SOUTH AFRICA'S STRATEGY FOR DEVELOPING ITS BIOTECHNOLOGY INDUSTRY BY ESTABLISHING BIOTECHNOLOGY REGIONAL INNOVATION CENTRES (BRICs)

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Abstract

South Africa has failed to develop a viable Biotechnology industry despite strong life sciences facilities and academic training. Government has pursued various strategies for developing this industry since 1982 however none have succeeded. The most recent strategy entails the establishment of four Biotechnology Regional Innovation Centres (BRICs).

Competitiveness at a nation level is arguably best described using Porter's Diamond of National Competitiveness model which provides a framework for analysing an industry cluster. The South African National Biotechnology Strategy has been designed to stimulate cluster formation with the BRIC at the core. In order to assess the success of the BRIC strategy it is necessary to establish a baseline analysis of the biotechnology sector. To do this an analysis was performed by means of a quantitative email survey which assessed the South African biotechnology sector in terms of the four attributes of the Diamond model.

The analysis presented here found that the South African biotechnology industry is deficient in all four attributes of the Diamond model. Positives do exist and can be leveraged to attempt to address the deficiencies. The most notable deficiencies identified were a skills shortage, poor access to funding and a poor understanding of the fundamentals of biotechnology. The establishment of a dedicated Biotechnology Park was found to be of interest to stakeholders.

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Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Masters of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University.

RAYMOND DONNINGER **DATE**

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Contents

Table of Tables

Table of Figures

CHAPTER 1: DEFINITION OF THE PROBLEM

1.1. INTRODUCTION

The globalizing world is witnessing increased health, poverty and knowledge gaps between developed countries and developing countries (Persaud, 2001 and Sachs, 2005). Biotechnology has the potential to address health and development issues in the developing world (Singer and Daar, 2001). Marshall (2004) quotes the United Nations Development Program as saying "Biotechnology innovation and globalization is a means of helping the poor of the world live fuller, richer and more secure lives". This makes the biotechnology industry a very important industry for the growth of South Africa's modern economy.

This chapter provides an overview of the Biotechnology industry in South Africa and addresses the motivation for the research.

1.2. BACKGROUND

1.2.1. INTRODUCTION TO BIOTECHNOLOGY

The term "Biotechnology" needs to be defined in order to ensure that what is being analysed is standardised. The South African National Biotechnology Strategy (2001 p7) defines biotechnology as "a set of technologies including, but not confined to, tissue culture and recombinant DNA techniques, bioinformatics and genomics, proteomics and structural biology, and all other techniques employed for the genetic modification of living organisms, used to exploit and modify living organisms so as to produce new intellectual property, tools, goods, products and services". From this definition it is clear that biotechnology is the commercialisation of products that are made or modified by living organisms. Biotechnology is not the only the science or research that leads to the product but most importantly is the application of the science for commercial gain.

Biotechnology is not a new industry. Biotechnology is usually divided into three broad groups. First generation biotechnology refers to the use of natural (wild-type) organisms in the production of a product. Beer-brewing is an example of first generation biotechnology where naturally occurring yeast strains are used in the fermentation of the product. Second generation biotechnology refers to the use of specially selected or bred strains of an organism or cell which are used in the production of a product. These strains are selected over time for a specific quality and no foreign genetic material is inserted or introduced into the organisms. This is a more advanced form of biotechnology than first generation biotechnology. Third generation biotechnology is relatively new and also the most advanced form of biotechnology. Third generation biotechnology involves the altering of the genetic make-up of a cell or organism by artificial means in order to introduce a quality that would not normally be present in the naturally occurring organism or cell (South African National Biotechnology Strategy, 2001; Mulder, 2003). Modern biotechnology (3rd generation) is relatively new, starting with the advent of modern molecular biology in the early 1970's (Murphy and Perrella, 1993).

The modern biotechnology industry turns 30 years old in 2006. In the early 1970's scientific breakthroughs in molecular biology allowed scientists to delve into the genetic material at the core of living cells (Deoxyribose Nucleic Acid - DNA) and identify and extract specific genes. These genes could then be transferred to a new host cell and translated into proteins that would not normally be expressed in the host cell. This technology heralded the beginning of modern biotechnology allowing proteins to be expressed across species and in commercially viable quantities (Ernst & Young, 2006).

The modern biotechnology industry today employs over 200,000 people globally and is dominated by the "developed' world countries. The majority of the innovation, funding and consumption occur in the world's rich nations (Marshall, 2004).

1.2.2. THE GLOBAL BIOTECHNOLOGY INDUSTRY AT A GLANCE

In 2005 the global biotechnology industry's publicly traded companies generated revenues of US$ 63.2 billion, an increase of 18% over 2004. The United States of America accounted for 75% of this total (Ernst and Young, 2006).

It is interesting to note that this 18% increase from 2004 in sales was generated with only a 4% increase in Research and Development costs to US$ 20.4 billion. In 2005 the biotechnology sector globally raised US$ 19.7 billion in funding (Ernst and Young, 2006).

Most significant, however, is that for the first time in 2003 and continuing to 2005, the biotechnology industry generated more new drug approvals by the Food and Drug Administration of the United States than did big pharma (Ernst and Young, 2006).

1.2.3. THE IMPORTANCE OF BIOTECHNOLOGY FOR THE DEVELOPING WORLD

Biotechnology has the potential to address health and development issues in the developing world (Singer and Daar, 2001). Thorsteinsdóttir, Martin, Daar and Singer (2004a) state: "Nowhere is the need for science and technology as a tool for development more relevant than in addressing the health needs of the world's poor". Thorsteinsdóttir *et al* go further in suggesting: "It is now becoming clear that biotechnology solutions for health problems in developing countries are both appropriate and feasible".

Human Immunodeficiency Virus (HIV)/Acquired Immunodeficiency Syndrome (AIDS) is one example of a health crisis in Southern Africa with an estimated 5.5 million people infected in South Africa alone (UNAIDS, 2006). South Africa is utilizing biotechnology in the fight against this disease with the establishment of the South African AIDS Vaccine Initiative (SAAVI). This is one example of the important role that health biotechnology can play in South Africa.

The World Health Organisation (WHO) lists Tuberculosis, HIV/AIDS and Malaria as the "Big Three" infectious diseases. These three diseases are particularly relevant to Africa and South Africa in particular. Developed countries have relatively low incidences of these diseases and as such there is relatively little motivation for large pharmaceutical or biotechnology companies to commit resources to developing treatments for these diseases. To illustrate this point Médecins Sans Frontières (2001) have estimated that from 1975 to 1999 only 15 new drugs to treat tropical diseases were developed compared to 179 new drugs to treat heart disease in the same period.

International efforts mainly involving private-public partnerships are being established to address these diseases in the developing world. Examples of these partnerships include the International AIDS Vaccine Initiative, Medicine for Malaria Venture and Global Alliance for TB Drug Development (Thorsteinsdóttir *et al*, 2004a). These initiatives have made a significant amount of capital available to both research and commercialisation of novel treatments for these diseases.

Another reason why biotechnology is important for the developing world lies in economics. Thorsteinsdóttir *et al* (2004a) argue that organisations in developing countries are likely to be able to develop treatments at a lower cost than those in developed countries because many of the factors of production are cheaper in the developing world. This is critical in populations that have very limited purchasing power. They go further in arguing that the so-called "diseases of poverty" could be viewed as market opportunities for firms in developing countries and a way to gain a foothold on competitiveness.

The Healthcare sector is not the only reason why biotechnology is important to the developing world. As developing countries move from a resourced-based economy to a knowledge-based economy biotechnology become more critical. The biotechnology industry has application in major sectors of an economy including agriculture, healthcare, industrial processing, mining and environmental sectors (Mulder, 2003). How would a developing country go about encouraging entrepreneurs to engage in developing the biotechnology industry within their country?

1.2.4. BIOTECHNOLOGY IN SOUTH AFRICA

The South African government has identified the important role biotechnology can play in improving the health and welfare of the people of South and Southern Africa and have developed a strategy for the development of the biotechnology industry in South Africa (South African National Biotechnology Strategy, 2001).

The most comprehensive survey of biotechnology activity in South Africa took place in 2003, The National Biotechnology Survey (Mulder, 2003). One hundred and six companies were identified as participating in biotechnology activities (47 core and 59 non-core). Mulder (2003) defines core biotechnology companies as those whose business is substantially or entirely biotechnology related. Non-core biotechnology companies are those that do not have biotechnology as their core focus but utilise biotechnology in some aspects of their business, or participate in biotechnology research and development. The survey also focussed on modern biotechnology companies thereby excluding the larger brewing, food and beverage and wine companies.

The 2003 National Biotechnology Survey showed that the majority of core biotechnology companies are located in Gauteng (41%) followed by the Western Cape (37%) and Kwazulu-Natal (15%). The other provinces did not feature significantly in the sample. The human health sector had the highest number of core biotechnology companies (39%).

Six hundred and twenty two research groups were identified by the 2003 survey focussing on 911 projects relevant to biotechnology. This confirms that South Africa has a strength in research (Mulder, 2003).

Mulder (2003) concluded that the dominant focus areas in South Africa are:

- Human health
- Animal health (vaccines and diagnostics)
- Plant biotechnology (GM crops, biological control, propagation)

- Food and beverage (ingredients, analysis, probiotics, nutraceuticals and processing)
- Industrial (bioproduction and bioprocessing)
- Environment (waste treatment, bioremediation and water purification)

The above list shows that South African biotechnology is trying to address a wide variety of areas. While the wide focus is commendable it might dilute resources and cause fragmentation. Why is the South African biotechnology industry not well developed at present?

1.3. THE RESEARCH PROBLEM AND PURPOSE

South Africa has failed to develop a viable Biotechnology industry despite strong life sciences facilities and academic training (South African Department of Science and Technology, 2001). Government has pursued various strategies for developing this industry since 1982 however none have succeeded. The most recent strategy entails the establishment of four Biotechnology Regional Innovation Centres (BRICs) (South African Department of Science and Technology, 2001). Each BRIC is established in a particular region and with a particular focus. At present there is no specific means to assess the effectiveness and success of the BRIC system.

Two South African-specific studies have looked at the South African Biotechnology industry since adoption of the South African National Biotechnology Strategy, one by Motari, Quach, Thorsteinsdóttir, Martin, Daar and Singer (2004) and the other, commissioned by the Department of Science and Technology and Egoli Bio Life Sciences Incubator, by Mulder (2003). Both studies simply look at the state of the industry at a moment in time and neither study attempts to assess the industry development or success of the strategy.

South Africa's National Biotechnology Strategy is addressing the "Top 10 Biotechnologies for Improving Health in Developing Countries" as identified by Acharya, Kennedy, Daar and Singer (2004). Government has established BRICs which are mandated to target the development of key biotechnologies (South African Department of Science and Technology, 2001) however there is no information available currently regarding the success of the strategy or of the BRICs. In order to assess the impact of the National Strategy a framework needs to be used. The framework for assessment should be specific to the conditions in South Africa.

With this in mind this study will assess the current biotechnology sector in South Africa in terms of Porter's Diamond of National Competitiveness (Porter, 1990a) to identify which of the four attributes are weak and where the strengths lie. Once this base line is established future studies can assess whether the BRICs have been successful in improving the sector in terms of the four determinants.

The research will:

- Assess the biotechnology sector in terms of the four broad attributes of the Diamond of National Competitiveness.
- Establish where the strengths and deficiencies lie in terms of the Diamond model.

- Investigate the attractiveness for South African organisations or firms in locating within a biotechnology park using the factors identified by Chan and Lau (2005).
- Perform a preliminary assessment of the National Strategy at a point in time to be used as a basis for future assessment.

The research will not:

- Assess companies involved in 1st generation biotechnology activities.
- Ascertain any financial performance figures or trends.
- Be a case report on the biotechnology cluster in South Africa.
- Be a comprehensive survey of the Biotechnology industry in South Africa.

1.4. CONCLUSION

Biotechnology has the potential to address health, nutrition and economic issues in the developing world. South Africa has a small and diverse biotechnology industry however government realises the potential of the biotechnology industry and has devised a national strategy for the development of biotechnology in South Africa.

Porter's Diamond of National Competitiveness (Porter, 1990a) is a tool for analysing industry clusters in terms of four broad attributes (Factor Conditions, Firm Strategy and Rivalry, Demand Conditions and Related and Supporting Industries).

This study will focus on individuals at management level within biotechnology organisations from government, industry and academia and will seek their opinions with respect to the current status of the biotechnology industry in South Africa in terms of the Diamond model.

CHAPTER 2: THEORY AND LITERATURE REVIEW

The literature review and supporting theory base used focuses on the emergence and principles of the New Economy (Knowledge or Network Economy) and then explores the Cluster concept in this context and relates this to the Biotechnology industry. The literature review will also look at the development of "high technology" industries by the establishment of Science Parks or Incubators and Innovation Centres which are aimed at promoting the development of clusters.

