IWBT, thus contributing towards the global competitiveness of the South African wine industry (Moore, 2008).

To initiate the company, funding was obtained from Cape Biotech Initiative (CBI). The CBI was tasked with funding, promoting and supporting biotechnology activities in the Western Cape. The venture was in a three year project development phase after which it is envisaged that a private company will be incorporated, representing the commercialisation arm of the Institute for Wine Biotechnology (Stellenbosch University, 2005; Moore, 2008; www.agri.snowball.co.za, accessed in 2 November 2012; Innovus, 2012; www.wynboer.co.za). The details of the projects that Company A were working on, illustrate the potential they believed they could develop to bring to market:

1. *Wine Yeast Strains* - Yeast plays a critical role in the production of wine, and determines many of the specific characteristics of the product. It not only conducts the fermentation process, turning grape sugars into alcohol and carbon dioxide, but also produces many aroma and flavour active metabolites. Company A planned to use both recombinant DNA technology and breeding and selection procedures to produce novel commercial yeast strains with clearly identifiable, marketable advantages. Many of the modified yeasts have already reached the proof of concept stage, which means that most scientific questions have been answered, but further development was necessary for the projects to become commercially viable.

2. *Health and Wine* - A change in consumer lifestyles has resulted in a renewed growth phase in the health and wellness product market world-wide. Consumers are demanding healthy, good tasting, convenient food and drink that is less processed, less preserved and more natural, to keep up with their fast-paced, 21st century lifestyles. With projects geared toward the low alcohol producing, and nutraceutical producing wine yeasts, Company A sought to cater for the unique needs of the discerning modern consumer. A regular glass of red wine is often suggested as part of a balanced, healthy eating plan. Antioxidants add to the health benefits of red wine and one of the compounds identified as contributing to this is resveratrol, found naturally in grape skins. Studies suggest that resveratrol reduces both the risk of heart disease and cancer. Company A intended producing yeast strains that increased levels of resveratrol, thus providing additional health benefits to the wine consumer. Another project at Company A was to develop yeasts that produce carnitine, a nutraceutical found mainly in meat and dairy products that help the body produce energy. The production of carnitine in wine would reduce the need for nutritional supplements, thereby allowing consumers to maintain a healthy diet, and enjoy a glass of good wine at the same time.
3. *Enzymes in Yeast* - Enzymes important for winemaking either originate from the grape, the yeast, or are added during the fermentation process. Company A was attempting to improve the efficiency of this process, by manipulating wine yeasts to produce enhanced levels of certain enzymes that play an important role during fermentation. Ideally, this will translate into reduced input costs for the winemaker, with better control of the fermentation process, and ultimately an end product of higher quality.
4. *Wine Spoilage Organisms* - The control of spoilage micro-organisms during wine fermentation is currently achieved with the use of chemical preservatives, such as sulphur dioxide (SO2). However, the excessive use of these chemical preservatives is

detrimental to the quality of the wine. Additionally, the wine industry is being confronted by mounting consumer resistance to the use of chemical preservatives such as SO2. This is reflected in the recent regulations introduced for wine exported to the European Union, which states that if the finished wine contains more than 10 milligrams per litre of sulphur dioxide and sulphites expressed as SO2, it will have to carry a label stipulating this. In response to these trends, there has been interest in safe, food-grade preservatives of biological origin. Company A's Bacteriocin Project aimed to target bacteriocins produced by lactic acid bacteria (LAB), for control of spoilage. This presents an alternative to the use of sulphur dioxide as an antibacterial ingredient, and the opportunity to reduce the reliance on SO2 during the fermentation process (www.wynboer.co.za).

There was much hope that this company would be a successful example for future biotech spin-offs. Scott (2007) reported that a California-based businesswoman noted that biotechnology start-ups could provide a critical kick-start to South Africa's economic growth as well as fight poverty. The example she gave referred to the fledgling Stellenbosch University company, Company A, which was one of fifteen Western Cape "baby biotechs" financially supported by the Cape Biotech Trust and designed to commercialise and utilise academic discoveries. Unfortunately, Company A was terminated in 2010. Some of its projects reverted to the IWBT and are pursued there.

4.3.2.2.Company B

Company B was created in 2006 by a PhD student who developed the technology at University of Cape Town. It was a start-up biotechnology company developing a production process for the manufacture and marketing of natural products derived from microalgae. The objective of its project was to produce natural astaxanthin from microalgae for the local and international markets using closed system cultivation technology for better process control (www.fao.org). The astaxanthin project used technology developed at the University of Cape Town by the founder, who also received assistance the Professor who supervised his of the PhD research and heads the Centre for Bioprocess Engineering Research (CeBER) in the Department of Chemical Engineering at UCT. The research group at the university provided Company B with inocula (starter algal cultures), maintaining the algal culture to mitigate the risk of contamination at the Upington site, as well as providing routine analytical support (UCT Innovation, 2010).

Astaxanthin is a valuable carotenoid pigment used in the aquaculture and animal feed industry and is gaining increasing status as a human nutritional supplement because of its antioxidant properties. The astaxanthin, which is produced by microalgae, is one of the most powerful antioxidants and is also found in certain fish and shell-fish species, giving them their distinctive pink colour. According to the report the algae are grown in small, shallow ponds for a short period. The algal strain has been derived from fresh water culture collections which has been adapted for commercial use. Once grown, the algae will be 'stressed' by changing the growth conditions which induces it to synthesize astaxanthin. Astaxanthin is produced by the cells as a secondary metabolite, which is only found in a specific cell state. The algal cells are then harvested and processed (www.fao.org, accessed 1 November 2012).

The major market for astaxanthin is the aquaculture industry which provides feed for salmon (80%), trout (15%) and shrimp (3%). Other markets include the food and nutraceutical/ over the counter (OTC) market segments. Together these markets constitute about 2% of the global market value. Astaxanthin for the feed industry sells for between $2000-$3000 per kg, but is considerably more costly for the OTC markets as this requires further processing of the crude product. Worldwide consumption of astaxanthin was about 170 tons per annum in 2008. Major consumers of astaxanthin include Europe (65%), Latin America (25%) and Asia (10). Natural astaxanthin for the OTC or nutraceutical market for human consumption is sold at a premium due to its associated health benefits (www.fao.org, accessed 1 November 2012). Ongoing research has proved that natural astaxanthin is effective against a number of health problems including age-related muscular degeneration, neurodegenerative diseases, cardiovascular diseases, cancer and blindness (www.fao.org, accessed 1 November 2012; www.biotech-weblog.com, accessed 2 November 2012).

Available funding for this project was used to further develop the technology and to establish a pilot production facility. Company B uses facilities in Upington for its manufacturing and piloting studies where the climatic conditions are favourable to algal growth. The location offers the best combination of maximal sunshine and light intensity coupled with minimal rainfall. The facility used both municipal and fresh river water in ponds cultivation system where nitrogen and carbon nutrients are added. The carbon source is carbon dioxide while the nitrogen source is nitrates. The waste water is recycled to recover nutrients and to reuse. There was a plan for setting up an algal technologies platform at the pilot plant facilities in Upington where nascent algal companies can be accommodated. The market depends very much on the type of product e.g. astaxanthin market in South Africa is miniscule; hence most of the product was aimed at the export market. It was thought that Company B might act as primary algal products producers with onward distribution to established global formulation companies in Europe (www.fao.org, accessed 1 November 2012).

Company B was incorporated in March 2006 after receiving funding of 3.8 million Rand

(~USD 600.000) from the Cape Biotech Trust, who funded the start-up operation, linking in with their other algal initiatives in Upington (UCT Innovation, 2010; www.fao.org, accessed 1 November 2012). Company B was in a three year development phase from 2006 to 2009. After this phase a full scale plant capable of producing up to 2 tons of 100% astaxanthin were to be established. Company B was then in need of a second round of funding to progress to full scale production. (www.fao.org, accessed 1 November 2012). Not succeeding in acquiring the needed funds, the company was terminated in 2011.

4.4. Anatomy of failure in biotechnology spin-offs: an internal and external environment perspective

Using the insights from the literature discussed earlier in the section and the information garnered from the interviews, the research tabulate the factors linked to the failure by the interviewees in Tables 4.1 and 4.2. This allows to systematically identifying similarities and differences in the reasons for failure advanced from the different perspectives.

Table 4.1: Reasons for termination from different perspectives

COMPANY A				
Firm perspective				
	Managerial skills	**Sufficient capital**	**Technology**	**Others**
Lack of knowledge and communication	-	-	-	O
Funding	-	O	-	-
New mandate in TIA	-	-	-	O
TTO Perspective				
New mandate in TIA	-	-	-	O
Technology was too far from the market	-	-	O	-
Unclear market	O	-	O	-
Timing	O	O	-	O
Uncertainty in Company	O	-	-	-
Having no leader	O	-	-	-
Conservative market	-	-	O	-
Expectations	-	-	-	O
Freedom	-	-	-	O
Not having a sustainable business plan	O	-	-	-
TIA perspective				
Having no leader	O	-	-	-
Having no commercial products	-	-	O	-
Technology was too far from the market	-	-	O	-
Unclear market	O	-	O	-
Business model	O	-	-	-
Expectations	-	-	-	O
R&D driven	O	-	-	-
COMPANY B				
TIA perspective				
No managerial and technical (engineering) skills	O	-	-	-

Source: Authors' own construction, 2012

The research group the relevant factors for analytical purposes in terms of internal (firm-specific) factors and external (relating to the environment in which they operated, and specifically to the relevant institutions or organizations in the NIS and RIS respectively).

4.4.1. Firm specific factors

4.4.1.1. Managerial skills and leadership

Out of the three interviews conducted for Company A, only the TTO representative and the senior staff member at the TIA identified managerial factors as contributing to the demise of the company. According to the senior member of staff of the Company A the managers' skills were not such a big problem, because the early challenges were of a scientific and technological nature. She believes the need for business and financial skills would only become critical once the firm became a fully-fledged company. She stated that the company had created a pleasant and healthy working environment where the team, including the founders worked well together. The only hiccup was the fact that they had lost a project manager to another company and had difficulties finding another one. According to senior staff member at Innovus, the TTO at Stellenbosch University, the company did not have a CEO or a clear leader to take the projects further and this resulted in instability and uncertainty. That the company did not have feasible business plan and disagreed with the funder about it, also complicated matters (more on this below). According to the senior staff member interviewed at the TIA, the right person, with the right leadership and managerial skills, especially to drive the commercialisation and 'hunt money', rather than research output, would have made all the difference. In the interviewee's mind, the business model of chasing revenue from licensing, rather than further commercialisation was not the right one. The company already had something to commercialise, but the focus was too much on R & D, and not commercial products.

The same interviewee also asserted that Company B failed because it had no managerial and technical (engineering) skills.

4.4.1.2. Insufficient capital

Both companies had funding from the Cape Biotech trust to fund start-up and development costs, but in both instances they were not able to muster enough funding to scale up operations to produce marketable products. From the firm's perspectives, the trouble started when the TIA absorbed Cape Biotech in 2010, with resultant uncertainty and changes (staff turnover, loss of key contacts in Cape Biotech), new business plan investigations and viability studies. The end result was that the TIA concluded that the Company did not fit their mission, and funding was terminated. The Innovus representative lamented the timing of this upheaval: “Company A needed about four more months of funding to get the desired results that would generate income, but the TIA decided to terminate the venture in November 2010. If they could just have continued for another season, they could have had wonderful results.” The TIA representative’s view was that there were expectations that the company should have commercialized some output from the project by year 3. The TIA position was clear: commercialise or the funding would be stopped. Commercialisation was not forthcoming, so the funding stopped. Company B had, according to the TIA representative ‘ a brilliant product, for which they had funding, but they could not take the project to the next level, i.e. scale it up, and therefore the TIA decided to terminate the company.