2.1. THE NETWORK ECONOMY

Compartmentalising industries into a hierarchical system was first described by the Fisher-Clark thesis (Fisher, 1939; Clark, 1940). They proposed a simple hierarchical system consisting of farming and mining (primary), manufacturing (secondary) and services (tertiary). This theory is ageing as the distinctions blur between goods and services (Marshall and Wood, 1995). A new addition to this system is knowledge. Peter Drucker (1993) commented: "…the basic economic resource – "the means of production" …is no longer capital, nor natural resources…nor labour. It is and will be knowledge".

Knowledge is defined by Ghadar (2006) as the production and dissemination of context-dependent information. We can infer from this definition that knowledge is powerful through its ability to be disseminated. In his book New Rules for the New Economy, Kevin Kelly (1998) describes the "New Economy". The New Economy relates to the knowledge age or knowledge economy and is driven by telecommunications, information and, most importantly, technology. Bernstein (1998) suggests that we are living in a connected world and that the communications revolution is powerful and pervasive.

Kelly (1998) describes the coming of this "connected world economy" and calls it the Network Economy. He uses an analogy which is highly relevant to this topic. He writes in his introduction:

> "*It took several billion years on Earth for unicellular life to evolve. And it took another billion years or so for that single-celled life to evolve multi-cellular arrangements—each cell touching a few cells near it to make a living spherical organism. At first, the sphere was the only form multicellular life could take because its cells had to be near one another to coordinate their functions. After another billion years, life eventually evolved the first cellular neuron—a thin strand of tissue—which enabled two cells to communicate over a distance. With that single enabling innovation, the variety of life boomed. With neurons, life no longer had to remain bounded in a blob. It was possible to arrange cells into almost any shape, size, and function. Butterflies, orchids, and kangaroos all became possible. Life quickly exploded in a million different unexpected ways, into fantastic awesome varieties, until wonderful life was everywhere."*

This analogy suggests that through communication between cells (via neurons) life was able to take on new forms and discover novel ways of existing.

Companies in the Network Economy similarly are able to make new connections and transfer knowledge and information in novel ways thanks to technology (Bernstein, 1998).

While Kelly (1998) considers technology to be the key driver of the Network Economy, Bernstein (1998) argues that this is too simplistic a view. Bernstein argues that technology has been with us since the Stone Age. Rather, Bernstein suggests that it is the drive towards using technology to accelerate the pace of innovation and create monopolistic positions that give firms a competitive advantage.

Whatever the reason, the consensus is that knowledge and interconnectedness allowing the spread of this knowledge is the basis for the Network Economy. What is the implication of this connectedness for companies, industries and nations?

2.2. CLUSTER THEORY

The concept of a group of similar entities existing in a geographically localised area is not new and can be traced back to Alfred Marshall who studied the impact of localisation and published an article in 1890 entitled “The Principles of Economics” (cited in Porter, 1998 and Martin and Sunley, 2003). Marshall (1890, cited in Martin and Sunley, 2003 p7) identified three factors important for localisation, namely the availability of skilled labour, the growth of supporting and ancillary trades and the specialisation of different firms in different stages and branches of production.

Martin and Sunley (2003) point out that there has been an appreciable interest in the role of location in recent years. Two diametrically opposite views exist on the impact of globalisation on location. Some argue that globalisation is rendering location irrelevant as technology and free movement of labour in the globalised world allow firms to exist wherever they choose (O'Brien, 1992; Cairncross, 1997; Gray, 1998). The opposite view is that globalisation is, in fact promoting greater regional economic autonomy and that globalisation is increasing the importance of regional economies (Porter, 1998; Coyle, 1997, 2001; Fujita, 2000).

Martin and Sunley (2003) observe that one of the most influential exponents of economic localisation is Michael Porter who refers to "industrial or business clusters" in reference to firms that agglomerate with other firms in order to benefit from external economies of scale. Martin and Sunley (2003) also point out that Porter promotes the idea of "clusters" not only as an analytical tool but also as a policy tool. What then is a cluster?

2.3. CLUSTER DEFINITION

Porter (1998 p199) defines clusters as "geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries and associated institutions in particular fields that compete but also cooperate". This definition highlights the importance of this core of associated and competing firms and industries in the development of competitive advantage by first being locally competitive and also symbiotic. How are these companies interlinked?

2.4. PORTER'S DIAMOND OF NATIONAL COMPETITIVENESS

The origins of Porter's theory on clustering can be traced to his earlier work in the late 1980's and early 1990's on national competitive advantage (Martin and Sunley, 2003). In 1990 Porter developed a model called the "Diamond of National Competitiveness". The Diamond shows the relationship between four sets of factors or attributes which together influence the success of a nation's firms (Porter, 1990a, 1998).

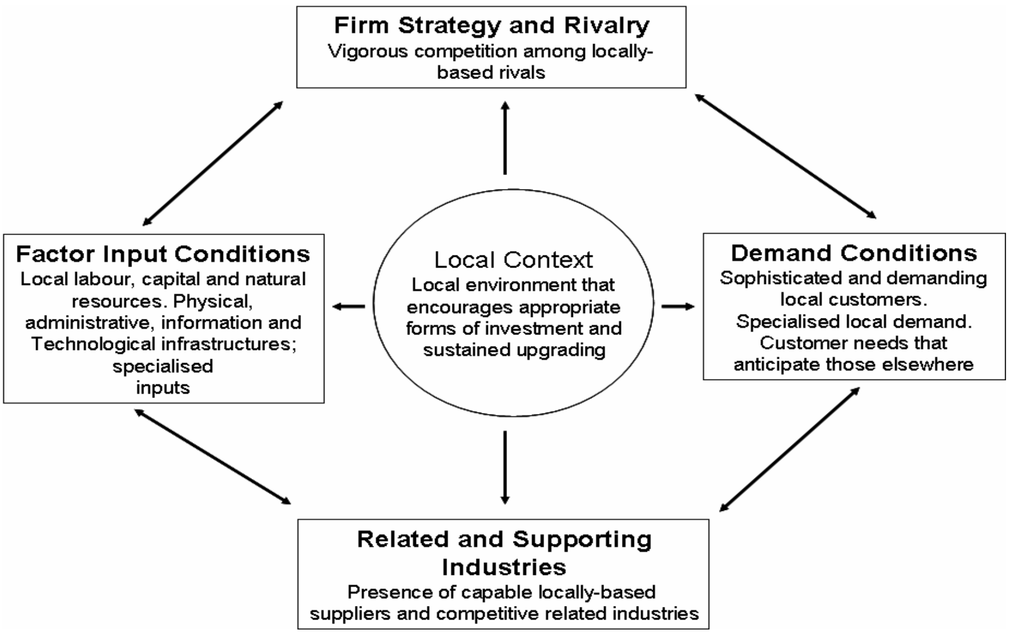


Figure 1: Porter's Diamond of National Competitiveness (Modified from Porter, 1990 p77)

2.4.1. FACTOR CONDITIONS

Factors are, amongst others, the skilled labour pool, raw materials and capital. The biotechnology industry requires highly skilled individuals in terms of both technical skills as well as business skills. The most recent survey of the South African biotechnology industry by Mulder (2003) identified a skills shortage. Porter (1990b p78) states that "to support competitive advantage, a factor must be highly specialised to an industry's particular needs".

2.4.2. DEMAND CONDITIONS

Porter (1990b) argues that home demand is critical to competition and success. Porter (1990b p79) states "Nations gain competitive advantage in industries where the home demand gives their companies a clearer or earlier picture of emerging buyer needs, and where demanding buyers pressure companies to innovate faster and achieve more sophisticated competitive advantages than their foreign rivals."

2.4.3. RELATED AND SUPPORTING INDUSTRIES

Porter (1990b p80) defines related and supporting industries as "the presence of capable locally based suppliers and competitive related industries". The biotechnology industry has many input requirements and the majority of the large life sciences materials suppliers have agencies in South Africa (Mulder, 2003).

2.4.4. Firm Strategy and Rivalry

Porter (1990b p81) defines this attribute as "the conditions in the nation which govern how companies are created, organised and managed, as well as the nature of domestic rivalry".

The attributes of the Diamond are inter-related and, when combined into a system, can lead to competitiveness at a nation level (Porter, 1998).

Porter (1990b p73) states:

"National prosperity is created, not inherited. It does not grow out of a country's natural endowments, its labour pool, its interest rates, or its currency's value, as classical economics insists.

"A nation's competitiveness depends on the capacity of its industry to innovate and upgrade. Companies gain advantage against the world's best competitors because of pressure and challenge. They benefit from having strong domestic rivals, aggressive home-based suppliers, and demanding local customers.

"In a world of increasing global competition, nations have become more, not less, important. As the basis of competition has shifted more and more to the creation and assimilation of knowledge, the role of the nation has grown."

Porter (1990b) suggests that pressures and challenges force companies to innovate and through this mechanism the companies either become globally competitive or cease to exist. Porter's Diamond model addresses the four attributes which he has identified as playing the critical roles in competitiveness. Porter (1990b, p83) argues that an effect on one of the attributes often depends on the state of the others. The example he uses to illustrate this point is that sophisticated buyers will not necessarily lead to advanced products if the quality of human resources does not allow the company to meet the buyer's needs (Porter, 1990b, p83).

The above defines "clusters" in terms of Porter's work and this concept has been rapidly adopted by academics and policy makers alike (Martin and Sunley, 2003, p6). Martin and Sunley (2003) however suggest caution regarding the concept of clusters and argue that there are problems with the concept. Their greatest criticism of the cluster concept is the very definition. They argue that the concept is "…deliberately vague and sufficiently indeterminate as to admit a very wide spectrum of industrial groupings and specialisations, demand-supply linkages, factor conditions, institutional setups, and so on, while at the same time claiming to be based on what are argued to be fundamental processes of business strategy, industrial organisation, and economic interaction" (Martin and Sunley, 2003, p9).

Martin and Sunley (2003) observe that, due to the difficulty in defining exactly what a cluster is, it has become what they term a "chaotic concept" with a lack of clear boundaries, both industrial and geographic.

Although criticism of the cluster concept, such as that of Martin and Sunley (2003), does exist, it remains a useful analytical tool for assessing and developing industry strategy and has been utilised by the World Bank and the national governments of Germany, the Netherlands, Portugal and New Zealand (Martin and Sunley, 2003). How have countries such as those mentioned above used Network economy and cluster theory to develop industries?

2.5. STRATEGIES FOR DEVELOPING "NEW TECHNOLOGY BASED" INDUSTRIES

Countries throughout Europe and North America have identified that so-called "New technology based firms" (Information and Communications Technology and Biotechnology for the most part) have a role in national and regional economic development (Westhead, 2000). In order to stimulate the development of these industries governments and policy makers have introduced various measures to encourage the formation and development of firms in these industries (Ferrer, 2004; Motari, 2004; Thorsteindóttir, 2004b; Chan and Lau, 2005).

Developing countries like Cuba, Taiwan, Brazil and China have developed their Biotechnology industries by establishing institutes or science parks where biotechnology is the sole focus of the facilities and all the firms located within these parks are biotechnology firms which is an attempt to force or accelerate the development of clusters (Ferrer, 2004, Thorsteinsdóttir, 2004b and Zhenzhen, 2004). South Africa's strategy is based on developing industry-academic entrepreneurial partnerships which are facilitated by a regional innovation centre which lends financial, business and intellectual property support to the venture (South African National Biotechnology Strategy, 2001). What conditions lead to the success of an industry?

Michael Porter (1998 p155) states that "prosperity is created, not inherited." He also states that "nations succeed in particular industries because their home environment is the most forward looking, dynamic and challenging".

Porter (1990a) describes the role of clusters in establishing a firm's, industry's and nation's competitiveness globally and highlights the importance of this core of associated and competing firms and industries in the development of competitive advantage by first being locally competitive and also symbiotic.

Porter (1998) points out that nations succeed in industries where they are particularly good at factor creation. He also observes that in some instances selective disadvantages in the more basic factors can, in fact, force companies to innovate and upgrade thus driving the development of competitive advantage.

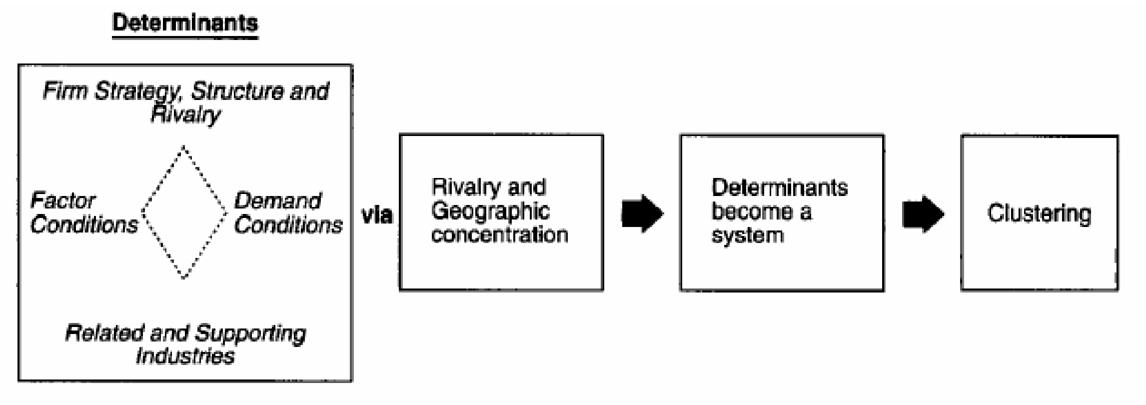
While this may be true, Porter (1998) stresses that transforming disadvantages into advantages requires favourable circumstances elsewhere in the Diamond. He states (Porter, 1998 p173) "To innovate, companies must have access to people with the appropriate skills and have home-demand conditions that send the right signals. They must also have active domestic rivals who create pressure to innovate". How is South Africa addressing the above issues?