4.4.1.3. Technology

For both companies, the nature of the technologies they were trying to turn into marketable products, were such as to require a long lead time and many resources to bring the projects from production in pilot plants to production for large markets. According to the TTO representative as well as the TIA representative, the technology from Company A were still too far from being market ready, and for this reason, it was also unclear precisely which market to target to achieve the best pay-off.

4.4.1.4. Market-related factors

Both the TTO and TIA representatives identified market-related factors as problematic. Apart from emphasizing the fact that it was not yet possible to target a market for products that are still too far from market-ready (discussed above), the Innovus interviewee also mentioned that the market that Company A chose (wine producers) are still fairly conservative and not likely to adopt genetically modified products. In fact only America and Canada allow genetically modified wines to be sold.

4.4.2. External (NIS, RIS) factors

Most of the factors in this section have to do with the impact of changes in the institutions supporting the development of the biotechnology sector, and specifically the changes brought by the establishment of the Technology Innovation Agency (a national body) in 2010 and the absorption of Cape Biotech (a regional body) into the TIA.

4.4.2.1. Knowledge and communication gaps

When the TIA took over, much uncertainty was created, with paralyzing effects. The company interviewee opined "the people appointed to the TIA did not know what was going on and their communication was terrible." Almost a year elapsed before they were informed that their funding was terminated.

4.4.2.2. Discontinuities: from Cape Biotech to TIA

The TTO representative stated that the creation of the TIA resulted in a period of chaos, shifting the focus and mandate from a regional one under Cape Biotech to a national one under the TIA. Also, whereas Cape Biotech understood that biotechnology has a very long lead time before significant revenue is generated; the mind-set of the TIA was one that preferred funding companies with products and technologies close to market ready. This is an unfortunate development, in the face of the persistent refrain in the empirical literature and earlier research reported in section 2 and 3, about the long and costly development paths in biotechnology and the lack of venture capital markets in developing economies. On this latter point the research elaborate in the next section.

4.4.2.3. Funding sources in the innovation system

The interviewees indicated that try as they might, the management teams at the biotech start-ups under discussion here, could not garner the necessary funds to ensure their survival. Private financing for biotechnology remains severely limited in South Africa. The problem in South Africa is the lack of finance available for seed and start-up companies, the bulk of the capital going into replacement capital, such as management buy-outs and black economic empowerment transactions (Sherwin, 2007). Biotechnology companies usually run through multiple rounds of funding in order to achieve maturity. In the USA and European countries there can be as many as six rounds of venture capital funding before a company is self-sustaining or lists on a stock exchange. In South Africa, several fledgling biotechnology companies have received two to three rounds of financing but are facing the 'valley of death' with no means of support (Sherwin, 2007; Al-Bader, 2009). Government funds for the biotechnology industry are limited, and South Africa's investment community is immature in biotechnology, with having only one VC in biotechnology[55]. Without a change in this funding picture, the efforts that the government has made so far in stimulating biotechnology will be threatened (Al-Bader, 2009). In addition to the above explanations, Sherwin (2007) adds note that both the South African government and the private sector need to be realistic about the time frames and the amount of capital that required developing the biotechnology. According to her, this is not a three to a five year commitment, but a ten to a twenty year commitment at least.

[55] Only private biotechnology Venture Capital was dormant in 2010 due to investing in their whole portfolio (information received through interview with a manager at the TIA, 7 November 2012). The Biotech VC firm raised a size of R80 million funds in 2001. By the time in May 2010 company invested R76 million in to total number of 8 private equity/venture capital investments and current portfolio size was 3 (www.accessmylibrary.com, accessed 09 November 2012).

4.4.2.4. Timing of interventions

According to the interviewees at Company A and the TTO, the timing of the TIA interventions were very unfortunate. They believe that, if allowed to continue to work normally (absent the interruptions by TIA officials) and if they had funding for a few more months, they would have been able to deliver on commercialisation.

Table 4.2: Firm-specific, NIS and RIS explanations for biotechnology spin-off failure

COMPANY A		
	Firms	**RIS Institutions/Organisations**
Firm perspective		
Lack of knowledge and communication	-	O
Funding	-	O
New mandate in TIA	-	O
TTO Perspective		
New mandate in TIA	-	O
Technology was too far from the market	O	-
Unclear market	O	-
Timing	O	O
Uncertainty in Company	O	-
Having no leader	O	-
Conservative market	O	-
Expectations	-	O
Freedom	-	O
Not having a sustainable business plan	O	-
TIA perspective		
Having no leader	O	-
Having no commercial products	O	-
Technology was too far from the market	O	-
Unclear market	O	-
Business model	O	-
Expectations	-	O
R&D driven	O	-
COMPANY B		
TIA perspective		
No managerial and technical (engineering) skills	O	-
Limited scalability	O	-

Source: Authors' own construction, 2012

4.4.2.5. Expectations and business perspective of funder

Insights from the TTO interviewee suggest that even before the discontinuity created by the takeover of Cape Biotech by the TIA, Company A and the former were at odds over the appropriate business plan for the company. She observes that Company A did not seem to have the freedom to choose their business model or the line of products that they wanted to pursue.

When the funder and the beneficiary are at odds, end goals are complicated and the desired outcomes are not clear. It may result in expectations not being met.

In sum, these factors confirm the main obstacles that biotechnology start-ups face, as identified in the literature and our research for this thesis. The results further point to useful insights regarding the NIS and RIS.

RIS structure in Figure 1 (see Part I earlier in this study; Cooke, 2002a) draws the main features and relationships of a functioning regional innovation system. But it only shows the linkages in a neutral way. To capture the variety of degrees of influence and decision-making authority, the presence or absence, or weaker and stronger relationships amongst the diverse possible kinds of application, exploitation, generation and diffusion elements of specific regions and their degrees of "systemness" (Cooke, 2002b: 137), one needs to investigate the interactions amongst the constituent parts of the system. Although the research have only focused here on biotechnology firms and certain institutions in the RIS, the research have learned plenty about the weak points and potential weak pints in the system. The research highlights the implications of these in the conclusion.

4.5. Conclusion

In this last part of the study, the research wanted to trace the growth paths of the biotechnology companies that spun off from universities in the Western Cape RIS. The research efforts to find the spin-offs that were still active in the biotechnology sector, made it clear that a more relevant question to ask, would be 'why do they fail?' rather than 'how did they succeed?'.

With the aid of the three pillars of successful biotechnology commercialisation from the literature, and the information on the case study companies, gathered from interviews with company, TTO and TIA representatives, the research constructed two sets of factors that led to the demise of these firms. These were the internal, or firm-specific factors, and external or NIS/RIS related factors.

The research findings on the firm-specific factors underscore the importance a diverse set of managerial skills, discussed here, and in particular in the section on bio-entrepreneurship training. This is an important message for several players in the NIS and RIS, for example educational and training institutions, agencies such as the TIA that must play a supporting role, Technology Transfer Offices, some of which operate training programmes and incubators for biotechnology entrepreneurs.

With respect to the factors related to the RIS and NIS, the following stand out:

- The imperative to mindful of disruptive effects in the very sector or system that an institutional change is supposed to assist and support. In the case of Cape Biotech and the TIA, the change was clearly turbulent and competence and capacity destroying, rather than enhancing.
- Funding for seed and start-up capital is consistently identified as an obstacle to growth in a promising sector of the economy. The nature of the technology and the longer-term investment horizon required makes the sector unattractive for investors with a shorter term perspective. It would now seem that the government agency tasked with promoting growth in the biotechnology sector has adopted the latter view. In addition, the venture capital market in South Africa is underdeveloped and resources scarce. Until this aspect

of the innovation system is addressed more effectively, firm formation and innovation in the sector may continue to remain under its potential level.

5. CONCLUSION AND RECOMMENDATIONS

The aim of this study was to apprehend how the regional innovation system in the Western Cape region was reconstructed, in order to allow for the evolution of the biotechnology sector in the region. Various institutions and organisations played a crucial role in affecting these changes. One of the most important changes involved legislation that altered the role that universities play in bridging the gap between research outputs and reaping commercial benefits from such outputs. Following the logic of the regional innovation system, the study focused on the institutional changes, the mechanisms employed to bridge this gap (from creating spin-off firms, and licensing technologies based on university research, to designing programmes that support the development of bio-entrepreneurs).

When embarking on the reconstruction of the NIS or RIS, the initiators of the change presumably believe that the altered system will be better than the *status quo*. The NIS and RIS literature emphasize the importance of effective linkages amongst the actors in the system. Deviating from the standpoint that firms are the units that bring innovations to the market, alterations to the innovation system require an understanding of the incentives and motives that lead to firm formation, the obstacles young firms encounter, and the factors that enhance or impede the growth of new firms. In South Africa several changes were enacted to support the development and growth of the biotechnology sector which is a relatively young, but promising sector in the economy. The most important changes observed were:

- The National Biotechnology Strategy (2001) at NIS level;
- The creation of the BRICS (2002) at RIS level;

- Intellectual Property from Publicly Financed Research and Development Act (2008), which altered the roles of universities, enabling universities and inventors to benefit from publicly funded research and creating technology transfer offices; [national level change; affecting regions]
- The creation of the Technology Innovation Agency (2009/10), subsuming the BRICS. [National level].

This study focused on the outcome of these changes in a sub-sector of the Western Cape RIS, namely biotechnology. Six research questions (two main and four sub-questions) were presented, where all of them are relating to the aim of the thesis, namely:

- *What should be the alternative ways of developing a favourable environment for regional biotechnology concentration to emerge and develop in the knowledge-based economy?*
    - ➢ *What were the key mechanisms used to bring the output of scientists to market, i.e. spinning off or licensing technologies?*
    - ➢ *What motivated academics to create spin-offs or license their technologies and what were the main obstacles that they have encountered?*
    - ➢ *How effective was the first attempts at building a bridge between science and the market through bio-entrepreneurship training in the region?*
    - ➢ *What happened to the biotechnology spin-offs and start-ups over time, and what effect did the changes in the institutional and policy environment have on their growth or demise?*
- *What are the strong and weak points to promote a biotechnology innovation system in Western Cape region?*

Some conclusions with regards to each of these research questions mentioned are presented in the following sections.

Since all the efforts to effect the changes to the RIS that would enhance the growth of a promising industry are relatively new, the study faced the usual problems associated with pioneering developments, such as small samples, a complete lack of databases, etc. For this reason, the questionnaire survey and case study methods were used throughout the study. A caveat is therefore sounded throughout, that because of the small samples, the results must be interpreted with care and generalisations cannot be made. The study, however, makes a significant contribution in the insights that it yields in a number of areas where the literature on spin-offs, biotechnology and bio-entrepreneurship training in developing countries is still sparse. The most important findings for the individual parts are summarised below and implications for policy makers and practitioners derived.

6.1. The Contributions of this thesis and its findings

In this section, an attempt is made to draw up the results of the thesis in order to gain the essence of the many lessons that have been learned during the duration of the study. In terms of the overall research design and the specific contribution that each of the five papers make, the limitations of this thesis have already been discussed. However, to what extent can more general conclusions be drawn from the thesis as a whole? What is the reach of these conclusions? As a matter of degree, the conclusions drawn in the following case study are those relating to the nature of innovation processes;

Contributions 1: The study was confined to knowledge and technology transfers from the university to the market irrespective of whether they received university support or not.

Specifically, the thesis presented an understanding of the spin-off phenomena e.g. historical status, characteristics of spin-offs (including motivations behind certain creations, relationships with universities, obstacles they faced, etc.) from Western Cape universities in South Africa and identifying the biotechnology spin-offs from universities. From this contribution flow the following insights that are valuable to inform further research:

Findings 1a: The research contributes to a practical definition of a spin-off company in the South African context as "*A new firm created to exploit some knowledge, technology or research results conducted at the university by faculty members or students who receive (any kind) of support from the university (the TTO); a new firm created around a university license of intellectual property (founders may be or may not be from university); a firm created by the university itself (wholly university-owned)*".

Findings 1b: Different interpretations of the definition of a spin-off firm exist in the minds of the founders themselves, as well as the people involved in the technology transfer process. This implies that researchers have to be very precise in how they define a spin-off and communicate this clearly to the respondents.

Findings 1c: Universities keep records of spin-offs, but these records do not seem to be updated, i.e. the universities do not closely track the progress of their spin-offs (except in the cases where they have equity). After the field excursion, research revealed that some of the spin-offs do not exist anymore, and others were discovered that do not appear on the lists.

Findings 1d: In this thesis one of the main findings was that progress is slow in the creation of spin-off companies at universities, specifically, in biotechnology industry as a tool to increase the knowledge transfer from universities. It was therefore important to understand why scientists, who are in a position to spin off, opted not to. One of the main reasons for researchers' decisions not to create a company, but to license their technologies, is the challenge of finding funding, which still plays a significant role in creating spin-offs. Furthermore, those, who did create spin-offs, were motivated by the desire to put knowledge to practical use. This motivation bodes well for a country sorely in need of innovations that will address socio-economic challenges and spur economic growth.

Contributions 2: There is an increasing trend towards spin-off companies in Asia as well, although only a small number of studies have so far dealt with biotechnology spin-offs from universities in Hong Kong as latecomer in biotechnology. One of the merits of this study, however, lies in the fact that it focused on university spin-offs in biotechnology in order to understand the dynamics and influence of this phenomenon as knowledge transfer process in biotechnology in Hong Kong. The study analyzed the local activity as an important step towards understanding the emerging biotechnology industry in latecomers. This study yielded the following insights:

Findings 2a: that there is an increasing awareness of academic entrepreneurship in the form of creating university spin-offs in Hong Kong, but not yet for the biotechnology sector, where spin-offs are relatively few.

Findings 2b: this study also contributed to refining the definition of biotechnology spin-offs, where it was evident that some companies clearly fitted the textbook definition but some others were more complex and required an expanded definition.

Findings 2c: This study contributed to the understanding of the *rationale* for and the nature of biotechnology spin-offs from Hong Kong universities.

Contributions 3: Empirical literature on bio-entrepreneurship training in developing countries is still sparse. Thus, this study is novel as it assessed the first structured attempts in South Africa to equip bio-entrepreneurs with the skills necessary to build a bridge between the science of biotechnology and the commercialisation of knowledge and ideas in this field. Through this assessment, the following insights emerged:

Findings 3a: Like other countries, South Africa also faces a shortage of entrepreneurial skills that would bridge the gap between science outputs and marketable bio-products. The effectiveness of the first programme in terms of the number of enterprises created following the training; do not show a rapid progression. However, a beam of light is the relative success achieved with the development and implementation of a bio-entrepreneurship training programme, when measured against its own objectives and the expectations of the participants. This positive outcome laid the foundation to build a more sustainable bridge between the science of biotechnology and the commercial world where the wealth creation opportunities reside.

Contributions 4: One of the merits of this part of the study lies in the fact that it draws together many of the advantageous insights from previous papers and the literature, and with the aid of the case studies, it shows how a complex series of internal (to the firms) and external factors (in the national and regional innovation systems) combined to lead to the failure of the biotechnology spin-offs.

With the aid of the three pillars of successful biotechnology commercialisation from the literature, and the information on the case study companies, gathered from interviews with the company, TTO and TIA representatives, two sets of factors that led to the demise of these firms were identified. These were the internal, or firm-specific factors, and external or NIS/RIS related factors.

Findings 4a: Findings on the firm-specific factors underscore the importance of a diverse set of managerial skills, discussed here. This is an important message for several players in the NIS and RIS, for example educational and training institutions, agencies such as the TIA that must play a supporting role, and Technology Transfer Offices, some of which operate training programmes and incubators for biotechnology entrepreneurs.

Findings 4b: With respect to the factors related to the RIS and NIS, the following stand out:

- The imperative to be mindful of disruptive effects in the very sector or system that an institutional change is supposed to assist and support. In the case of Cape Biotech and the TIA, the change was clearly turbulent and competence and capacity destroying, rather than enhancing.
- Funding for seed and start-up capital is consistently identified as an obstacle to growth in a promising sector of the economy. The nature of the technology and the longer-term investment horizon required make the sector unattractive for investors with a shorter term perspective. It would now seem that the government agency tasked with promoting growth in the biotechnology sector has adopted the latter view. In addition, the venture capital market in South Africa is underdeveloped and resources scarce. Until this aspect of the innovation system is addressed more effectively, firm formation and innovation in the sector may continue to remain under its potential level.

6.2. Recommendations

Recommendations 1: The literature has shown that university systems differ across countries. The primary goal of universities usually lies in conducting scientific research and educating students. Over time, a third function has been added that today generates much interest: since the enactment of the Bayh-Dole Act in the United States of America (US) in 1980, the promotion and commercialisation of universities' research results has been a focus of attention. In other words, transfer of technologies arising from university research, to industry, through patenting, licensing and creating companies, has come to be seen as a third function. Intellectual Property from Publicly Financed Research and Development Act (2008) has been created which modified the roles of universities, enabling universities and inventors to benefit from publicly funded research and creating technology transfer offices. However, in this study, findings on spin-off creation suggest that policy-makers and university management should reconsider the resources in terms of capabilities (amongst university management, technology transfer staff and scientists) and funding that are necessary for successful technology transfer and sustainable venture creation through spin-offs.

This implies that universities need to adopt a strategic approach regarding knowledge and technology transfer. While they make choices concerning institutional goals and priorities, resource allocation, technological emphasis, patent strategies and modes of technology transfer, they can choose a mixture of licensing, spin-offs creation, sponsored research and other mechanisms for knowledge and technology transfer. However, universities should bear in mind that a spin-off strategy requires different resources and capabilities from those required for licensing and sponsored research activities (Mustar *et al*., 2008).

Recommendations 3: In South Africa, the survival rate of the spin-offs from universities is very low. Thus, universities and policymakers should consider strategies to improve this outcome. The literature on university spin-offs suggests some interventions such as incubators in universities to support those early-stage companies.

Recommendations 4: Universities should update records of spin-offs and track the progress of their spin-offs. Some of the spin-offs do not exist anymore, and others were discovered that do not appear on the lists. For future studies, the research recommend that they publish their history of spin-offs creation. But, more importantly, for their own effectiveness, TTOs need to document and update technology transfer activities, including spin-offs.

Recommendations 5: Prior to raising commercial interest, universities need to be aware in developing effective IP and patent strategies. In addition TTOs need to ensure that IP is clean, well-defined and protected. Therefore, the IP and patent strategy should consider what technology is proprietary to the department, which is licensed on an exclusive base and which parts are licensed on a non-exclusive basis (Mustar *et al*., 2008). Uncertainty in this regard may act as deterrent to technology transfer activity on the part of successful scientists.

Recommendations 6: If so desired, universities should introduce programmes to stimulate academics to start spin-offs; the structure through which most universities operate creates constraints since career progression typically still depends largely upon the evaluation of a scientist's academic output. There is a great need for the adaptation of promotion and remuneration systems both at a systemic level and within universities, so that commercialisation activities are valued (Mustar *et al*., 2008).

If the universities are more flexible on academic's position at university, more scientists might consider spin-offs. Some scientist who have output that could be commercialised may be hesitant to spin off, because it might force them to leave academia. A flexible hybrid position may enable the university to gain the best of both worlds, i.e. first-hand experience from the business world and the retention of good scientists.

Recommendations 7: Government should assess existing policies and their effectiveness of bridging the financial and knowledge gaps. In order to achieve this concept, the support for academic spin-off firms may play a larger role regarding knowledge transfer policy, which its sole purpose is to develop the transfer of knowledge between universities, business, and the society that constitutes third-stream activities of universities. The aim of the policy in concern should be concentrated on filling both the financial and knowledge gaps based on the notion of addressing market failure (Mustar *et al*., 2008).

Recommendations 8: Government need to create awareness of biotechnology and the opportunities it holds for entrepreneurship at school, college and university level. Policy-makers should consider whether, in order to develop an awareness of biotechnology enterprise and biotechnology entrepreneurial spirit, such aspects should be incorporated into the school and college curricula.

Recommendations 9: Although the National Biotechnology Strategy identified the need for a dedicated agency to champion the biotechnology sector, no such agencies exist. Neither is there one to promote bio-entrepreneurship. Aspects relevant to entrepreneurship policy can be found across a broad spectrum of ministries and agencies, ranging from education to trade and immigration (Audretsch 2013). The research recommends that the DST and TIA revisit the idea of a dedicated agency to champion biotechnology and manage the relevant activities to ensure coherence and efficiency in programmes designed to support the sector.

Recommendations 10: An institutional change is supposed to assist and support in national and/or regional level. In the case of Cape Biotech (regional level) and the TIA (national level), the change was clearly turbulent and competence and capacity destroying, rather than enhancing. The research strongly recommends that the DST should revisit the idea of changing support system and reorganise for the innovative sectors, e.g. biotechnology.

From this study, bearing in mind the small scale and the danger of generalisations, it would seem as if the reconstruction of the RIS and related changes in the NIS did not generate the results that the strategy hoped for (at least in the Western Cape, the focus of this study). A beam of light is the relative success achieved with the development and implementation of a bio-entrepreneurship training programme, which laid the foundation to build a more sustainable bridge between the science of biotechnology and the commercial world where the wealth creation opportunities reside.

6. REFERENCES

Akermann B. and F. Kermani (2006a), The promise of South African biotech, *Drug Discovery Today*, volume 11, numbers 21/22, pp. 962-965

Al-bader, S., Frew, S., Essajee, I., Liu, V., Saar A., Singer P. (2009) 'Small but tenacious: South Africa's health biotech sector' *Nature Biotechnology*, volume 27, number 5, pp.427-445.

AUTM (2010a), AUTM U. S. Licensing Activity Survey Highlights: FY2010, http://www.autm.net/AM/Template.cfm?Section=FY_2010_Licensing_Survey&Template=/CM/ContentDisplay.cfm&ContentID=6874.

AUTM (2010b), AUTM Canadian Licensing Activity Survey Highlights: FY2010, *http://www.autm.net/AM/Template.cfm?Section=FY_2010_Licensing_Survey&Template=/CM/ContentDisplay.cfm&ContentID=6870*.

AUTM (2012), Association of University Technology Managers Licensing Activity Survey 2011, http://www/autm.net

Avnimelech, G. and Feldman, M. (2011), "The impact of institution quality, cluster strength and TLO licensing capacity on the rate of academic staff spin-offs", http://conferences.library.gatech.edu/acsip/index.php/acsip/ATLC11/paper/viewFile/622/498.