It is possible to infer that the reason for establishing science parks or incubators is to attempt to "kick-start" the development of a cluster. The regional innovation centre in South Africa is envisaged to act as a hub around which Biotechnology start-up companies will develop (South African National Biotechnology Strategy, 2001). The National Strategy envisages that the BRICs will act as the nuclei for the development of biotechnology clusters within the BRIC regions. How then is the success of these initiatives measured?

2.6. SUCCESS OF CLUSTERS, SCIENCE PARKS AND INNOVATION CENTRES

There is much debate in the literature over the costs and benefits of these programs (Chan and Lau, 2005). One reason given for this by Colombo and Delmastro (2002) is the lack of large scale longitudinal data on the performance and characteristics of such incubated firms. South Africa has developed a strategy which aims, in part, to follow this incubator model at present. The assessment of the success of this strategy is thus vital and to date no published work relating to the South African-specific biotechnology context is available. How do clusters promote or influence competition?

Porter (1998) argues that clusters influence competition in three broad ways. First by supporting innovation and increasing the capacity for innovation and thus for productivity growth; second by increasing the productivity of individual firms within the cluster due to competition and benchmarking; and third by stimulating new business formation which supports innovation and expands the cluster. This suggests that a strong, competitive cluster feeds its own momentum. Figure 2 shows the attributes of the Diamond Model and the determinants of competitive advantage and clustering.



<u>Figure 2: Determinants of Competitive Advantage</u>
(Source: O'Donnell, 1994 cited in O'Connell, 1999)

Figure 2 shows that the determinants of Porter's Diamond (factor conditions, related and supporting industries, demand conditions and firm strategy, structure and rivalry) when influenced by rivalry and geographic concentration become a system which leads to clustering.

The presence of firms and industries within a specific location does not imply that there will be the creation of economic value (Porter, 1998), however they improve the probability. Burt (1997) describes social capital as a quality created between people, whereas human capital is a quality of individuals. Social capital thus relates to the interactions between people and could be extrapolated to include firms and industries that are located in proximity to each other.

Burt (1997) argues that social capital relates to opportunity which evolves through networking. Expanding opportunity through contacts is referred to in network theory. Porter (1998) goes further by stating that cluster theory bridges network theory and competition. He mentions that "successful cluster upgrading depends on paying explicit attention to relationship building, an important characteristic of cluster development initiatives." Essentially this means that by building up these networks within the cluster, the cluster as a whole becomes more competitive. Porter (1998) thus suggests that a successful cluster will exhibit good networking relationships and strong local competition but also collaboration between the cluster firms.

O'Connell and Clancy (1999) state that there is considerable support for Porter's theory that successful industries are usually part of competitive clusters. They site the work by Cartwright (1993), Rugman and Verbeke (1993) and Beije and Nuys (1995) which support Porter. They do point out however that while many aspects of Porter's attributes are significant determinants of competitiveness and competitive advantage the attributes do not always carry equal weight. They mention specifically the influence of domestic demand, rivalry and suppliers. They argue that these attributes do not always have a key influence on at least some part of the industries and that they are often overshadowed by the characteristics of foreign markets.

O'Connell and Clancy (1999) also argue that geographical proximity does not always augment the impact of the Diamond which is core to Porter. Their study looked at Ireland specifically and the boom in the Irish economy. While this may be true for Ireland there is a large body of support for Porter's model and it is still heavily utilised for national industry analysis. What alternatives or additional approaches are there to assess industry development?

Chan and Lau (2005) attempted to consolidate the assessment approaches for science parks in the literature and develop an assessment framework for IT science parks in Hong Kong. They identified seven factors which could be useful in assessing the science park or innovation centre model. The factors are:

1. Cost advantage in terms of rental subsidies and other expenses.
2. Pooling resources to reach a "critical mass" to enable organising central functions like training, networking events. Sharing of basic structural resources (administrative support, office equipment) but not technical resources.
3. Increased access to funding.
4. Seeking consulting advice on product development (may or may not be important).
5. Benefits through clustering and networking.
6. Good public image of the science park on tenants.

7. University-technology start-ups relationship.

Although this analysis was performed in the IT sector it may be applicable in broad terms in the Biotechnology sector.

These seven factors can be assessed in conjunction with the Diamond Model in order to assess the current South African biotechnology sector. One of the factors namely the benefit of clustering and networking lies at the heart of Porter's Diamond Model so the list of seven factors can be reduced to six if combined with the Diamond analysis. What does the biotechnology sector look like in South Africa?

2.7. SOUTH AFRICAN BIOTECHNOLOGY SECTOR

Mulder (2003) identified the following positive contributing factors for the South African biotechnology sector:

- A sophisticated and lengthy tradition of first generation biotechnology.
- World-class researchers and research institutions.
- A pipeline of projects that could lead to new products or processes.
- An unrivalled biodiversity and biological resource base.
- Indigenous medical knowledge going back centuries.
- Access to a large human genetic diversity pool.
- Access to a high number of clinical samples for major infectious diseases.

- A relatively low cost base for research, product development and manufacturing.
- Sound legal and regulatory frameworks, and a world-class banking system and ICT infrastructure.

She also identified the following inhibiting factors to the growth and development of the biotechnology sector in South Africa:

- A general lack of cohesion in research programmes.
- A shortage of market-focussed research and a relatively low tendency among academics to commercialize research.
- A scarcity of suitably qualified R&D personnel, particularly at the MSc and PhD levels.
- A lack of clear IP policies that incentivise commercialisation.
- An overall lack of confidence in African governments, which affects foreign investment.
- An increasing dependence on imported products, machinery, equipment, materials and technologies.
- A relatively small local market.
- A severe shortage of entrepreneurial and technology transfer skills and mechanisms.
- Insufficient public and private funding for research and product commercialisation.

The factors identified by Mulder (2003) can be located within the Diamond of National Competitiveness. Many of the factors identified by Mulder (2003) are as a direct result of the history of South Africa and the Country's isolation under the apartheid regime. This isolation forced the Country to develop its own scientific and technological capacity (Motari, 2004).

2.8. CONCLUSION

The two studies focussing on the South African biotechnology sector since 2001 have focussed mainly on the scientific aspects of the sector (Motari 2004, Mulder, 2003). Neither has looked at the sector from an economic and business view point. The studies have identified various factors, both positive and negative which are impacting on the sector.

Competitiveness at a nation level is arguably best described using Porter's Diamond model which provides a framework for analysing an industry cluster. The South African National Biotechnology Strategy has been designed to stimulate cluster formation with the BRIC at the core. In order to assess the success of the BRIC strategy it is necessary to establish a base line analysis of the biotechnology sector. To do this an analysis is required which assesses the South African biotechnology sector in terms of the four attributes of the Diamond model.

There are situations in the literature, for example Ireland, where Porter's Diamond model and the cluster theory are perhaps not as applicable however there appear to be very few such examples. On the other hand there are numerous examples where the Diamond model and cluster theory do provide valuable insights as to the success of an industry within a nation (Martin and Sunley, 2003, Porter, 1998).

While it is accepted that conditions are unique from country to country and industry to industry Porter's theory provides a framework for assessing an industry in a generic fashion and to provide a base line for future analyses.

CHAPTER 3: RESEARCH PROPOSITIONS AND QUESTIONS

The literature review has revealed that the Diamond model is a useful tool in assessing clusters and industries within a country. The Diamond defines four broad attributes that together function as a system which, when optimal, can lead to an industry becoming globally competitive. South Africa's biotechnology industry is small and the strategy for encouraging the development of this industry appears to focus on cluster development. The biotechnology industry in South Africa as stated is not internationally successful at present suggesting that, in terms of cluster theory, the industry would be poor in terms of most, if not all of the attributes of the Diamond.

This research will assess the industry in terms of the four broad attributes and also assess industry stake holder views with regards to locating their business within dedicated science parks in order to facilitate clustering.

The following five propositions and further two research questions will be addressed:

Proposition 1:

Factor conditions are a problem for South African biotechnology institutions or firms.

Proposition 2:

There is a deficiency in related and supporting industries for biotechnology institutions or firms in South Africa.

Proposition 3:

Demand conditions within the South African Biotechnology sector are poorly developed.

Proposition 4:

Firm strategy and rivalry is poorly developed in the South African biotechnology industry.

Proposition 5:

South African biotechnology institutions or firms have no interest in the establishment of a dedicated biotechnology (science) park.

Research Question 1:

What is the primary motivation for South African biotechnology institutions or firms to relocate to a dedicated biotechnology park?

Research Question 2:

What is the single most critical factor for the success of the South African biotechnology industry?

CHAPTER 4: RESEARCH METHODOLOGY

4.1. INTRODUCTION

Welman and Kruger (2005) identify four different types of research design. The research designs are:

- Experimental research
- Quasi-experimental research
- Non-experimental research
- Qualitative research

(Experimental, quasi-experimental and non-experimental research: Quantitative research)

This research used a quantitative research design in order to test the propositions and research questions by means of a questionnaire.

4.2. POPULATION OF RELEVANCE

Biotechnology can be split into “old” biotechnology which refers to fermentation-type biotechnology (examples include beer production and dairy products by fermentation like cheese and yoghurt) and “new” biotechnology (or modern biotechnology) where DNA modification technologies are used (Organisation for Economic Cooperation and Development, 2001). For the purposes of this study the population of relevance was confined to the “new” biotechnology sector.

The population of relevance consisted of Government agents from the Department of Science and Technology, Heads of the BRICs (EcoBio, BioPad, PlantBio and Cape Biotech), Life Sciences Academics from the University of Witwatersrand, University of Cape Town and the University of the Western Cape and Biotechnology Industry players within South Africa. This indicates a cross-sectional design (Welman and Kruger, 2005).

4.3. SAMPLING METHOD

Due to the small size of the "new" biotechnology industry in South Africa the sampling could not be random. Welman and Kruger (2005) define Non-probability sampling as "The probability that any element will be included in a non-probability sample cannot be specified". Non-probability sampling was thus used.

The type of non-probability sampling used was purposive sampling. Welman and Kruger (2005) define purposive sampling where "researchers rely on their experience, ingenuity and/or previous research findings to deliberately obtain units of analysis in such a manner that the sample they obtain may be regarded as being representative of the relevant population". To this end the 2003 biotechnology survey (Mulder, 2003) was used as a starting point to identify the total number of units of analysis and identify the population sample.

Individuals directly involved in the National Strategy (government and academia) were sampled, as well as individuals from biotechnology companies who are not directly involved in the National strategy. The strength of this sampling method was that a relatively large percentage of the relevant population could be sampled.

4.4. SAMPLE SIZE

Mulder (2003) identified a total of 106 biotechnology companies in South Africa in 2003. These figures served as a starting point to determine the total population size. Added to this number were the four BRICs and the Department of Science and Technology. Website searching using the BRIC websites as a starting point identified individual contacts within government, academia and industry. Dr Mulder was also contacted directly and kindly provided individual contact details based on her research. In total 74 individuals at senior management level were identified spanning the four BRICs, government, academia and industry.

4.5. RESEARCH INSTRUMENT USED

The design of the study was a non-experimental, natural environment design (Welman and Kruger, 2005). Individuals' opinions with respect to the attributes of Porter's Diamond model and Chan and Lau's factors were field surveyed by means of an email questionnaire. The respondents were asked to complete a

Likert Scale questionnaire indicating their level of disagreement to agreement with a specific statement (See Appendix 1).

4.5.1. DEMOGRAPHIC DATA

Demographic data (nominal data) was collected (namely Sector, Number of Employees, Years involved in biotechnology (experience) and Product on the market).

4.5.1.1. SECTOR DATA

Respondents were identified that could be classified into three broad categories with respect to in which sector of the Biotechnology industry they functioned. The three sectors were Government (Department of Science and Technology Ministry and BRIC), Industry (Commercial entities whose primary focus is on manufacturing and commercialising products) and Academia (University departments). The reason for defining the sectors was to evaluate whether respondents from different sectors viewed the status of the industry and importance of factors differently.

4.5.1.2. YEARS INVOLVED IN BIOTECHNOLOGY

This demographic was selected to assess the industry experience of respondents. Comparing industry experience and factor rating was thus possible.

4.5.1.3. Company Employees

The number of employees in the organisation gave some information regarding the nature of the industry. The main purpose was to assess whether the industry is dominated by a few large players or whether small to medium enterprises (SMEs) predominate.

4.5.1.4. Company Product on the Market

This demographic gave the opportunity to assess how many of the respondents came from backgrounds where they were exposed to market competition.

4.5.2. Questionnaire Questions

The questionnaire was split into three sections although no clear split was shown in the layout.

- Questions 1 to 10 assessed the attributes of Porter's Diamond of National Competitiveness (1990a),
- Questions 11 to 18 assessed Chan and Lau's factors (2005), and
- Questions 19 and 20 assessed the overlap between Chan and Lau's factors and Porter's Diamond attributes.

4.5.2.1. Questions 1 to 10 (Porter's Diamond)

- *Question 1* assessed the respondents' overall opinions regarding the success of the South African biotechnology industry. This allowed the analyser to be aware of potential response bias in a positive or negative way and also allowed for an internal check of the validity of the responses (for example if the respondent answered that they thought South Africa had an unsuccessful biotechnology industry but then continued to make highly positive answers the questionnaire could be flagged as potentially inaccurate).
- *Questions 2 to 4* assessed the respondents' attitudes towards the Factor Condition attribute of Porter's Diamond model (Proposition 1).
- *Questions 5 and 6* assessed the respondents' attitudes towards the Related and Supporting Industry attribute of Porter's Diamond model (Proposition 2).
- *Questions 7 and 8* assessed the respondents' attitudes towards the Demand Condition attribute of Porter's Diamond model (Proposition 3).
- *Questions 9 and 10* assessed the respondents' attitudes towards the Firm Strategy and Rivalry attribute of Porter's Diamond model (Proposition 4).

4.5.2.2. Questions 11 (Biotechnology Park)

(Testing Proposition 5)

- *Question 11* was similar in design to Question 1 in that it assessed the respondents' overall opinions regarding the establishment of dedicated Biotechnology Parks in South Africa. This allowed the analyser to be aware of potential response bias in a positive or negative way and also allowed for an internal check of the validity of the responses to questions 12 to 19.

4.5.2.3. QUESTIONS 12 TO 18 (CHAN AND LAU'S FACTORS)

(Testing Research Question 1)

- *Questions 12 to 17:* Respondents were simply asked to rank order the 6 factors.
- *Question 18* provided a means to weight the responses to questions 12 to 17. The reasoning behind this was that if a respondent felt that they had no interest in locating within a dedicated biotechnology park their factor ranking for questions 12 to 17 would carry a lower weighting.

4.5.2.4. QUESTIONS 19 AND 20 (PORTER'S DIAMOND AND CHAN AND LAU COMBINED)

(Testing Research Question 2)

- *Question 19* provided a means to weight the responses to question 20. The reasoning behind this was that if a respondent felt that South Africa would not be able to develop a biotechnology sector that could compete globally, their factor ranking for question 20 would carry a lower weighting.

- *Question 20* was used to assess whether a specific factor was considered the most important for a successful biotechnology industry in South Africa.

The attributes and factors were considered interval data and respondents were asked to rate a statement from strongly disagree to strongly agree (with a not applicable answer also available).

An email questionnaire was decided upon due to the geographically diverse location of the population sample (Eastern Cape, Western Cape, Gauteng and Kwazulu-Natal).

4.6. DATA COLLECTION

The questionnaire was initially tested on three individuals, one from industry, one from government and one who had no biotechnology background. Feedback from these individuals was used to reformat the questionnaire which was then internally tested in a South African Biotechnology company. The rationale for this approach was to ensure that the questionnaire was not ambiguous and that the instructions were easy to follow.

The first round of emailed questionnaires was sent out to 32 of the 74 individuals that made up the population sample. A second round of questionnaires was then sent to the rest of the population sample once it was observed that the first round did not reveal any previously unidentified problems with instructions or interpretations. Respondents were given one week to return the completed questionnaire before a reminder was sent out. In total 3 reminders were sent out.

4.7. PROCESS OF ANALYSIS

The responses received were coded as per the coding sheet (see Appendix 2) and entered into Microsoft Excel to form a data base for analysis (see Appendix 3). Descriptive statistics on the demographic data was performed in Microsoft Excel. The analytical statistics was performed using the NCSS software package. The analysis included cross tabulation assessing the Chi-square test for independence and one-way ANOVA testing between the demographic data and responses to the attribute and factor questions. A 5% significance level was used (i.e. p value of <0.05). The reason for this approach was to determine whether different demographic variables influenced the responses obtained (for example did more years of experience in the biotechnology sector influence which factor was considered critical to the success of biotechnology in South Africa?).

The propositions were assessed by using one sample T-tests to assess the significance of responses to each question. The one sample T-test was used to compare the mean or median of a single group to a target value. The target value in the case of this research was 3.0 (neutral response) for the Likert-type scale questions and 1.5 for the “Yes” or “No” questions. Responses falling below or above 3 for Likert scale questions or 1.5 for “Yes” or “No” questions were assessed for the significance level.

Likert scale questionnaire data is considered ordinal (Pett, 1997; Blaikie, 2003; Hansen, 2003) however the intervals between the values can not be presumed to be equal (Blaikie, 2003). The described deficiency (ordinal data but intervals not equal) in Likert scale questionnaire data is the reason why no attempt was made to assess the differences between strongly agree/disagree with agree/disagree. The only analysis performed was assessing a generally negative or positive perception i.e. above or below Neutral (three in the coding).

4.8. LIMITATIONS OF THE CURRENT RESEARCH

1. The small size of the South African biotechnology sector meant that sample size restricted the generalisability of the findings. A small sample size could have led to difficulties in analysis and in drawing conclusions that were fully representative. Nevertheless, the purposive sampling methodology ensured the usefulness of the data.
2. The industry is relatively young and thus experience in industry is relatively lacking in general. This may have influenced responses.
3. The study was intended as an exploratory study to be used as a baseline for future assessment. As such it was not intended to be a case study of the Biotechnology industry in South Africa.

CHAPTER 5: RESULTS

5.1. INTRODUCTION

The results have been presented in the following manner. Demographic data has been presented in section 5.2. The rest of the results were presented according to the research proposition and research questions.

Each section was divided into:

- Descriptive statistics (presenting sample number, means and standard error).
- A bar graph of responses was shown for each question and observations drawn from the bar graphs;
  - One sample T-tests were performed on the Likert scale questions to determine whether the observations made were statistically significant;
  - Cross tabulation testing using Chi-square tests of independence was used for “Yes and No” questions again to determine whether the observations were statistically significant.
- One-way ANOVA analysis was then performed to assess dependence of the demographic variables to responses.

The one sample T-test results data, cross tabulation results data and ANOVA results data were only presented in full if a significant result was observed. In the absence of a significant result a statement was made to that effect.

5.2. DESCRIPTIVE STATISTICS

5.2.1. RESPONSE RATE

Of the 74 questionnaires distributed a total of 36 were returned fully completed. This represents a response rate of 48.65%.

5.2.2. DEMOGRAPHIC DATA

5.2.2.1. SECTOR DATA

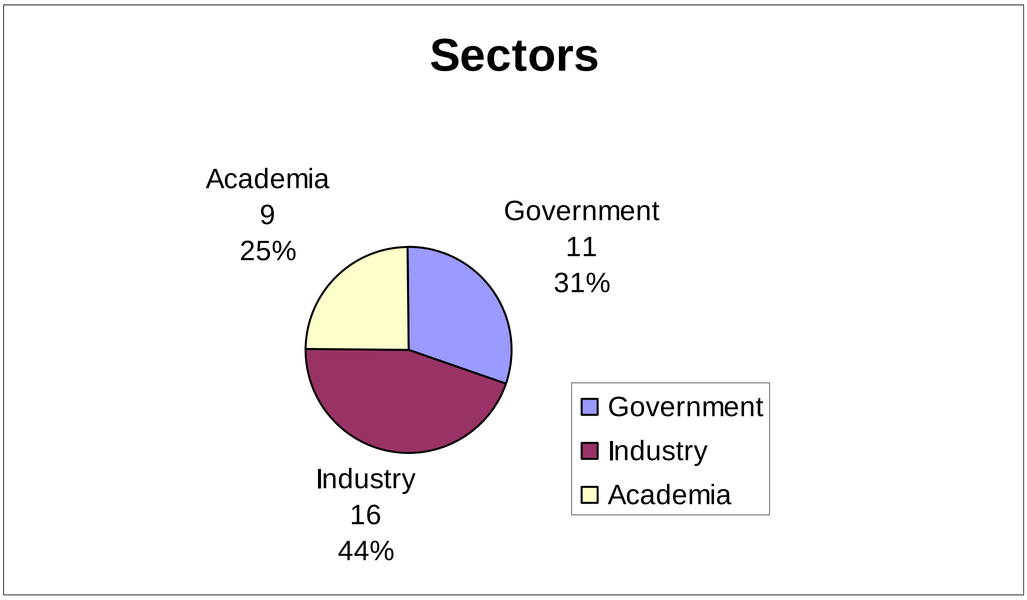
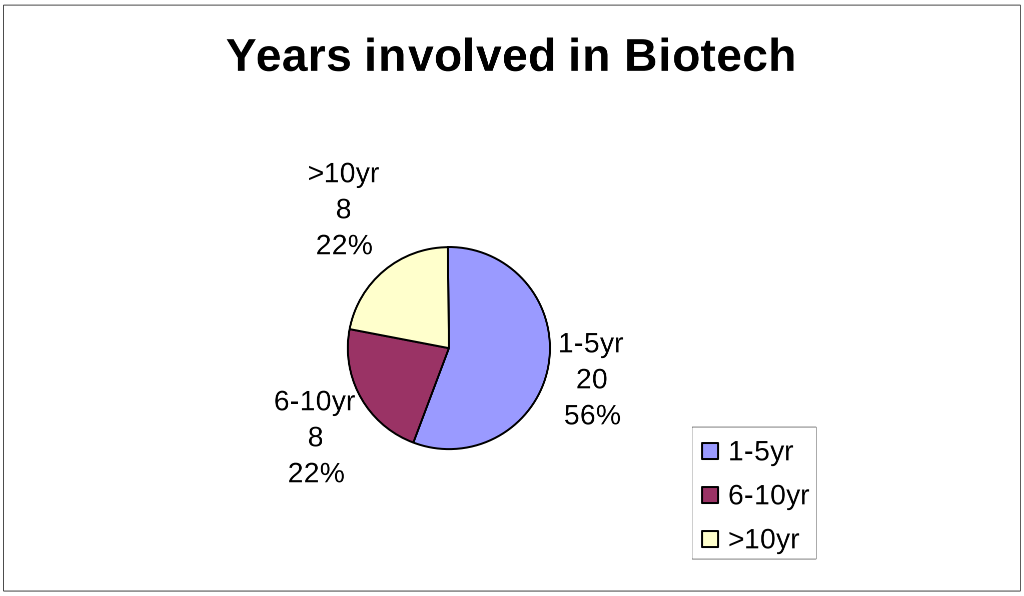


Figure 3: Breakdown of responses received by Sector

Respondents were obtained from all three sectors. Industry respondents made up 44% of the sample, Government respondents 31% and Academia respondents 25%. The Industry sector was represented most which was important considering that the research focussed on the industry.

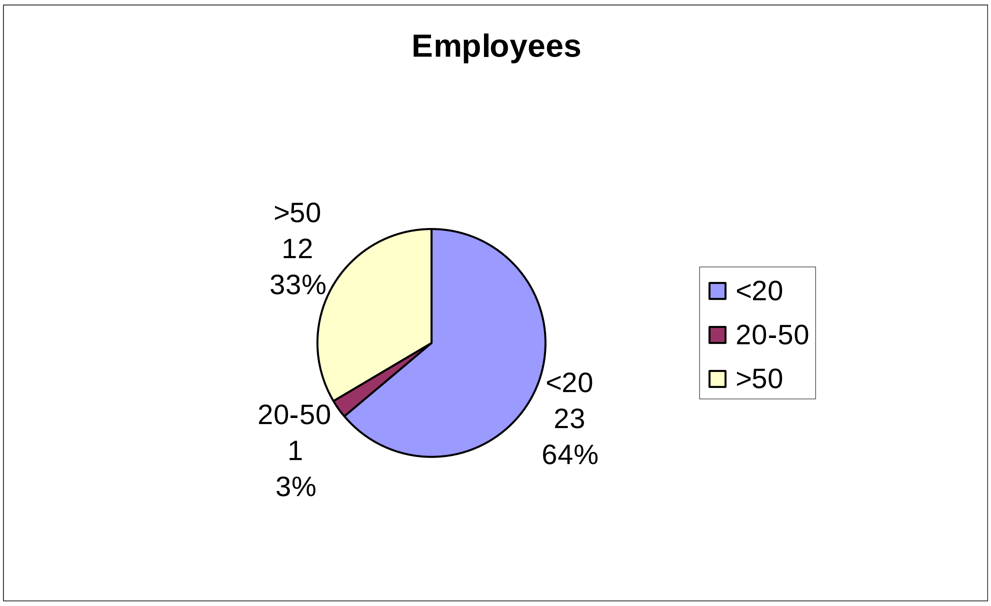
5.2.2.2. YEARS INVOLVED IN BIOTECHNOLOGY (EXPERIENCE)



<u>Figure 4: Breakdown of responses received by years involved in Biotechnology</u>

Fifty six percent of respondents had <5 years experience in Biotechnology illustrating the relative inexperience of the industry. 44% of respondents had >5 years experience and of this only 22% > 10 years experience. This observation could be important in terms of skills transfer and mentoring programmes.