Baark, E. (2005), "Innovation Policy Forensics: An Analysis of Biotechnology in Hong Kong", *http://www.druid.dk/uploads/tx_picturedb/ds2005-1557.pdf*.

Baptista R. and Karagoz M. (2006), "Determinants of Turbulence in Entry and Exit for High-Growth and Declining Industries", Paper Submitted for Presentation at the Workshop on Firm Exit and Serial Entrepreneurship – Max Planck Institute for Economics, 13-14 January 2006

Back S.M. (2009), The Bioentrepreneurship MBA: Options for mid-tier business schools, *Journal of Commercial Biotechnology*, vol 14, no 2, p 183-193

Benneworth, B. and Charles, D. (2004), "University spin-off policies and economic development in less successful regions: learning from two decades of policy practice", http://www.diw.de/sixcms/detail.php/43097.

Bercovitz J. and Feldmann M. (2006), "Entrepreneurial Universities and Technology Transfer: A Conceptual Framework for Understanding Knowledge-Based Economic Development", *Journal of Technology Transfer*, 31: 175–188

Bergek A. (2007), Analyzing the functional dynamics of technological innovation systems: A scheme of analysis, *Research Policy* 37 (2008) 407–429.

Bosma N. and Nieuwenhuijsen H. (2000), *Turbulence and productivity in the Netherlands* Research Report 9909/E, Zoetermeer, March 2000

Bower, D. (2003), "Business model fashion and the academic spinout firm", *R&D Management*, 33 (2), 97–105.

Breschi, S. and F. Malerba (1997), "Sectoral innovation systems: technological regimes, Schumpeterian dynamics, and spatial boundaries", in Edquist, C. (ed.) 1997 *Systems of Innovation: Technologies, Institutions and Organizations.* London and Washington: Pinter/Cassell

Bruijn P. and A. Lagendijk (2005), "Regional Innovation Systems in the Lisbon Strategy", *European Planning Studies*, Vol. 13, No. 8

Buesa M, J. Heijs, M. M. Pellitero and T. Baumert (2006), Regional systems of innovation and the knowledge production function: the Spanish case, *Technovation* 26, 463-472

Bureth A., J. Penin and S. Wolff (2010), "Start-up creation in biotechnology: lessons from the case of four new ventures in the Upper Rhine Biovalley", *International Journal of Innovation Management* Vol. 14, No. 2, pp. 253-283

Byrd, A.C. (2002), "Profile of Spin-off Companies in the Biotechnology Sector: Results from the Biotechnology Use and Development Survey – 1999", *http://www.statcan.ca/cgibin/downpub/research.cgi?subject=193*.

Carlsson B. and R *Stankiewicz* (*1991*), "On the Nature, Function and Composition of Technological Systems," Journal of Evolutionary Economics, 1(2): 93-118

Carlsson B. et al. (2002), Innovation systems: analytical and methodological issues, *Research Policy* 31 (2002) 233–245

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

Cartaxo R. and Godinho M. M. (2011), "University patenting, licensing and technology transfer: How organizational context and available resources determine performance", http://www.globelicsacademy.org/2011_pdf/cartaxo%20and%20godinho.pdf

Cervantes M. (2003), "Academic Patenting: How universities and public research organizations are using their intellectual property to boost research and spur innovative startups", http://www.wipo.int/sme/en/documents/academic_patenting.htm

Chiesa, V. and Piccaluga, A. (2000), "Exploitation and Diffusion of Public Research: The Case of Academic Spin-off Companies in Italy", *R&D Management*, Vol. 30, No. 4, pp. 329-339.

Chiesa V. and D. Chiaroni (2005), *Industrial Clusters in Biotechnology Driving Forces, Development Processes and Management Practices,* Imperial College Press, 2005

Chung S. (2002), "Building a national innovation system through regional innovation systems", *Technovation* , 22, p.485–491

Cloete, T., Nel, L., Theron, J. (2006) 'Biotechnology in South Africa' *Trends in Biotechnology*, vol.24, no.12, pp.557-562.

Collet, C. and Wyatt, D. (2005) "Bioneering" – teaching biotechnology entrepreneurship at the undergraduate level" *Education + Training* 47(6), pp. 408-421

Coenen L., J. Moodysson and B. Asheim (2004), ''Nodes, Networks and Proximities: On the Knowledge Dynamics of the Medicon Valley Biotech Cluster', *European Planning Studies,* Vol. 12, No. 7

Cooke, P. (1992) Regional innovation systems: competitive regulation in the new Europe, Geoforum, 23, 365-382

Cooke P. (2002a), "Biotechnology Clusters as Regional, Sectoral Innovation Systems", International *Regional Science Review*, 25, 1: 8–37

Cooke P. (2002b), "Regional Innovation Systems: General Findings and Some New Evidence from Biotechnology Clusters", *Journal of Technology Transfer*, 27, 133–145

Cooke P., Uranga M. G. and Etxebarria G. (1997), "Regional innovation systems: Institutional and organisational dimensions", *Research Policy* Vol. 26, Issues 4-5. 475-491

Conti A., Gaule P and Foray D. (2007), Academic Licensing: A European Study, http://cdm-it.epfl.ch/repec/cmi-wpaper/cemi-workingpaper-2007-001.pdf

Crispeels T., O. Uecke, M. Goldchstein and M. Schefczyk (2009), Best practices for developing university bioentrepreneurship education programmes, *Journal of Commercial Biotechnology*, vol 15, no 2, p 136-150

Cozzens S. E. and Kaplinsky R. (2009), Innovation, poverty and inequality: cause, coincidence, or co-evolution?, in. Lundvall, B-Å., Joseph K. J., Chaminade C. and Vang J. (Ed.), **Handbook of Innovation Systems and Developing Countries**, Edward Elgar: UK

D'Allura G. M., Galvagno M. and Li Destri A. M. (2012), Regional Innovation Systems: A Literature Review, *Business Systems Review*, Volume 1 – Issue 1, pp. 139-156

Doloreux D. and S. Parto (2004), "Regional Innovation Systems: A Critical Review", unpublished paper, available at: http://www.ulb.ac.be/soco/asrdlf/documents/RIS_Doloreux-Parto_000.pdf

Doloreux D. and S. Parto (2005), "Regional innovation systems: Current discourse and unresolved issues", *Technology in Society*, 27, 133–153

Dos Santos M.E.R. and J.L.S. Rebolledo (2008), "Management of Technology Transfer Offices: Lessons for Brazilian Universities", proceed in Ethiopia Triple Helix Conference Transforming University-Industry Government Relations in Ethiopia (eds Henry Etzkowitz, Matthieu Roest), published by IKED: Malmo, 2008.

Durai *et al.* (2006) "Challenges in a biotech start-up", http://www.kellogg.northwestern.edu/biotech/faculty/articles/startupchallenges.pdf, accessed 5 August 2011

Education Investor, *http://www.educationinvestor.co.uk*.

Edquist C. (1997) 'Systems of innovation approaches - their emergence and characteristics' in Edquist, C. (ed.) (1997) *Systems of Innovation: Technologies, Institutions and Organizations,* London: Pinter/Cassell

Edquist C. (2001), The Systems of Innovation Approach and Innovation Policy: An account of the state of the art, paper presented at the DRUID Conference, Aalborg, June 12-15, 2001, under theme F: 'National Systems of Innovation, Institutions and Public Policies', Draft of 2001-06-01

Erden, Y. and Yurtseven, A. E. (2010), "Establishment and Development of Academic Spin-off Firms: Evidence from Turkey", http://www2.druid.dk/conferences/viewpaper.php?id=500569&cf=44.

Fagerberg J., C. Mowery D. C. and Verspagen B. (2008), Innovation-systems, path-dependency and policy: The co-evolution of science, technology and innovation policy and industrial structure in a small, resource-based economy, DIME Working paper 2008.1 in the series on "Dynamics of Knowledge Accumulation, Competitiveness, Regional Cohesion and Economic Policies" (DIME Working Package 3.1)

Fagerberg J. and Srholec M. (2009), Innovation systems, technology and development: unpacking the relationships, in. Lundvall, B-Å., Joseph K. J., Chaminade C. and Vang J. (Ed.), **Handbook of Innovation Systems and Developing Countries**, Edward Elgar: UK

Fernandez C. (2007), How to Set Up a Technology Transfer System in a Developing Country, In Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices (Eds. A Krattiger, RT Mahoney, L Nelsen, et al.). MIHR: Oxford, U.K., and PIPRA: Davis, U.S.A. Available online at www.ipHandbook.org.

Fini, R., Grimaldi, R. and Sobrero, M. (2009), "Factors Fostering Academics to Start-up New Ventures: An Assessment of Italian Founders' Incentives", *Journal of Technology Transfer*, Vol. 34, Issue. 4, pp. 380-402.

Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan,* (London: Pinter).

Friedman, J. and J. Silberman (2003). University Technology Transfer: Do Incentives, Management and Location Matter?. *Journal of Technology Transfer*, 28, 17-30

Gao S. and van Lente H. (2008), Comparing approaches to systems of innovation: Confronting to the Chinese telecommunication sector Paper for Globelics academy 2008, Tampere, 2-13 June

Garduno, E. (2004), *South African University Technology Transfer: A Comparative Analysis, International Intellectual Property Institute*, Washington, DC

Gastrow, M. (2008) 'Great expectations: the state of biotechnology research and development in South Africa' *African Journal of Biotechnology*, Vol. 7 (4), pp. 342-348.

Gertler M. S. and Y. M. Levitte (2005), „Local Nodes in Global Networks: The Geography of Knowledge Flows in Biotechnology Innovation", *Industry and Innovation*, Vol. 12, No. 4, 487–507

Government Gazette (2008), *No. 31745, No. 51 of 2008: Intellectual Property Rights from Publicly Financed Research and Development Act*, 2008

Grundling, J. P. And Steynberg, L. (2008), "Academic Entrepreneurship in South African HEIs", *Industry and Higher Education*, Vol 22, No 1, February 2008, pp 9-17.

Gubeli, M. H. And Doloreux, D. (2005), "An empirical study of university spin-off development", *European Journal of Innovation Management*, Vol. 8, No.3, 2005, pp 269-282.

Gumbi S. (2010), A review of performance standards to monitor, evaluate and assess the impact of technology transfer offices, *South African Journal of Science*, Vol. 106 No. 7/8, pp.1-9

Gunasekara C. (2006), Reframing the role of universities in the development of regional innovation systems, *Journal of technology transfer*, 31:101-113, 2006

Hameri A. (1996). Technology transfer between Basic research and industry. *Technovation*, 16(2) (1996) 51-57, doi: 0l66-4972(95)00030-5.

Hine D. and J. Kapeleris (2006), *Innovation and Entrepreneurship in Biotechnology, an International Perspective Concepts, Theories and Cases*, Edward Elgar, UK 2006

Innovus (2012), http://www.innovus.co.za/pages/english/technology/technologies-available-for-licensing/sunbio.php, accessed in 2 November 2012

IWBT, http://agri.snowball.co.za/english/research/projects.html, accessed in 2 November 2012

Jafta, R. and Uctu, R. (2009), Exploring University Spin-offs in the South African context: entrepreneurial activity at Cape Town and Stellenbosch Universities, paper presented at the biennial conference of the South African Economic Society Conference, 7-9 September 2009, Port Elizabeth, South Africa, http://www.essa.org.za/download/2009conference/papers2009.htm.