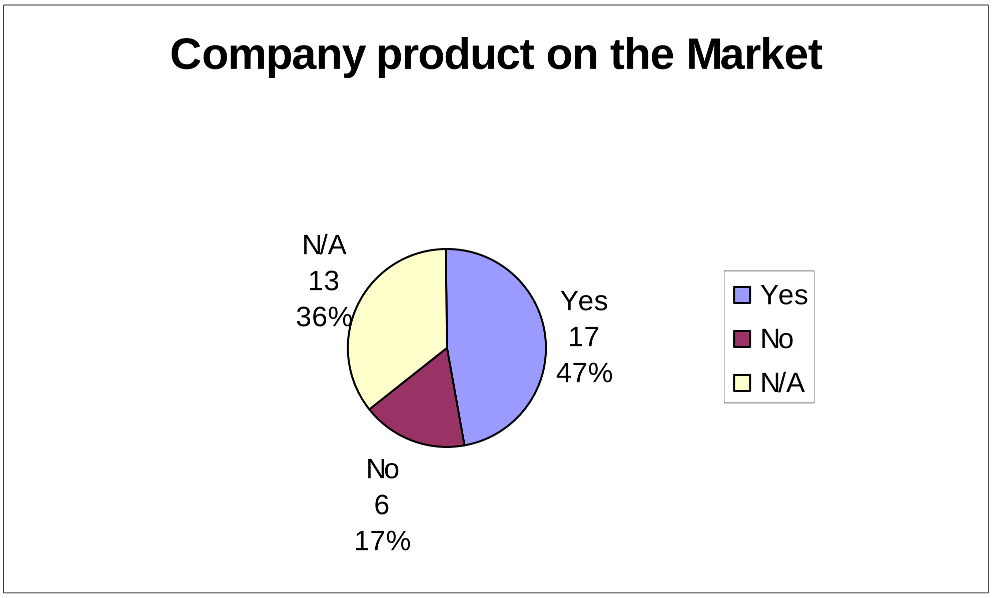
5.2.2.3. EMPLOYEES



<u>Figure 5: Breakdown of responses received by number of employees</u>

The respondents indicated that the majority of stakeholders in the Biotechnology sector were either small companies (<20 employees) - 64% or are part of larger organisations (>50 employees) - 33%. Industry respondents were almost exclusively from small organisations whereas government and academia ranged from small to larger.

5.2.2.4. PRODUCT ON THE MARKET



<u>Figure 6: Breakdown of responses received as to whether the company has product on the market</u>

Forty seven percent of respondents said that their organisation had product on the market. This observation is encouraging and shows that commercial use of ideas is occurring in South Africa. The nature of the product and commercialisation strategy did not form part of this research but should be investigated in future work.

5.3. QUESTIONNAIRE QUESTIONS ANALYSIS

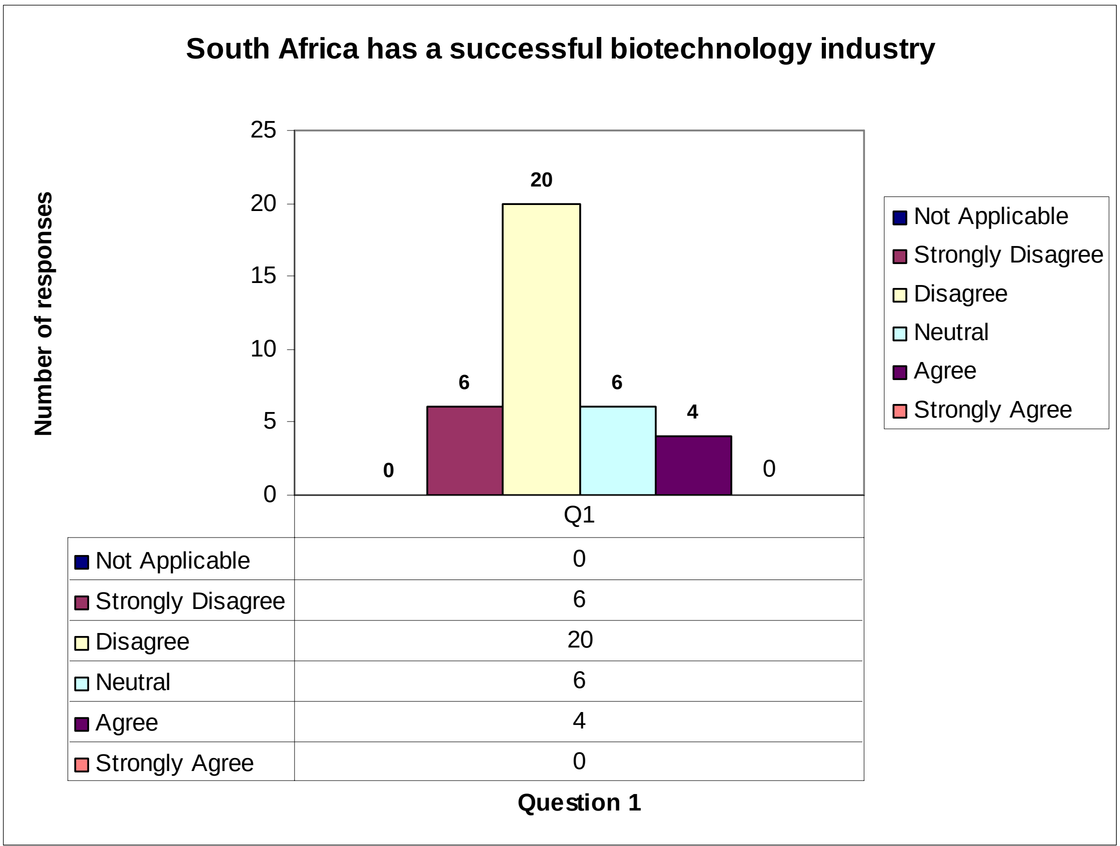
5.3.1. QUESTION 1

Question 1 sought to gauge the attitudes of respondents regarding the success of the South African biotechnology industry at the present time.

Question	n	Mean	Std Error
1	36	2.222	0.1443

Table 1: Descriptive statistics for question 1

The sample size for question 1 was 36 respondents. The mean response observed was 2.222 with a standard error of 0.1443. The mean was thus below 3 which was the "Neutral" response coding value. The following bar graph shows a break down of the responses.



	Q1
Not Applicable	0
Strongly Disagree	6
Disagree	20
Neutral	6
Agree	4
Strongly Agree	0

Figure 7: Breakdown of responses to the statement that South Africa has a successful biotechnology industry

Figure 7 showed that 72% of respondents (26 out of 36) disagree with the statement that South Africa has a successful biotechnology industry. In order to test the significance of the above observation a one sample T-test was performed.

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	1.6860	0.091801	Cannot reject normality
Kurtosis Normality	0.3440	0.730869	Cannot reject normality
Omnibus Normality	2.9608	0.227544	Cannot reject normality

Table 2: One sample T-test results for tests of assumptions section

Table 2 shows that all three tests for a normal distribution of the sample cannot reject normality. The sample was thus normally distributed. The T-test section was thus used.

T-Test for Difference between Mean and Value (3.0) Section

Alternative Hypothesis	T-Value	Probability level	Decision (5%)	Power (alpha = 0.05)	Power (alpha = 0.01)
Q1<>3	-5.3915	0.000005	Reject Ho	0.999479	0.994655
Q1 < 3	**-5.3915**	**0.000002**	**Reject Ho**	**0.999863**	**0.997815**
Q1 > 3	-5.3915	0.999998	Accept Ho	0.000000	0.000000

Table 3: T-Test for Difference between Mean and Value (3.0) Section

The null hypothesis for table 3 was that the mean response to question 1 was three. It was clear from table 3 that the null hypothesis was rejected where the mean equals three. Where the mean was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.0000002. This result confirmed that the mean response was less than three and that the observation was statistically significant at the 0.05 level.

Question 1 – ANOVA test Results

One way ANOVA testing was performed to assess the relationship between the demographic variables (sector, experience, employees and product on the market) and response to question 1. The aim was to see if any of the demographic variables influenced how a respondent responded.

No dependence between answers to question one and any of the demographic variables was observed using the ANOVA analysis.

5.3.1.1. SUMMARY OF RESULTS FOR QUESTION 1

- A statistically significant majority of respondents disagreed with the statement that South Africa has a successful biotechnology industry.
- No dependence between answers to question one and any of the demographic variables was observed.
- The conclusion drawn is that the majority of respondents from the sample assessed felt that **South Africa does not have a successful biotechnology industry** at present. The responses given were in no way influenced by sector, experience, organisation size or whether the organisation had commercialised product. This supports a true reflection of the industry at present.

5.3.2. PROPOSITION 1

Factor conditions are a problem for South African biotechnology institutions or firms.

QUESTIONS 2 TO 4 (FACTOR CONDITIONS)

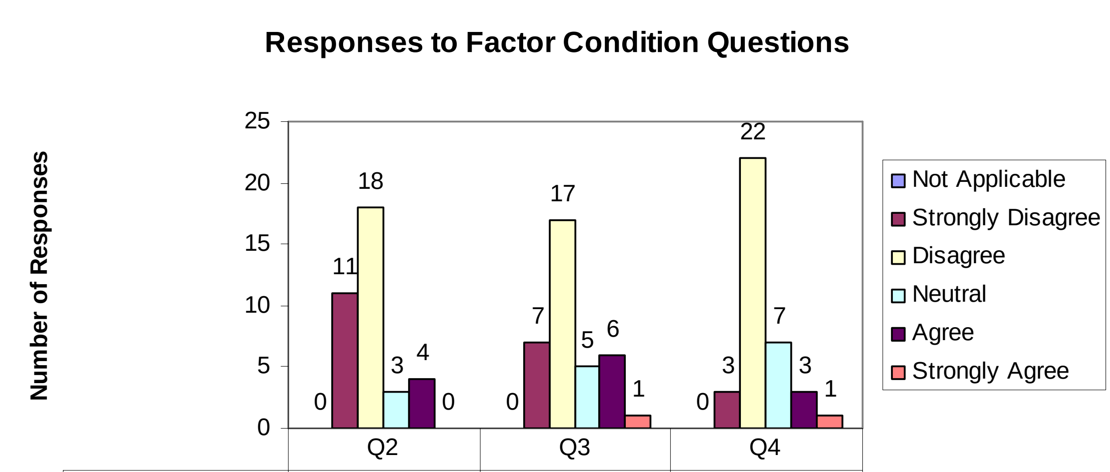
Questions 2 to 4 assessed the respondents' attitudes to the Factor Conditions attribute of Porter's Diamond model. Issues relating to capital, skills and infrastructure were addressed.

Question 3 was a negatively worded question whereas questions 2 and 4 were positively worded. This was done for internal control purposes. For the analysis question 3 responses were oppositely coded i.e. strongly disagree was coded 5 and not 1, and so on, as for the positively worded questions.

Question	N	Mean	Std Error
2	36	2.0000	0.1543
3	36	2.3611	0.1789
4	36	2.3611	0.1445

Table 4: Descriptive statistics for responses to Factor Condition Questions

Table 4 shows that the sample size was 36. Question 2 had a mean response of 2.0000 with a standard error of 0.1543. Question 3 had a mean response of 2.3611 and a standard error of 0.1789. Question 4 had a mean response of 2.3611 and a standard error of 0.1445. All three questions thus had a mean suggesting a negative response. The following bar graph shows a break down of the responses.



	Q2	Q3	Q4
Not Applicable	0	0	0
Strongly Disagree	11	7	3
Disagree	18	17	22
Neutral	3	5	7
Agree	4	6	3
Strongly Agree	0	1	1

Figure 8: Bar chart showing responses to the Factor Condition questions

Figure 8 shows that 72% of respondents answered negatively to the Factor condition questions indicating a negative perception of Factor conditions in the South African biotechnology industry. In order to test the significance of the above observation a one sample T-test was performed for each question 2, 3 and 4. The data below show the output.

Question 2

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	**2.2497**	**0.0245**	**Reject normality**
Kurtosis Normality	0.6463	0.5182	Cannot reject normality
Omnibus Normality	2.9608	0.0645	Cannot reject normality

Table 5: One sample T-test results for tests of assumptions section

The test for normality revealed that the sample was not normally distributed (highlighted in red). The data was thus assessed using the Wilcoxon signed-rank test for difference in medians.

Wilcoxon Signed-Rank Test for differences in medians

Alternative Hypothesis	Z-Value	Probability level	Decision (5%)
Median<>3	4.4129	0.000010	Reject Ho
Median < 3	**-4.4129**	**0.000005**	**Reject Ho**
Median > 3	-4.4129	0.999995	Accept Ho

Table 6: Wilcoxon Signed-Rank Test for differences in medians and Value (3.0) Section

The null hypothesis for table 6 was that the median response to questions 2 was three. It was clear from table 6 that the null hypothesis was rejected where the median equals three. Where the median was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.000005. This result confirmed that the median response was less than three and that the observation was statistically significant at the 0.05 level.

Question 3

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	1.7271	0.0842	Cannot reject normality
Kurtosis Normality	0.6463	0.5182	Cannot reject normality
Omnibus Normality	2.9608	0.0645	Cannot reject normality

Table 7: One sample T-test results for tests of assumptions section

Table 7 shows that all three tests for a normal distribution of the sample cannot reject normality. The sample was thus normally distributed. The T-test section was thus used.

T-Test for Difference between Mean and Value (3.0) Section

Alternative Hypothesis	T-Value	Probability level	Decision (5%)	Power (alpha = 0.05)	Power (alpha = 0.01)
Q1<>3	-3.5721	0.001055	Reject Ho	0.934803	0.795475
Q1 < 3	**-3.5721**	**0.000527**	**Reject Ho**	**0.968343**	**0.865636**
Q1 > 3	-3.5721	0.999473	Accept Ho	0.000000	0.000000

Table 8: T-Test for Difference between Mean and Value (3.0) Section

The null hypothesis for table 8 was that the mean response to questions 3 was three. It was clear from table 8 that the null hypothesis was rejected where the mean equals three. Where the mean was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.0000005. This result confirmed that the mean response was less than three and that the observation was statistically significant at the 0.05 level.

Question 4 (Physical infrastructure is easy to locate and access within South Africa)

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	**2.7179**	**0.0066**	**Reject normality**
Kurtosis Normality	1.7903	0.0734	Cannot reject normality
Omnibus Normality	**10.5924**	**0.0050**	**Reject normality**

Table 9: One sample T-test results for tests of assumptions section

Table 9 shows that the test for normality revealed that the sample was not normally distributed (highlighted in red). The data was thus assessed using the Wilcoxon signed-rank test for difference in medians.

Wilcoxon Signed-Rank Test for differences in medians

Alternative Hypothesis	Z-Value	Probability level	Decision (5%)
Median<>3	3.6956	0.000219	Reject Ho
Median < 3	**-3.6956**	**0.000110**	**Reject Ho**
Median > 3	-3.6956	0.999890	Accept Ho

Table 10: Wilcoxon Signed-Rank Test for differences in medians and Value (3.0) Section

The null hypothesis for table 10 was that the median response to question 4 was three. It was clear from table 10 that the null hypothesis was rejected where the median equals three. Where the median was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.000005. This result confirmed that the median response was less than three and that the observation was statistically significant at the 0.05 level.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. No dependence between answers to questions 2, 3 or 4 and any of the demographic variables was observed using the ANOVA analysis.

5.3.2.1. SUMMARY OF RESULTS FOR PROPOSITION 1

- All questions had mean responses statistically significantly less than 3 (neutral). This shows that the majority of respondents indicated that **Factor Conditions are a problem** for South African organisations in the biotechnology industry.
- No demographic variable was shown to be linked to response. This indicates that the Factor Condition problem is experienced throughout the industry, between all the stakeholders.

5.3.3. PROPOSITION 2

There is a deficiency in related and supporting industries for biotechnology institutions or firms in South Africa.

QUESTIONS 5 AND 6 (RELATED AND SUPPORTING INDUSTRIES)

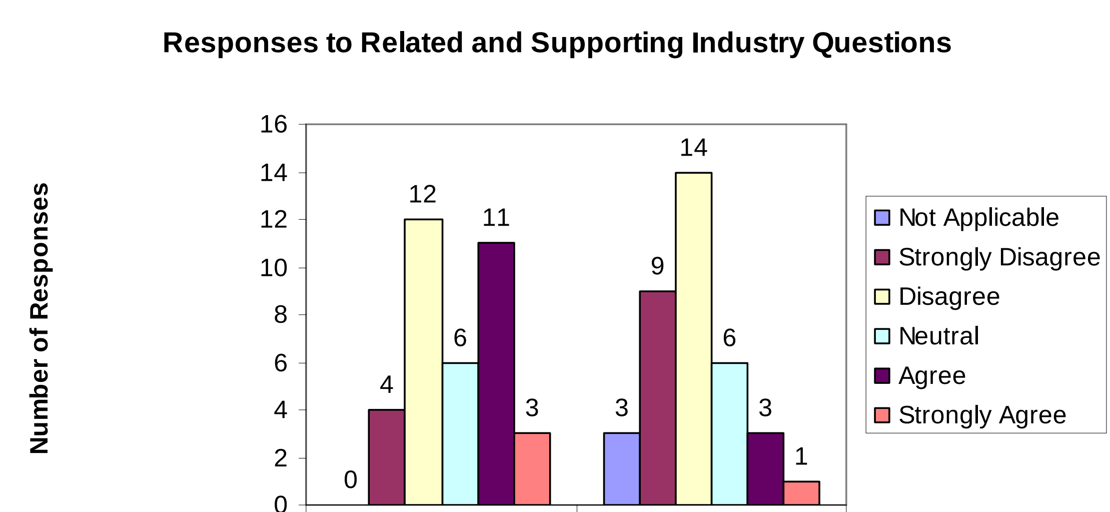
Questions 5 and 6 assessed the respondents' attitudes to the Related and Supporting Industries attribute of Porter's Diamond model. Issues relating to suppliers and related industries were addressed.

Question 6 was a negatively worded question whereas question 5 was positively worded. This was done for internal control purposes. For the analysis question 6 responses were oppositely coded i.e. strongly disagree was coded 5 and not 1, and so on, as for the positively worded questions.

Question	n	Mean	Std Error
5	36	2.9167	0.2007
6	36	2.0000	0.1952

Table 11: Descriptive statistics for responses to Related and Supporting Industries questions

Table 10 shows that the sample size was 36. The mean response was 2.9167 with a standard error of 0.2007 for question 5. Question 6 had a mean response of 2.0000 with a standard error of 0.1952. The following bar graph shows a break down of the responses.



	Q5	Q6
Not Applicable	0	3
Strongly Disagree	4	9
Disagree	12	14
Neutral	6	6
Agree	11	3
Strongly Agree	3	1

<u>Figure 9: Bar chart showing responses to Related and Supporting Industry questions</u>

Figure 9 showed that 44% of respondents felt negatively towards Question 5 however 39% felt positive. This demonstrated a bimodal response to Question 5. Seventy percent of respondents felt positively (look at negative values due to reverse coding) towards question 6.

The bimodal response to question 5 was investigated first by using the one sample T-test to check significance and then using the one-way ANOVA test to investigate whether a particular demographic variable was responsible for the distribution.

<u>Question 5 (Our organisation has a strong network of relationships with other biotechnology companies in South Africa)</u>

One sample T-testing for question 5 did not reveal any statistically significant level below or above 3. The conclusion drawn was that there was no statistically significant negative or positive bias to the answers to question 5.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response (Kruskal-Wallis results are shown due to small sample sizes).

Factor Variable	**Question 5**		**Accept or Reject Ho**
	Chi-square	Prob. level	
Sector	**7.52654**	**0.02321**	**Reject**
Experience	4.2558	0.11909	Accept
Employees	2.98501	0.22481	Accept
Product	1.88815	0.38904	Accept

<u>Table 12: ANOVA results showing demographic data responses to Factor Condition Questions</u>

The null hypothesis that was tested with the ANOVA test was that the mean response of each demographic group did not differ significantly from one another for responses to question 5. Table 12 shows the results obtained for the ANOVA analysis. Only the sector demographic rejected the null hypothesis suggesting that there was a difference in the mean responses to question 5 between the sector groups. In other words there was a significant difference in the means of the responses by sector at the 0.05 level for question 5. The following box plots assess which groups are responding differently.

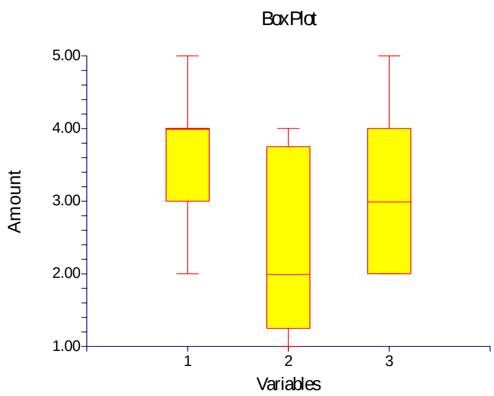


Figure 10: Box plot for responses to question 5 versus sector (1 = Government, 2 = Industry and 3 = Academia)

Figure 10 showed that the difference in means was occurring between the Government sector and Industry. Government was generally answering higher than 3 indicating a more positive attitude towards Question 5 (the organisation has a strong network of relationships with other biotechnology companies in South Africa) than was Industry who had a significantly greater negative response.

Question 6 (Equipment is difficult to source because we have to import most of it)

Seventy percent of respondents answered positively to question 6 (the answer appears negative due to the reverse coding used as described above). In order to test the significance of the above observation a one sample T-test was performed for question 6. The data below show the output.

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	1.1874	0.2351	Cannot reject normality
Kurtosis Normality	0.4784	0.6323	Cannot reject normality
Omnibus Normality	1.6388	0.4407	Cannot reject normality

Table 13: One sample T-test results for tests of assumptions section

Table 13 shows that all three tests for a normal distribution of the sample cannot reject normality. The sample was thus normally distributed. The T-test section was thus used.

T-Test for Difference between Mean and Value (3.0) Section

Alternative Hypothesis	T-Value	Probability level	Decision (5%)	Power (alpha = 0.05)	Power (alpha = 0.01)
Q1<>3	-5.1235	0.000011	Reject Ho	0.998730	0.989233
Q1 < 3	**-5.1235**	**0.000006**	**Reject Ho**	**0.999633**	**0.995249**
Q1 > 3	-5.1235	0.999994	Accept Ho	0.000000	0.000000

Table 14: T-Test for Difference between Mean and Value (3.0) Section

The null hypothesis for table 14 was that the mean response to questions 6 was three. It was clear from table 14 that the null hypothesis was rejected where the mean equals three. Where the mean was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.0000006. This result confirmed that the mean response was less than three and that the observation was statistically significant at the 0.05 level.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. No dependence between answers to question 6 and any of the demographic variables was observed using the ANOVA analysis.

5.3.3.1. SUMMARY OF RESULTS FOR PROPOSITION 2

- Question 5 had a bimodal distribution pattern of response. The Sector demographic was shown to be linked to response for question 5 with Government respondents having a higher mean response than Industry respondents. This suggests that government organisations are establishing relationships with biotechnology companies; however, industry organisations are not networking at present.
- Question 6 had mean responses statistically significantly less than 3 (neutral). This shows that suppliers were mainly agents for international companies and not strong local suppliers.
- Overall the **related and supporting industries attribute were shown to be deficient.**

5.3.4. PROPOSITION 3

Demand conditions within the South African Biotechnology sector are poorly developed.

QUESTIONS 7 AND 8 (DEMAND CONDITIONS)

Questions 7 and 8 assessed the respondents' attitudes to the Demand Conditions attribute of Porter's Diamond model. Issues relating to local customers were addressed.

Question	n	Mean	Std Error
7	36	3.5555	0.2010
8	36	1.5000	0.1351

Table 15: Descriptive statistics for Demand Conditions questions

Table 15 showed that the sample number was 36. Question 7 showed a mean response of 3.5555 with a standard error of 0.2010. Question 8 had a mean response of 1.5000 and a standard error of 0.1351. The following bar graph shows a break down of the responses.