Jafta R. and R. Uctu, (2013), "Exploring University Spin-offs in the South African context: Entrepreneurial activity at Cape Town and Stellenbosch Universities, *Industry and Higher Education*, Vol. 27, No.2, April 2013, pp. 117-128

Kamariah I. , Wan Zaidi O. W. and Izaidin A. M. (2011), The commercialisation process of patents by Universities, *African Journal of Business Management*, Vol. 5 (17), pp. 7198-7208

Klepper S. (1996), *Entry, exit, growth and innovation over the product life cycle*, American Economic Review, 86, 562-583

Konde V, (2012), "Financing know-hows for biotech start-ups in India", http://blogs.nature.com/tradesecrets/2011/04/04/financing-know-hows-for-biotech-start-ups-in-india, accessed 6 November 2012

Kondo, M. (2003), "Chinese Model to Create High-Tech Start-Ups from Universities and Research Institutes", in *Management of Technology: Growth through Business, Innovation and Entrepreneurship*, eds. M. von Zedtwitz, G. Haour, T. Khalil, L. Lefebvre, Oxford: Pergamon Press.

Kondo, M. (2004), University Spin-offs in Japan-From University-Industry Collaboration to University-Industry Crossover, *http://www.business-asia.net/regional/tech_entrepreneurship/Papers_and_articles/TT%20-%20Japan%20-%20University%20Spinoffs,%20by%20MK.pdf*.

Kondo, M. and Hasegawa, K. (2007), "Characteristics of Japan's University Spin-offs by Industry, Region and Founder-type", *Proceedings of Triple Helix VI (CD-ROM)*, pp. 1-15.

Kroll, H. (2009), "Demonstrating the Instrumentality of Motivation Oriented Approaches for The Explanation of Academic Spin-off Formation – An Application Based on the Chinese Case", *International Entrepreneurship Management Journal*, Vol. 5, Issue.1, pp. 97-116.

Kruss, G. (2005), *Working Partnerships in Higher Education, Industry and Innovation Financial or Intellectual Imperatives,* HSRC press: South Africa, 2005.

Kruss, G. (2008), "Knowledge-Intensive University Spin-Off Firms in South Africa: Fragile

Network Alignment?", *Industry and Higher Education*, Vol 22, No 4, August 2008, pp 233–243.

Kruss, G. *et al.* (2009), *Knowledge for Development: University-Firm Interaction in Sub-Saharan Africa, the Case of South Africa*, HSRC press: Cape Town, South Africa.

Kubeczko K., Rametsteiner E. and Weiss G. (2006), the role of sectoral and regional innovation systems in supporting innovations in forestry, *Forest Policy and Economics* 8 (2006) 704–715

Kunert K, J. Vorster, R. Chikwamba and U. Schluter (2008), Biotechnology Entrepreneurship and Education: A South African Experience, Chapter in *Best Practices in Biotechnology Education* edited by Yali Friedman, Logo Press, Washington DC, 2008

Kunert K, Okole B., Vorster B. J., Brewin N. J. and Cullis C. A. (2012), "A general model for training the next generation of biotechnology entrepreneurs based on recent experience of USA-UK-South Africa collaborations", *Journal of Commercial Biotechnology* (2012) Vol. 18, No 3, pp. 63–66

Landry, R., Amara, N. and Rherrad, I. (2005), "the determinants of university spin-offs: evidence from Canadian universities", http://www.triplehelix5.com/pdf/A067_THC5.pdf.

Lee J., and Win H.N. (2004), "Technology transfer between university research centers and industry in Singapore" *Technovation* 24 (2004) 433–442

Lee Y. J. (2010), “Identification of Technology Transfer Options Based on Technological Characteristics”, *Asian Journal of Technology Innovation*, Vol. 18, No. 1, pp. 1-21.

Lenger A. (2008), Regional Innovation Systems and the Role of State: Institutional Design and State Universities in Turkey, *European Planning Studies*, vol. 16, no. 8, 1101-1120

Leung, M. and Mathews, J. A. (2006), “Origins and Dynamics of University Spin-Off Enterprises in Hong Kong”, *www.cherry.gatech.edu/t2s2006/papers/leung-2015-T.pdf*.

Lindgren, A. (2008), “Working Together is Success”, *European Life Science Journal*, No. 1, pp. 80-82.

Littlehales C. (2006), “missing: entrepreneurial women in biotech”, http://www.nature.com/bioent/bioenews/012006/full/bioent901.html

Liu X. and White S. (2001), Comparing innovation systems: a framework and application to China’s transitional context, *Research Policy* 30 (2001) 1091–1114

Liu X. (2009), National innovation systems in developing countries: the Chinese national innovation systems in transition, in. Lundvall, B-Å., Joseph K. J., Chaminade C. and Vang J. (Ed.), **Handbook of Innovation Systems and Developing Countries**, Edward Elgar: UK

Locket A., Wright M. and Franklin S. (2003), Technology transfer and Universities’ Spin-out Strategies, *Small Business Economics*, Volume 20, Issue: 2: 185-200

Longhi, C. and Keeble, D. (2000), “High-Technology Clusters and Evolutionary Trends in the 1990s”, in *High-Technology Clusters, Networking and Collective Learning in Europe*, eds. D. Keeble and F. Wilkinson, Hampshire: Ashgate.

Louet, S. (2006) ‘Rainbow biotech- South Africa’s emerging sector’ *Nature Biotechnology*, Volume 24, number 11, pp 1313-1316.

Lundvall, B. (1992), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter: London.

Lundvall B-Å. (2007), National Innovation System: Analytical Focusing Device and Policy Learning Tool, Working paper R2007:004, Swedish Institute for Growth Policy Studies

Lundvall et al. (2009), Innovation system research and developing countries, in. Lundvall, B-Å., Joseph K. J., Chaminade C. and Vang J. (Ed.), **Handbook of Innovation Systems and Developing Countries**, Edward Elgar: UK

Malazgirt A. (2011), “Case Studies of Successful Commercialization of Biotechnology in Daedeok Valley”, *Asia-Pacific Tech Monitor,* Vol. 28, No. 2, pp. 37-44.

Malerba F. and Orsenigo L. (1996), *Schumpeterian patterns of innovation*, Cambridge, Journal of Economics, v.19. n.1, p.47-65

Markard J. and Truffer B. (2008), Technological innovation systems and the multi-level perspective: Towards an integrated framework, *Research Policy* 37 (2008) 596–615.

Marsh D. (2003), "Does New Zealand have an innovation system for biotechnology?", *Technovation,* 23 103–112

McEnrue, M.P. (2011). "Government policies to Enhance Entrepreneurial Activity among Scientists in Kenya.", Global Entrepreneurship Conference, Washington, D.C., 6-8 October, 2011.

McKelvey, M. (2004), "What about Innovation Collaboration in Biotech Companies? Revisiting Occurrence and Spatial Distribution", Biotech Business Working Paper No. 02 – 2004, Research Centre on Biotech Business, Copenhagen Business School, Denmark.

McQueen, D. H. and Wallmark J. T. (1982), "Spin-off Companies from Chalmers University of Technology", *Technovation* 1 (1982) 305-315.

Meyer, M. (2006), "Academic inventiveness and entrepreneurship: on the importance of start-up companies in commercializing academic patents" *Journal of Technology Transfer,* 31, 501-510.

Meyers A. D. and Hurley P. (2008), "Bio-entrepreneurship Education Programmes in the United States", *Journal of Commercial Biotechnology,* Vol. 14, No. 1, pp. 2-12.

Meyers A. D. (2008), Book reviews (Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences), *Journal of Commercial Biotechnology,* Vol 14. No 4, P 355-356

Moore J. P. *et al.* (2008), "Wine biotechnology in South Africa: Towards a systems approach to wine science", Biotechnology Journal, 3, 1355–1367

Morales-Gualdrón S. T., Gutiérrez-Gracia A. and Dobon S. R. (2009), "The Entrepreneurial Motivation in Academia: A Multidimensional Construct", *http://digital.csic.es/bitstream/10261/17681/1/Silvia%20Morales_%20Entrepreneurial%20Motivation.pdf*.

Muller C, T. Fujiwara and C. Herstatt (2004), Sources of Bioentrepreneurship: The cases of Germany and Japan, *Journal of Small Business Management*, 42 (1), pp. 93-101, 2004

Muller, K. (2010), "Academic Spin-off's Transfer Speed-Analyzing the Time from Leaving University to Venture", *Research Policy*, Vol. 39, Issue. 2, pp. 189-199.

Muscio A. (2006), "From Regional Innovation Systems to Local Innovation Systems: Evidence from Italian Industrial Districts", *European Planning Studies* Vol. 14, No. 6

Mustar P., M Wright and B. Clarysse (2008), University spin-off firms: lessons from ten years of experience in Europe", *Science and Public Policy,* 35(2), March 2008, pp. 67–80

Nel, A. (2009), "From Patent to Market: Setting up an Entrepreneurial University", http://www.wipo.int/edocs/mdocs/pct/en/wipo_pct_nbo_09/wipo_pct_nbo_09_www_121095.pdf.

Nelson, R. R. (Ed.) (1993), *National Innovation Systems: A Comparative Analysis,* (Oxford: Oxford University Press).

Nelson R. and Rosenberg N. (1993), Technical innovation and national system, in: Nelson, R. (Ed.), **National Innovation Systems: a Comparative Analysis**, Oxford University Press: Oxford

Nelsen L. (2007), Evaluating Inventions from Research Institutions. In *Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices* (eds. A Krattiger, RT Mahoney, L Nelsen, et al.). MIHR: Oxford, U.K., and PIPRA: Davis, U.S.A. Available online at www.ipHandbook.org

Nezu, R. (2005), "An Overview of University-Industry Collaborations in Asian Countries toward Effective University-Industry Partnerships toward Effective University-Industry Partnerships", *jp.fujitsu.com/group/fri/downloads/en/economic/20050613WIPO.pdf*.

Ngan, A. (2006), "From Conception to Commercialization – University Technology Transfer Practices in China (including Hong Kong), Japan, Korea and Singapore", *Les Nouvelles,* Vol. XLI, No. 2, pp. 68-71.

Niosi J. (2011), Building innovation systems: an introduction to the special section, *Industrial and Corporate Change*, Volume 20, Number 6, pp. 1637–1643 doi:10.1093/icc/dtr064

Niosi J. and B. Thomas (2001), The Competencies of regions Canada's Clusters in Biotechnology, *Small Business Economics* 17: 31–42, 2001

Niosi J. and T. Bas (2003), "Biotechnology Megacentres: Montreal and Toronto Regional Systems of Innovation", *European Planning Studies* Vol. 11, No. 7

Niosi J. and M. Banik (2005), “The evolution and performance of biotechnology regional systems of innovation”, *Cambridge Journal of Economics*, 29, 343–357

Nosella A., G. Petroni and C. Verbano (2006), “How Do Italian Biotechnology Startups Survive?”, *Journal of Business Chemistry*, vol. 3, issue 2, pp.7-14.

O'Shea, R., Allen, T. J., O'Gorman, C., and Roche, F. (2004). Universities and Technology Transfer: A Review of Academic Entrepreneurship Literature. *The Irish Journal of Management*, 25(2), 11-29.