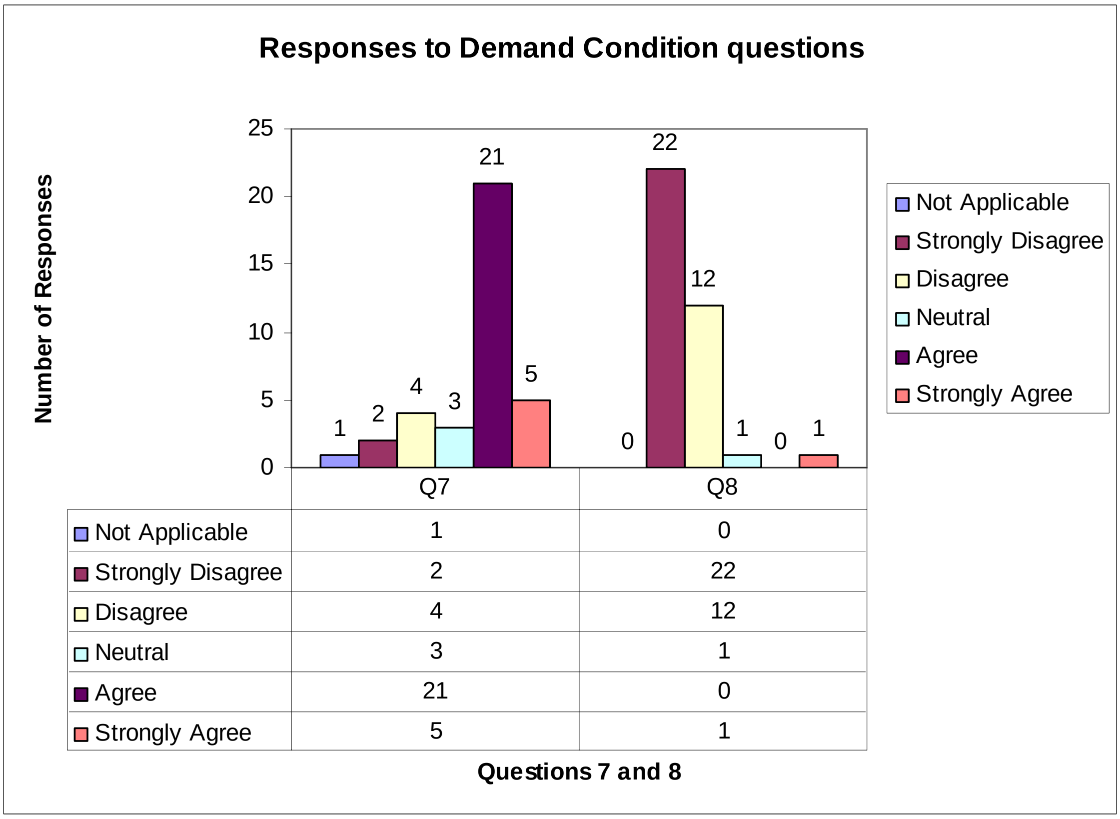


Figure 11: Bar chart showing responses to Demand Condition questions

Figure 11 showed that 72% of respondents agreed that their customers are mainly South African based (Question 7). Ninety four percent disagreed that the "lay person" has a good understanding of biotechnology (Question 8). In order to test the significance of the above observations one sample T-tests were performed for each question 7 and 8.

<u>Question 7 (Our customers are mainly South African-based)</u>

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	**-3.0363**	**0.0024**	**Reject normality**
Kurtosis Normality	1.6220	0.1048	Cannot reject normality
Omnibus Normality	**11.8500**	**0.0027**	**Reject normality**

<u>Table 16: One sample T-test results for tests of assumptions section</u>

The test for normality revealed that the sample was not normally distributed (highlighted in red). The data was thus assessed using the Wilcoxon signed-rank test for difference in medians.

Wilcoxon Signed-Rank Test for differences in medians

Alternative Hypothesis	Z-Value	Probability level	Decision (5%)
Median<>3	2.7231	0.006629	Reject Ho
Median < 3	2.7231	0.996767	Accept Ho
Median > 3	**2.7231**	**0.003233**	**Reject Ho**

<u>Table 17: Wilcoxon Signed-Rank Test for differences in medians and Value (3.0) Section</u>

The null hypothesis for table 17 was that the median response to questions 7 was three. It was clear from table 17 that the null hypothesis was rejected where the median equals three. Where the median was greater than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.003233. This result confirmed that the median response was greater than three and that the observation was statistically significant at the 0.05 level. Thus the majority of respondents agreed that their customers were mainly South African-based.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. No dependence between answers to question 7 and any of the demographic variables was observed using the ANOVA analysis.

Question 8 (There is a good understanding of the biotechnology industry in South Africa amongst the "lay person")

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	4.7080	0.000003	Reject normality
Kurtosis Normality	4.0296	0.000056	Reject normality
Omnibus Normality	38.4029	0.000000	Reject normality

Table 18: One sample T-test results for tests of assumptions section

The test for normality revealed that the sample was not normally distributed (highlighted in red). The data was thus assessed using the Wilcoxon signed-rank test for difference in medians.

Wilcoxon Signed-Rank Test for differences in medians

Alternative Hypothesis	Z-Value	Probability level	Decision (5%)
Median<>3	5.0131	0.000001	Reject Ho
Median < 3	**-5.0131**	**0.000000**	**Reject Ho**
Median > 3	-5.0131	1.000000	Accept Ho

Table 19: Wilcoxon Signed-Rank Test for differences in medians and Value (3.0) Section

The null hypothesis for table 19 was that the median response to questions 8 was three. It was clear from table 19 that the null hypothesis was rejected where the median equals three. Where the median was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.000000. This result confirmed that the median response was less than three and that the observation was statistically significant at the 0.05 level. Thus the majority of respondents disagreed with the statement that there is a good understanding of the biotechnology industry in South Africa amongst the "lay person".

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. No dependence between answers to question 8 and any of the demographic variables was observed using the ANOVA analysis.

5.3.4.1. SUMMARY OF RESULTS FOR PROPOSITION 3

- Question 7 had mean responses statistically significantly greater than 3 (neutral). This showed that the majority of respondents indicated that their organisations' customers were mainly South African-based.
- Question 8 had mean responses statistically significantly less than 3 (neutral) which showed that the majority of respondents felt that the "lay person" in South Africa does not have a good understanding of biotechnology. This indicates a potential serious weakness in local demand.
- Overall there was a **mixed response to Demand Conditions**.

5.3.5. PROPOSITION 4

Firm strategy and rivalry is poorly developed in the South African biotechnology industry.

QUESTIONS 9 AND 10 (FIRM STRATEGY AND RIVALRY)

Questions 9 and 10 assessed the respondents' attitudes to the Firm Strategy and Rivalry attribute of Porter's Diamond model. Issues relating to local and international competitors were addressed.

Question	n	Mean	Std Error
9	36	1.444	0.1224
10	36	1.3889	0.1277

Table 20: Descriptive statistics for Firm Strategy and Rivalry questions

Table 20 showed that the sample size was 36. Question 9 had a mean response of 1.444 with a standard error of 0.1224. Questions 9 and 10 were "Yes and No" questions not Likert scale questions hence the neutral value is 1.5 (between 1 and 2) and not 3.0 as for the Likert scale questions. Question 10 had a mean response of 1.3889 with a standard error of 0.1277. The following bar graph shows the responses obtained.

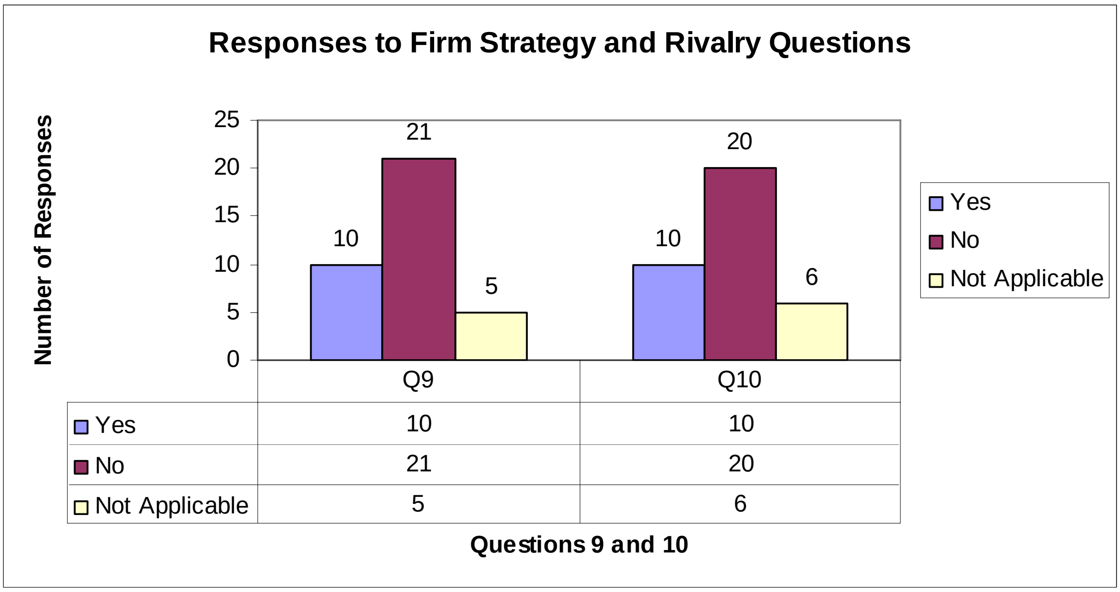


Figure 12: Bar chart showing responses to Firm Strategy and Rivalry questions

Figure 12 shows that 67% of respondents that considered this question relevant (i.e. excluding the "not applicable" responses) answered "No" to Question 9 indicating that their organisations did **not** have many competitors in South Africa. Sixty seven percent felt that their organisation did **not** have few, if any overseas competitors.

In order to test the significance of the above observations one sample T-test was performed for each question 9 and 10. No significant difference in the mean from the reference of 1.5 was observed at the 0.05 level for either question.

Due to the fact that questions 9 and 10 were not Likert scale questions (they were nominal data questions requiring a yes, no or not applicable answer), cross tabulation analysis using Chi-square test of independence was performed to determine if the responses were independent of the demographic variables.

Cross tabulation and Chi-square testing for Question 9 did not reveal any dependency between the demographic groups and responses.

Question 10 (Our organisation has few, if any overseas competitors)

The cross tabulation data generated for Question 10 versus sector is shown below.

Chi-square statistics section	**Value**	**Accept/Reject Ho**
Chi-square	10.1950	
Degrees of freedom	4	
Probability Level	0.0373	**Reject Ho**

Table 21: Cross tabulation of Sector vs response to question 10

Table 21 shows that the null hypothesis (that the row variables [response yes or no] and column variables [sectors] are independent of each other) is rejected (highlighted in red). This indicated that the response to question 10 was dependent on the Sector demographic. Exploring the Sector demographic more closely revealed the following cross tabulation tables for observed and expected counts:

Counts	Sector			
Question 10	Government	Industry	Academia	TOTAL
Yes	3	3	4	10
No	4	**13**	3	20
N/A	4	0	2	6
TOTAL	11	16	9	36

Table 22: Cross tabulation of observed counts section for Question 10 vs Sector

Expected	Sector			
Question 10	1	2	3	TOTAL
Yes	3.1	4.4	2.5	10
No	6.1	**8.9**	5.0	20
N/A	1.8	2.7	1.5	6
TOTAL	11	16	9	36

Table 23: Cross tabulation of expected counts section for Question 10 vs Sector

Tables 22 and 23 showed that the largest variation between the observed values and the expected values was seen in the Industry sector answering "no" (highlighted in red). The responses showed that Industry respondents indicated that their organisations did not have few, if any overseas competitors.

None of the other demographic variables showed any dependency.

5.3.5.1. SUMMARY OF RESULTS FOR PROPOSITION 4

- Questions 9 and 10 had mean responses not statistically significantly different than 1.5 (neutral).
- The Sector demographic was shown to be linked to response for question 10 with Industry respondents having a higher mean response than the other two respondent groups. Industry generally answered no to the question that their organisation has few, if any overseas competitors.
- The results **do not support nor refute the proposition** that Firm strategy and rivalry is poorly developed in the South African biotechnology industry.

5.3.6. PROPOSITION 5

South African biotechnology institutions or firms have no interest in the establishment of a dedicated biotechnology (science) park.

QUESTION 11 – BIOTECHNOLOGY PARKS

This question sought to assess the respondents' opinions with respect to the formation of dedicated biotechnology parks and whether they felt such a park or parks would help grow the biotechnology industry in South Africa.

Question	n	Mean	Std Error
11	36	2.2778	0.1809

Table 24: Descriptive statistics for Question 11

Table 24 shows that the sample size was 36. The mean response to question 11 was 2.2778 with a standard error of 0.1809. This suggested a negative response to question 11. The following bar graph shows a breakdown of the responses obtained.

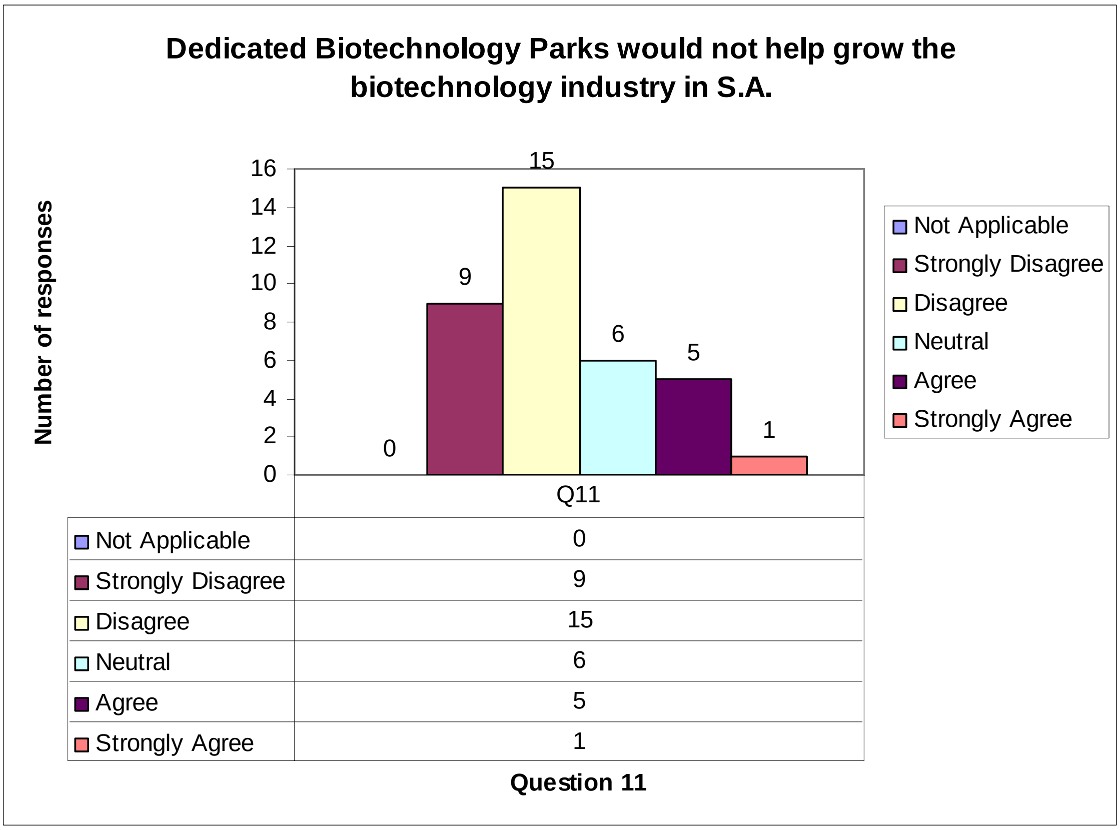


Figure 13: Bar Chart showing responses to question 11

Figure 13 shows that 67% of respondents disagreed with the statement that dedicated biotechnology parks would not help grow the South African biotechnology sector. In order to test the significance of the above observation a one sample T-test was performed. The data below show the output.

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	1.7427	0.0814	Cannot reject normality
Kurtosis Normality	-0.1192	0.9051	Cannot reject normality
Omnibus Normality	3.0513	0.2175	Cannot reject normality

Table 25: One sample T-test results for tests of assumptions section

Table 25 shows that all three tests for a normal distribution of the sample cannot reject normality. The sample was thus normally distributed. The T-test section was thus used.

T-Test for Difference between Mean and Value (3.0) Section

Alternative Hypothesis	T-Value	Probability level	Decision (5%)	Power (alpha = 0.05)	Power (alpha = 0.01)
Q1<>3	-3.9929	0.000319	Reject Ho	0.972645	0.889774
Q1 < 3	**-3.9929**	**0.000159**	**Reject Ho**	**0.988373**	**0.934431**
Q1 > 3	-3.9929	0.999841	Accept Ho	0.000000	0.000000

Table 26: T-Test for Difference between Mean and Value (3.0) Section

The null hypothesis for table 26 was that the mean response to questions 11 was three. It was clear from table 26 that the null hypothesis was rejected where the mean equals three. Where the mean was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.000159. This result confirmed that the mean response was less than three and that the observation was statistically significant at the 0.05 level. The majority of respondents thus disagreed with the statement that a dedicated biotechnology park would not help grow the South African biotechnology industry.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. No dependence between answers to question 11 and any of the demographic variables was observed using the ANOVA analysis.

5.3.6.1. SUMMARY OF RESULTS FOR PROPOSITION 5

- Question 11 showed that the majority of respondents disagreed with the statement that dedicated biotechnology parks would not help grow the biotechnology industry in South Africa. The results were found to be statistically significant at the 0.05 level.
- None of the demographic groups was shown to be linked to response for question 11.
- The **results refute Proposition 5** that South African biotechnology institutions or firms have no interest in the establishment of a dedicated biotechnology (science) park.

5.3.7. RESEARCH QUESTION 1

What is the primary motivation for South African biotechnology institutions or firms to relocate to a dedicated science park?

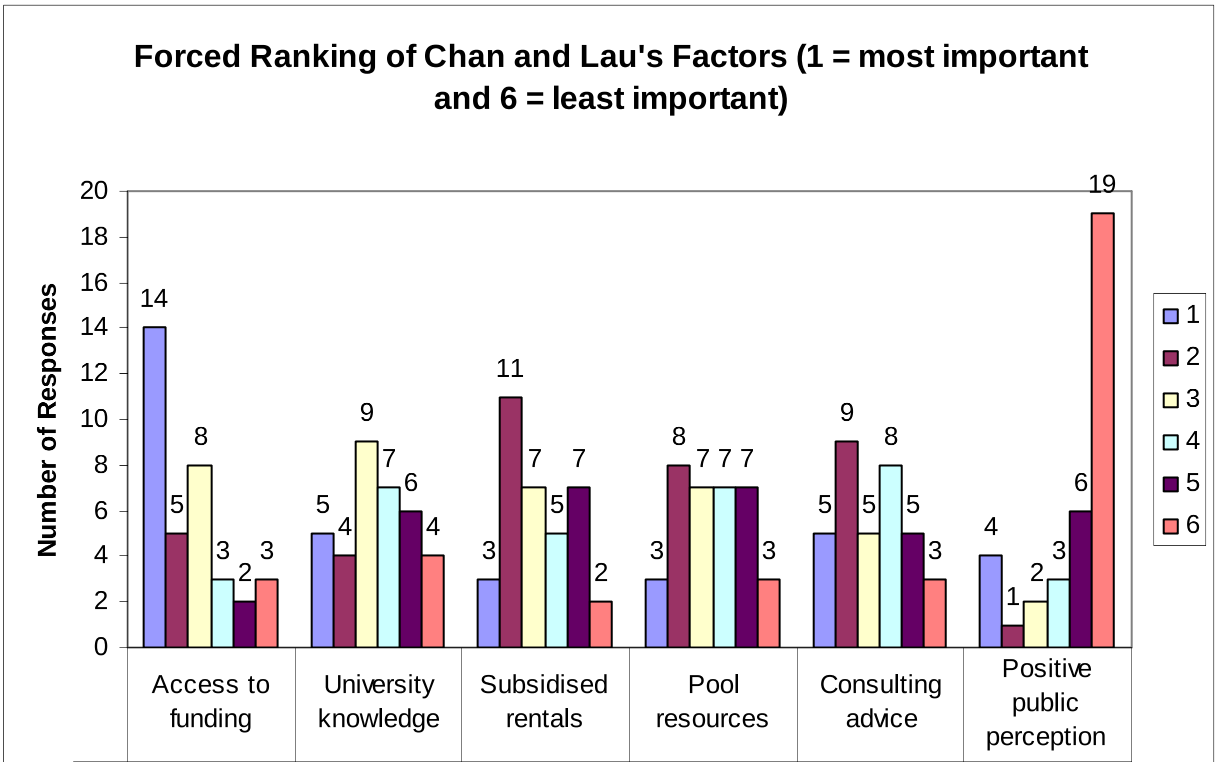
QUESTIONS 12 TO 17 – CHAN AND LAU'S FACTORS

This section assesses the six factors identified by Chan and Lau (2003) as being important for assessing the success of science parks. Respondents were asked to rank the factors from one (most important) to six (least important) if they were considering locating their organisation within a park.

Question	n	Mean	Std Error
12	35	2.5143	0.2761
13	35	3.4857	0.2637
14	35	3.2286	0.2463
15	35	3.4571	0.2505
16	35	3.2286	0.2628
17	35	4.8000	0.2922

Table 27: Descriptive statistics for Question 12 to 17

Table 27 shows that the sample size was 35 and not 36. One respondent incorrectly answered this question by rating all the factors "3". This respondent's answers were thus removed from the analysis. Question 12 had a mean response of 2.5143 with a standard error of 0.2761. Question 13 had a mean response of 3.4857 with a standard error of 0.2637. Question 14 had a mean response of 3.2286 with a standard error of 0.2463. Question 15 had a mean response of 3.4571 with a standard error of 0.2505. Question 16 had a mean response of 3.2286 with a standard error of 0.2628. Question 17 had a mean response of 4.8000 with a standard error of 0.2922. The following bar graph shows the responses obtained for each question.



	Access to funding	University knowledge	Subsidised rentals	Pool resources	Consulting advice	Positive public perception
1	14	5	3	3	5	4
2	5	4	11	8	9	1
3	8	9	7	7	5	2
4	3	7	5	7	8	3
5	2	6	7	7	5	6
6	3	4	2	3	3	19

Questions 12 to 17

Figure 14: Chart showing responses to questions 12 to 17

Figure 14 shows that only two factors can be rated from the data. Question 12 (Increased access to funding) was rated as the most important factor (1) by 40% of respondents. Question 17 (Public would view the company more favourably) was rated as the least important factor (6) by 54% of respondents.

Questions 13 to 17 show no clear rank of importance.

A weighting was thus performed on the data as per the table below. The weighted responses were then summed to give a final weighted response value for each question.

Response	1	2	3	4	5	6
Weighted Response	6	5	4	3	2	1

Table 28: Weighting of responses for Questions 12 to 17

The weighted responses were calculated as follows. Table 28 shows that if a factor was given a ranking of one by the respondent, that ranking would count for six points on the weighted ranking scale. A factor given a ranking of two was given 5 points on the weighted ranking scale, and so on. Each question's total points were calculated (simply the sum of the weighted scores) and these results are shown in the figure below:

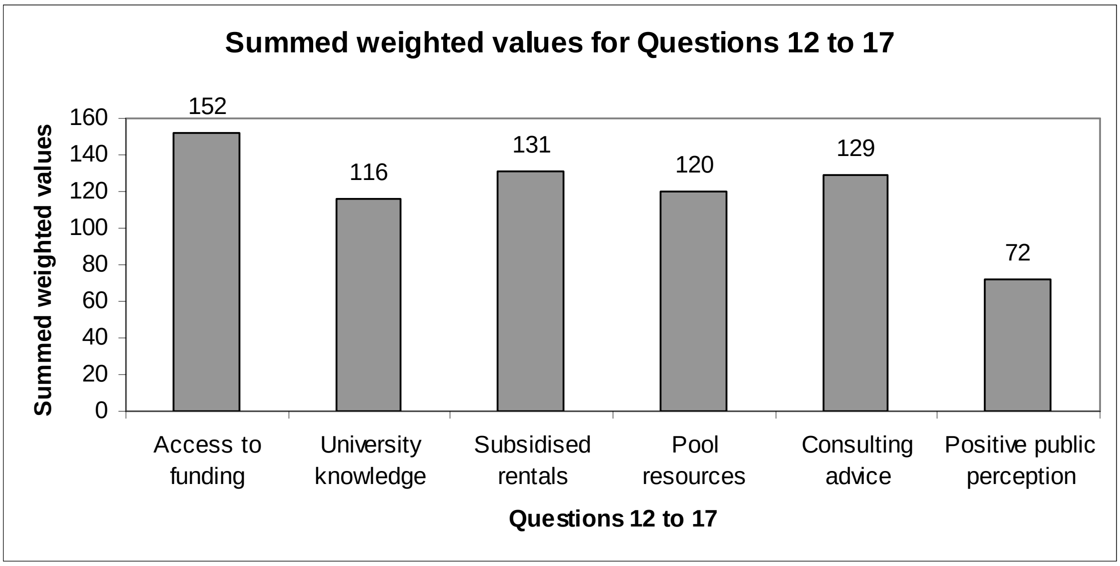


Figure 15: Total weighted scores for each factor from questions 12 to 17

Figure 15 shows the summed weighted values for questions 12 to 17. A forced ranking could be performed on these scores to assess the factor rankings. The table below gives the factor ranking based on the weighted scores.

Factor	**Weighted score**	**Ranking** (1 = most important factor; 6 = least important factor)
Increased access to funding	152	**1**
Subsidised rentals	131	**2**
Easier access to consulting advice on product development	129	**3**
Pool resources amongst tenants and lower training costs	120	**4**
Access to university knowledge	116	**5**
The public would view companies within the Park more favourably	72	**6**

Table 29: Ranking of factors from questions 12 to 17

Increased access to funding was ranked as the most important factor with subsidised rentals as the second most important. Easier access to consulting advice on product development was the third most important factor with pooling of resources amongst tenants and lower training costs fourth. Access to university knowledge was ranked fifth and the least important factor was public perception of a company within the park.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. The analysis showed that all the means were equal for responses versus demographic variables. No group's answers were skewed in any significant way.

QUESTION 18 – OVERALL