OShea, R. P., Allen, T. J., Chevalier, A. and Roche, F. (2005), “Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities”, *Research Policy*, 34, 994-1009.

OShea, R. P. (2007), *Determinants and consequences of university spin-off activity: a conceptual framework*, in F. Therin (eds), Handbook of Research on Techno-Entrepreneurship, Cheltenham: Edward Elgar.

Pepper M. (2009), Bioentrepreneurship course, presented at Human Capacity Development for Biotechnology Workshop at Innovation Hub, Pretoria, South Africa, 30 November 2009

Perez, M. P. and Sanchez, A. M. (2003), "The Development of University Spin-offs: Early Dynamics of Technology Transfer and Networking", *Technovation*, Vol. 23, Issue. 10, pp. 823-831.

Phan P. H. and D. Siegel (2006). The Effectiveness of University Technology Transfer. *Entrepreneurship* Vol. 2, No 2 (2006), 77-144, doi: 10.1561/0300000006.

Pietrobelli C. and Rabellotti R. (2009), the global dimension of innovation systems: linking innovation systems and global value chains, in. Lundvall, B-Å., Joseph K. J., Chaminade C. and Vang J. (Ed.), **Handbook of Innovation Systems and Developing Countries**, Edward Elgar: UK

Pirnay, F., Surlemont, B. and Nlemvo, F. (2003), "Toward a Typology of University Spin-offs", *Small Business Economics* 21: 355–369

Poon, P. and Liyange, L. (2004), "Commercialization of Biotechnology in Newly Industrialized Economies", *Int. J. Biotechnology*, Vol. 6, No. 2/3, pp. 243-259.

Poon, P. and Chan, K. S. (2007), "University–Industry Technology Transfer in Hong Kong", *Int. J. Learning and Change*, Vol. 2, No. 1, pp.109–125.

Pouris, A. (2005), "Technological Performance Judged by American Patents Awarded to South African Inventors", *South African Journal of Science,* Vol. 101, No. 5-6, pp. 221 – 224.

Rasmussen, E. (2006), "Spin-Off Venture Creation in a University Context –An Entrepreneurial Process View", http://www.ncsb2006.se/pdf/SpinOff%20Venture%20Creation.pdf.

Rasmussen, E. and Borch, O. J. (2010), "University Capabilities in Facilitating Entrepreneurship: A Longitudinal Study of Spin-off Ventures at Mid-Range Universities", *Research Policy*, Vol. 39, Issue 5, pp. 602-612.

Reichelt, K. M. (2007), "*University Technology Transfer and National Innovation Policy: Success Stories from Brazil, Colombia and South Africa*", http://iipi.org/wp-content/uploads/2010/07/UniversityTechTransfer_072507.pdf

Rippenaar L. (2006), "Activities at Institute for Wine Biotechnology at Stellenbosch University impresse Minister of Science and Technology", *SU Faculty of Agricultural and Forestry Sciences Newsletter,* Issue 27, p.5, March 2006

Roberts, E. B. and Wainer, H. A. (1968), "New enterprise on Rte. 128", *Science Journal,* 4 (12), 78-83.

Rothaermel, F.T., Agung, S.D. and Jiang, L. (2007), "University entrepreneurship: a taxonomy of the literature", *Industrial and Corporate Change, 16,* 691-791.

Rutherford, L. M. and Fulop, L. (2006) "Commercialisation of University-based Biotechnology Research and Internal Performance Issues for Spin-offs", *Int. J. Technology Transfer and Commercialisation,* Vol. 5, Nos.1/2, pp.123–139.

Schoemaker H. J. P. and Schoemaker A. F. (1998), “the Three Pillars of Bio-entrepreneurship”, *Nature Biotechnology*, Vol. 16, pp. 13-15.

Scott C. (2007), “South African economy "thirsty" for biotechnology”, http://www.scienceinafrica.co.za/2007/march/biotech.htm, accessed in 2 November 2012

Seppänen S. K. (2008), Regional Innovation Systems and Regional Competitiveness: An Analysis of Competitiveness Indexes, Paper to be presented at DRUID-DIME Academy Winter 2008 PhD Conference on Geography, Innovation and Industrial Dynamics

Sharif, N. and Baark, E. (2008), “Mobilizing Technology Transfer from University to Industry: The Experience of Hong Kong Universities.” Journal of Technology Management in China, *Vol.* 3, No. 1, pp. 47-65.

Sharif N. (2006), Emergence and development of the National Innovation Systems concept, *Research Policy* 35 (2006) 745–766

Shane, S. (2004), *Academic Entrepreneurship University Spin-offs and Wealth Creation*, USA: Edward Elgar.

Shane S. and Stuart T. (2002), Organisational Endowment and Performance of University Start-up, *Management Science*, Volume 48, Issue 1, pp. 154-170

Sherwin H. (2007), “the challenges of starting up a biotech company in South Africa” chapter in Biotechnology and Health South Africa's aspirations in health-related biotechnology, (eds.) Chataway J. and James W., Van Schaik Publishers, Pretoria, 2007.

Siegel, D.S., Waldman, D.A., Atwater, L.E., and Link, A.N. (2003), "Commercial knowledge transfers from universities to firms: improving the effectiveness of university–industry collaboration", *Journal of High Technology Management Research* 14 (2003) 111–133

Siegel D., D. Waldman and A. Link (2003). Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: an Exploratory Study. *Research Policy*, Volume 32, Issue 1, 27-48.

Siegel D. S., Veugelers R. and Wright M. (2007), "Technology transfer offices and commercialisation of university intellectual property: performance and policy implications", *Oxford Review of Economic Policy*, Volume 23, Number 4, 2007, pp.640–660

Smilor, R. W., Gibson, D. V. and Dietrich, G. B. (1990), "University spin-out companies: Technology start-ups from UT-Austin", *Journal of Business Venturing* 5, 63–76.

Smith, H. L. and Bernardy, M. (2000), "University and Public Research Institute links with Regional High-Technology SMEs", in *High-Technology Clusters, Networking and Collective Learning in Europe,* eds. D. Keeble and F. Wilkinson, Hampshire: Ashgate.

Snyder S., M. Johns, J. J. Mongan and J. R. Utaski (2003) "*Accelerating Technology Transfer and Commercialization in the Life and Health Sciences*" Final Report of the Panel of

Advisors on the Life Sciences, Ewing Marion Kauffman Foundation, 4801 Rockhill Road, Kansas City, Missouri, USA

So AD, Sampat BN, Rai AK, Cook-Deegan R, Reichman JH (2008), Is Bayh-Dole good for developing countries? Lessons from the US experience, *PLoS Biology* 6(10): e262. doi:10.1371/ journal.pbio.0060262

Soete L., Verspagen B. and ter Weel B. (2010), Systems of Innovation, CPB Discussion Paper, No 138 February 2010

Spilling, O. R. (2004), "Commercilisation of Knowledge- A Conceptual Framework", http://www.bi.no/ncsb2004.

Steffensen, M., Rogers E. M., and Speakman, K. (1999), "Spin-offs from Research Centers at a Research University", *Journal of Business Venturing*, 15, 93-111.

Stellenbosch University (2005), "A commercialisation arm for the Institute for Wine Biotechnology", *Faculty of Agricultural and Forestry Sciences Newsletter* Issue 21, p.5, August 2005

SunBio: Embracing Biotechnology in the Wine Industry, http://www.wynboer.co.za/recentarticles/200511biotech.php3, accessed in 1 November 2012

Suurs R. A. A. (2009), Motors of Sustainable Innovation- Towards a theory on the dynamics of technological innovation systems

Thanabalasingam Y. (2012), "Biotechnology Start-Ups in Singapore: Inspiring Future Entrepreneurs",http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2002_03_22/noDOI.8141079393122221611, accessed 2 November 2012

Thursby J. G. and Thursby M. C. (2002), "Who is Selling the Ivory Tower? Sources of Growth in University Licensing", Special Issue on University Entrepreneurship and Technology Transfer (Jan., 2002), *Management Science*, Vol. 48, No. 1, pp. 90-104

Todt O, E. Munoz, J.E. Monteros and V. M. Diaz (2004), "Biotechnology Development in Spain: A Change of Paradigm?", *Technology Analysis and Strategic Management,* Vol. 16, No. 3, 415–429

Trippl M. and F. Todtling (2007), Developing Biotechnology Clusters in Non-high Technology Regions—the Case of Austria, *Industry and Innovation*, Vol. 14, No. 1, pp.47–67

Tsui-Auch, L. S. (2000), "Functional versus Sectoral Industrial Policy: A Comparative Study of the Biotechnology Development in Hong Kong and Singapore", *http://www3.ntu.edu.sg/nbs/sabre/working_papers/05-99.pdf*.

Innovation at UCT 2010, *UCT Annual Report* (2010), UCT: Cape Town

Uctu, R. and R. Jafta (2012), "Academic entrepreneurship in South East Asia: An Exploratory Study of Spin-offs in Biotechnology from Hong Kong Universities", *Asian Journal of Technology Innovation*, Vol. 20, No. 1, June 2012, 141–154.

Uctu, R. and R. Jafta (2013), "Bio-entrepreneurship as bridge between science and business in a regional cluster: South Africa's first attempts", *Science and Public Policy*, July 2013, doi:10.1093/scipol/sct049, pp. 1-15.

Valentin, F. and Jensen, R. L. (2006), "Effects on Academia – Industry Collaboration of Extending University Property Rights", *http://openarchive.cbs.dk/bitstream/handle/10398/6771/wp01-2005.pdf?sequence=1*.

Van Geenhuizen, M. and Soetanto, D. P. (2009), "Academic spin-offs at different ages: A case study in search of key obstacles to growth", *Technovation* 29, pp. 671-681.

Vendrell-Herrero F. (2008), Transfer of knowledge from the lab to the market: the idiosyncrasy of academic entrepreneurs, published doctoral thesis, Economics Department, Universitat Autonoma de Barcelona

Volery *et al.* (2007), "Management competencies in the biotech industry in Switzerland", paper presented at the 37th EISB Conference, 13-14 September 2007, accessed 5 August 2011

Waltz E. (2005), Biotech entrepreneur, educate thyself!, http://www.nature.com/bioent/bioenews/122005/pf/bioent896_pf.html accessed at 14/12/2008

Weatherston, J. (1995), “Academic Entrepreneurs: Is A Spin-off Company too Risky?” http://www.sbaer.uca.edu/research/icsb/1995/pdf/20.pdf.

Williams, E. and Majewsky, I. (2002), “Academic Spin-off Companies: Myths and Pitfalls”, http://www.inoverzum.eu/files/Tomaz_Cerne/myths-and-pitfalls.pdf.

Wolson R. (2007). The role of technology transfer offices in building the South African biotechnology sector: an assessment of policies practices and impact. *Journal of Technology Transfer* (2007) 32:343–365

Yin R. K. (2003) Case study research: Design and methods, 3rd edition, London, SAGE Publications

York A., K. McCarthy and T. Darnold (2009), From the Classroom Teaming in biotechnology commercialization: The diversity-performance connection and how university programmes can make a difference, *Journal of Commercial Biotechnology*, Vol 15. No 1, P 3- 11

Young T. A. (2005). Academic Technology Transfer, *International Journal of Intellectual Property Law, Economy and Management* 1 (2005) 13-18

Zhang, J. (2009), “The Performance of University Spin-offs: An Exploratory Analysis Using Venture Capital Data”, *Journal of Technology Transfer*, Vol. 34, No. 3, pp. 255–285.

Zhu D. and J. Tann (2005), “A Regional Innovation System in a Small-sized Region: A

Clustering Model in Zhongguancun Science Park”, *Technology Analysis and Strategic Management*, Vol. 17, No. 3, 375–390

Zuniga M. P. and Guellec D. (2009), “Who Licenses Out Patents and Why? Lessons from a Business Survey”, http://www.oecd.org/sti/working-papers

Internet Sources:

www.innovus.co.za

www.dti.gov.za

www.sarimaconference.co.za

www.sun.ac.za

www.tektique.co.za

www.uct.ac.za

http://www.capegateway.gov.za/eng/directories/services/11442/10425

http://www.blueprintbiotechlab.co.za/b2b-capebiotech.php

http://www.fdimagazine.com/news/fullstory.php/aid/688/Cape_Biotech:Boosting_biotechnologyinnovation.html

www.capebitech.co.za

http://scarlacc.up.ac.za/ceatup/Courses/CourseDetail.aspx?dcxCourseID=1679

http://www.rishibiotech.com/bioentrepreneurship

http://www.accessmylibrary.com/article-1G1-227120637/biotech-venture-partners-pty.html,

http://www.fao.org/docrep/012/i1704e/i1704e03.pdf,

http://www.biotechweblog.com/50226711/cape_carotene_to_produce_astaxanthin_from_algae.php

APPENDIX

Appendix A: Questionnaire for Technology Transfer Offices at Hong Kong Universities

RESEARCH SURVEY: UNIVERSITY SPIN-OFF COMPANIES IN HONG KONG

The aim of this study is to analyse the biotechnology university spin-off companies in Hong Kong. These questions are sent to Technology Transfer Offices at the Chinese University of Hong Kong, Hong Kong Polytechnic University, University of Hong Kong, Hong Kong University of Science and Technology and City University of Hong Kong. All information gathered by this survey will be held in the confidential.

PLEASE MARK APPROPRIATE FIELDS WITH AN "X"

LEAVE ALL NON APPLICABLE FIELDS BLANK

PART A

Technology Transfer Office Particulars

A1 University name:

CUHK		PolyU		HKU		HKUST		CityU	

A2 Official TTO name: ______________________________

A3 Year of TTO's foundation: ______________________________

A4 Date of filling in: ______________________________

A5 Director: ______________________________

A6 Contact person(s): ______________________________

A7 Address: ______________________________

____

____

A8 Telephone/Fax: ____

A9 Website: ____

A10 Email: ____

A11 How many staff works in TTO? ____

A12 How many of them are full time staffs? _____________________________________

Department				
No of staff				

A13 How many of them are part time staffs? ____________________________________

Department				
No of staff				

PART B

Spin-Off History

B1 Are there any spin-off companies/ joint ventures in your university?

Yes	
No	

If YES continue, if NO please go to **QB4**

B2 How many spin-offs/joint ventures (JV) are in the following sectors?

	Spin-off	JV
• Biotechnology		
• Chinese Medicines		
• Information and Technology & Telecommunications		
• Precision Engineering		
• Electronics		
• Nanotechnology		
• Green Technology		

• Professional Services		
• Others Please specify………………………………		
TOTAL:		

If there are biotechnology spin-off companies/ joint ventures, please continue. Otherwise, please go to **QB4**

B3 Biotechnology spin-off companies/ joint ventures details:

Name of the company	
Nature of the company	
Contact person (s)	
Tel	
Email	
Web page	
Address	

Name of the company	
Nature of the company	
Contact person (s)	
Tel	
Email	
Web page	
Address	

Name of the company	

Name of the company	
Nature of the company	
Contact person (s)	
Tel	
Email	
Web page	
Address	

B4 What is your TTO's object?

____

____

____

B5 To what extent do you think your office achieved the objectives?

____

____

____

Thank you for your participation!

Appendix B: Biotechnology Spinoffs Questionnaire for Hong Kong Universities

RESEARCH SURVEY: BIOTECHNOLOGY SPIN-OFF COMPANIES

The aim of this study is to analyse the biotechnology university spin-off companies in Hong Kong. These questions are sent to the companies that spun off from the Universities in Hong Kong. All information gathered by this survey will be held confidential.

PLEASE MARK APPROPRIATE FIELDS WITH AN "X"

LEAVE ALL NON APPLICABLE FIELDS BLANK

Date: ________________

Fill in by: _________________

<u>PART A</u>

Company Particulars

A1 Spun-off from:

CUHK		PolyU		HKU		HKUST		CityU	

A2 Official company name:

A3 Year of Start-up:

A4 Year of foundation:

A5 Director:

A6 Address:

A7 Telephone/Fax:

A8 Email:

A9 Website:

A10 Company's turnover (million HK$ in 2008):

<3	
4-10	
11-50	
51-100	
101-300	
301-500	
>501	

A11 Company's classification by type of activity:

Manufacturing-type Company	
Service-type Company	
Consultancy-type Company	
Research-type Company	

A12 Which sector does the company belong to?

Product-development Company	

Biotechnology	
Chinese Medicine	
Information Technology & Telecommunications	
Precision Engineering	
Electronics	
Nanotechnology	
Green Technology	
Professional Services	
Others Please specify____________________________	

A13 What is the nature of company's business?

- ____

PART B

Company's History

B1 Number of Founder(s):

a. 1
b. 2-3
c. 4-5
d. 6-10
e. >10

B2 Founder(s)' original affiliation (fill in number):

a. University	
b. Government research centre	
c. University and Government research centre	
d. University and industry	
e. Government research centre and Industry	
f. Industry	

B3 Where is the company's market at start-up? (You can choose more than one region)

a. Hong Kong
b. China
c. South East Asia
d. Other(s)
Please specify: ________________________

B4 How important are the following motivations at start-up?

1: Not important **2:** Slightly important **3**: Neutral **4:** Important **5:** Most important

	1	2	3	4	5
Identification of market opportunities					
Complete the projects					
Apply knowledge into practical applications					
Profit making					
Fully utilise existing knowledge					
Aversion for bureaucracy and low risk orientation of the research environment					
Personal success					
To be independent					
Other factors					

Current Situation

C1 Where is the company's current market ? (You can choose more then one region)

a. Hong Kong
b. China
c. South East Asia
d. Others (Please specify)

Current number of
C2 Senior scientists:
C3 Post-doctoral assistants:
C4 Research students (masters/PhD students):

C5 Technicians: | |
C6 Administrative personnel: | |
C7 Marketing and sales' staff: | |
C8 Total staff: | |

C9 Major areas of research in which the company is actively involved:

a. ____

b. ____

c. ____

C10 Publications of the company in international peer-reviewed journals (last 5 years):

1. Article Title ____

Journal ______________________ Year ________ Volume ___ Number _______

2. Article Title ____

Journal ______________________ Year ________ Volume ___ Number _______

3. Article Title ____

Journal ______________________ Year ________ Volume ___ Number _______

4. Article Title ____

Journal ______________________ Year ________ Volume ___ Number _______

C11 Commercial products and services developed by the company:

1. ____

2. ____

3. ____

C12 Does the company collaborate with government organisation(s)?

YES		NO	

If yes, which government organisation?

1. ____

2. ____

3. ____

C13 Does the company collaborate with research group(s) at universities and/or research institute(s)?

YES		NO	

If yes, which research group(s)/ research institute(s)?

1. ____

2. ____

3. ____

Where is/are this research group(s)/ research institute(s) located?

	Locally	China	SEA	Other part of the world
Universities Research groups				
Research institutes				

C14 Does the company collaborate with other spin-off companies?

YES		NO	

If yes, please provide the company's names:

1. ____

2. ____

3. ____

C15 Total annual Research & Development (R&D) budget of the company (thousand HK$):

a.	<150	☐
b.	151-300	☐
c.	301-500	☐
d.	501-1000	☐
e.	1001-5000	☐
f.	>5000	☐

C16 Sources of funds for start-up (please specify sources and percentage of the total capital of the company at start up):

Category	Source	Percentage of total capital at start-up
Personal resources (include friends and relatives)		
Governments		
Bank Loans		
Venture Capital		
International research foundations		
Competitive grants		
Other(s) Please specify; ______________________		

C17a Does the company own any patent or licence?

YES		NO	

Detail(s) ____

(Worldwide ____________________or local ______________________________)

C17b Does the company use any patent or licence?

YES		NO	

Detail(s) ____

(Worldwide ____________________or local ______________________________)

C18 What are the main driving forces behind the company?

____

____

____

C19 How important are the following obstacles that hinder the company's growth?

1: Not important **2:** Slightly important **3:** Neutral **4:** Important **5:** Most important

	1	2	3	4	5
Funding					
Commercialisation					
Estimation of the market demand					
Distribution					
Technical problems in development and production					
Problems in the management of human resources					
Problems among owners					
Contractual problems					
Relationships with the parent university					
Problems related with the position played in the parent university					
Patenting					
Regulatory Compliance					
Others factor(s) Please specify; ______________________________					

C20 Which definition fits in the company?

(a) The core technology and the founder(s) came from the parent university, and the founder(s) continue to work for the parent university.

(b) The core technology of the company created in the parent university, while the founder(s) employed by or was/were research student(s) at the parent university.

(c) The core technology of the company originated in the parent university, but the founder(s) was/were not from the parent university.

(d) The core technology did not originate from the parent university, but the founder(s) was/were an employee of the parent university

(e) The core technology did not originate from the parent university, nor the founder(s) employed by the parent university, but the spin- off company used certain resources from the parent university.

(f) The spin-off company was created by the parent university (wholly university-owned spin-off company).

(g) Others
Please specify: ____ ☐

Thank you for your support and cooperation!

Please write a contact person for the further question(s);
Contact person:
Email:
Phone number:

Appendix C: Spinoffs Questionnaire for South African Universities

RESEARCH SURVEY: UNIVERSITY SPIN-OFF COMPANIES

The aim of this study is to analyse university spin-off companies in South Africa, particularly in the Western Cape. These questions are sent to the companies that spun off from the University of Cape Town and Stellenbosch University. All information gathered by this survey will be used for academic research only.

PLEASE MARK APPROPRIATE FIELDS WITH AN "X"

LEAVE ALL NON APPLICABLE FIELDS BLANK

Date: _______________

Fill in by: ________________

PART A

Company Particulars

A1 Spun-off from:

UCT		SUN	

A2 Official company name:

A3 Year of Start-up:

A4 Year of foundation:

A5 Director:

A6 Address:

A7 Telephone/Fax:

A8 Email:

A9 Website:

A10 Company’s turnover (million Rand in 2008):

<3	
4-10	
11-50	
51-100	
101-300	
301-500	
>501	

A11 Company’s classification by type of activity:

Manufacturing-type Company	
Service-type Company	
Consultancy-type Company	
Research-type Company	
Product-development Company	

A12 Which sector does the company belong to?

Biotechnology	
Information Technology & Telecommunications	
Precision Engineering	
Electronics	
Nanotechnology	
Green Technology	
Professional Services	
Others Please specify____________________________	

A13 What is the nature of company's business?

____

PART B

Company's History

B4 Number of Founder(s):

a. 1

b. 2-3

c. 4-5

d. 6-10

e. >10

[ ]

B5 Founder(s)' original affiliation (fill in number):

a. University [ ]

b. Government research centre [ ]

c. University and Government research centre [ ]

d. University and industry [ ]

e. Government research centre and Industry [ ]

f. Industry [ ]

B6 Where is the company's market at start-up? (You can choose more than one region)

a. Provincial

b. National

c. Other(s)

Please specify: ___________________________

B4 How important are the following motivations at start-up?

1: Not important **2:** Slightly important **3**: Neutral **4:** Important **5:** Most important

	1	2	3	4	5
Identification of market opportunities					
Complete the projects					
Apply knowledge into practical applications					
Profit making					
Fully utilise existing knowledge					
Aversion for bureaucracy and low risk orientation of the research environment					
Personal success					
To be independent					
Other factors					

<u>Current Situation</u>

C1 Where is the company's current market? (You can choose more then one region)

a. Provincial

b. National

d. Others

Please specify: ___________________________

Current number of

C2 Senior scientists:

C3 Post-doctoral assistants:

C4 Research students (masters/PhD students):

C5 Technicians:

C6 Administrative personnel:

C7 Marketing and sales' staff:

C8 Total staff: [ ]

C9 Major areas of research in which the company is actively involved:

a. ____

b. ____

c. ____

C10 Publications of the company in international peer-reviewed journals (last 5 years):

5. Article Title ____

Journal ________________________ Year ________ Volume ___ Number _______

6. Article Title ____

Journal ________________________ Year ________ Volume ___ Number _______

7. Article Title ____

Journal ________________________ Year ________ Volume ___ Number _______

8. Article Title ____

Journal ________________________ Year ________ Volume ___ Number _______

C11 Commercial products and services developed by the company:

1. ____

2. ____

3. ____

C12 Does the company collaborate with government organisation(s)?

YES		NO	

If yes, which government organisation?

1. ______________________________

2. ______________________________

3. ______________________________

C13 Does the company collaborate with research group(s) at universities and/or research institute(s)?

YES		NO	

If yes, which research group(s)/ research institute(s)?

1. ______________________________

2. ______________________________

3. ______________________________

Where is/are this research group(s)/ research institute(s) located?

	Locally	Other parts of South Africa	Other part of the world
Universities Research groups			
Research institutes			

C14 Does the company collaborate with other spin-off companies?

YES		NO	

If yes, please provide the company's names:

1. ______________________________

2. ______________________________

3. ____

C15 Total annual Research & Development (R&D) budget of the company (thousand Rand):

A. <50	
B. 50-150	
C. 151-300	
D. 301-500	
E. 501-1000	
F. >1000	

C16 Sources of funds for start-up (please specify sources and percentage of the total capital of the company at start up):

Category	Source	Percentage of total capital at start-up
Personal resources (include friends and relatives)		
Governments		
Bank Loans		
Venture Capital		
International research foundations		
Competitive grants		
Other(s) Please specify; _________________________		

C17a Does the company own any patent or licence?

YES		NO	

Detail(s) ____

(Worldwide _____________________or local _________________________________)

C17b Does the company use any patent or licence?

YES		NO	

Detail(s) ____

(Worldwide ____________________ or local ________________________________)

C18 What are the main driving forces behind the company?

____

____

____

C19 How important are the following obstacles that hinder the company's growth?

1: Not important **2:** Slightly important **3:** Neutral **4:** Important **5:** Most important

	1	2	3	4	5
Funding					
Commercialisation					
Estimation of the market demand					
Distribution					
Technical problems in development and production					
Problems in the management of human resources					
Problems among owners					
Contractual problems					
Relationships with the parent university					
Problems related with the position played in the parent university					
Patenting					
Regulatory Compliance					
Others factor(s) Please specify; ____					

C20 Which definition fits in the company?

(h) The core technology and the founder(s) came from the parent university, and the founder(s) continue to work for the parent university.

(i) The core technology of the company created in the parent university, while the founder(s) employed by or was/were research student(s) at the parent university.

(j) The core technology of the company originated in the parent university, but the founder(s) was/were not from the parent university.

(k) The core technology did not originate from the parent university, but the founder(s) was/were an employee of the parent university

(l) The core technology did not originate from the parent university, nor the founder(s) employed by the parent university, but the spin- off company used certain resources from the parent university.

(m) The spin-off company was created by the parent university (wholly university-owned spin-off company).

(n) Others ☐

Please specify: ____

Thank you for your support and cooperation!

Please write a contact person for the further question(s);
Contact person:
Email:
Phone number:

Appendix D: Interview Questions for Bio-entrepreneurs

RESEARCH SURVEY: BIO-ENTREPRENEURSHIP IN WESTERN CAPE

Date: ________________

Interviewed with: ________________

Statement of purpose

The purpose of this study is to investigate the bio-entrepreneurship program and its impact on the growth of the biotechnology industry. Specifically, how it addresses the need to foster an entrepreneurial spirit and expertise in the biotechnology industry in the Western Cape.

Before I start this tape, for the record, I would like to ask. Do I have your permission to tape this interview?

I assure you that this interview is confidential and that the information gathered will be used for research purposes only.

You can stop this interview at any time should you wish to do so.

Background to case and general impression

To begin with, can you tell me about the general details concerning your background and your involvement in the biotechnology industry?

PERSONAL:

Age:

Gender:

Degree obtained:

Current position:

INTERVIEW QUESTIONS:

1. What do you think about the South African biotechnology prospects in global competition?

2. What are the strengths and weaknesses of the Western Cape's biotechnology industry?

3. How do you define a bio-entrepreneur?

4. You were the one of the graduates from the bio-entrepreneurship program. What were your expectations about the programme before enrol and what did you expect to be able to do after complete the programme?
5. Why did you choose to enrol for the bio-entrepreneurship program? Why not an MBA, for example?
6. What are the strong and weak points of the program?
7. How beneficial was it for you?
8. Do you use the skills and knowledge gained from the programme in your work?
9. Will you suggest it to other entrepreneurs?
10. Anything that you like to add about South African biotech of bio-entrepreneurship program;

Thank you for your support and cooperation!

Please write a contact person for the further question(s);
Contact person:
Email:
Phone number:

Appendix E: Interview Questions for Bio-entrepreneurship Program Director

RESEARCH INTERVIEW: BIO-ENTREPRENEURSHIP IN WESTERN CAPE

Date: ________________

Interviewed with: _________________

Statement of purpose

The purpose of this study is to investigate the bio-entrepreneurship program and its impact on the growth of biotechnology industry. Specifically, how it addresses the need to foster an entrepreneurial spirit and expertise in the biotechnology industry in the Western Cape.

Before I start this tape, for the record, I would like to ask. Do I have your permission to tape this interview?

I assure you that this interview is confidential and that the information gathered will be used for research purposes only.

You can stop this interview at any time should you wish to do so.

Background to case and general impression

To begin with, can you tell me about the general details concerning your background and your involvement in the biotechnology industry?

Interview questions

1- What do you think about the South African biotechnology industry prospects in global competition?

2- What is bio-entrepreneurship? How do you define it?

3- How do you see the "bio-entrepreneurship" progress in South Africa and particularly in Western Cape?

1: Not important **2:** Slightly important **3**: Neutral **4:** Important **5:** Most important

	1	2	3	4	5

4- In 2005, there was an initiative to offer a collaborative bio-entrepreneurship programme with a British Company, which was supposed to initiate in 2007. This did not go well, l believe. What were the lessons you learned?

5- What did the bio-entrepreneurship program in 2008 entail? Can you give brief information about the program?

6- What modules have been taught in the program?

7- How did you establish the program? Have you benchmarked against international programs (Done this with national or regional biotech objectives in mind)?

8- How many staff members have you had for teaching at the program? Who were the staff members' origins/backgrounds?

9- How did you select the students for the program?

10- Do you keep track of the graduates? Collaborations with them?

11- Measured against objectives and outcomes

- How did the program do?
- Changes? What were they?

12- Plans to start new one?

Thank you for your support and cooperation!

Please write a contact person for the further question(s);
Contact person:
Email:
Phone number:

Appendix F: South African Universities' licensing survey

<u>RESEARCH SURVEY: UNIVERSITY LICENSING OF TECHNOLOGIES VERSUS SPIN-OFFS</u>

The researchers are conducting a project which is entitled "Delineating the concept of university spin-off companies in the South African context: an exploratory study of spin-offs at the Universities of Cape Town and Stellenbosch" and garnered information about the history and innovative status of spin-off companies in the Western Cape in order to understand the nature of this phenomenon in South Africa. During the research an interesting question arose: why would academics that are in a position to create a spin-off, choose NOT do so? Hence the focus of this questionnaire is to explore this question with a set of academics at Western Cape universities. These questions are sent to the principle researchers who have licensed technologies while at the Western Cape Universities. All information gathered by this survey will be used for academic research only.

PLEASE MARK APPROPRIATE FIELDS WITH AN "X"

LEAVE ALL NON APPLICABLE FIELDS BLANK

Date: _______________

Fill in by: ________________

<u>PART A</u>

A1 Licensing at:

UCT		SUN		UWC		CPUT	

A2 Title of the technology:

A3 Number of Researcher (s):

a. 1

b. 2-3

c. 4-5

d. 6-10

e. >10

A4 Principle researchers (please identify with the title):

1	
2	
3	
4	
5	
6	
7	

A5 Which sector does the technology belong to?

Biotechnology	
Information Technology & Telecommunications	
Precision Engineering	
Electronics	
Nanotechnology	
Green Technology	
Professional Services	
Others Please specify______________________________	

A6 Which faculty does/do the researcher(s) come(s) from? (Please specify the department (s))

Faculty of Agri-Sciences Department of______________________________________	
Faculty of Engineering Department of______________________________________	
Faculty of Science: Department of______________________________________	
Faculty of Health Sciences: Department of______________________________________	

A7 Is a patent linked to the technology?

YES		NO	

Detail(s) ____

(Worldwide ______________________or local ___________________________________)

A8 How important are the following motivations for licensing your technology?

1: Not important **2:** Slightly important **3**: Neutral **4:** Important **5:** Most important

Motivations	1	2	3	4	5
It is a niche technology					
The technology is near market and requires little further development and investment					
A company is linked with the research either as a sponsor or interested observer					
The technology fits an existing company's IP/product portfolio					
Licensing is a common strategy within the industry sector					
Building an industrial network					
Fully utilize existing knowledge					

Final step to complete existing project(s)					
Profit making					
Personal success					
Apply knowledge into practical applications					
Others factor(s) Please specify; ____					

A9 How important are the following obstacles in reaping the benefits when the technology is licensed?

1: Not important **2:** Slightly important **3:** Neutral **4:** Important **5:** Most important

Obstacles	1	2	3	4	5
Further investment is required in the technology and associated infrastructure in order to reach the market					
Estimation of the market demand					
Distribution of revenue streams					
Relationships with the parent organisation(s)					
Ownership and/or rights to develop technology					
Regulatory compliance					
Protection of the technology (e.g. patenting)					
The formation of partnerships					
Others factor(s) Please specify; ____					

A10 How important are the following factors in your decision NOT to create a spin-off company?

1: Not important **2:** Slightly important **3:** Neutral **4:** Important **5:** Most important

Factors	1	2	3	4	5
Leaving the academic position					
Funding					
Commercialisation					
Estimation of the market demand					
Distribution (product and/or services)					

Technical problems in development and production					
Problems in human resources					
Problems among owner(s) of the technology					
Relationships with the parent university					
Regulatory compliance					
Family commitment(s)					
Others factor(s) Please specify; ____					

Thank you for your support and cooperation!

Please write a contact person for further question(s) or feedback of results;
Contact person:
Email:
Phone number: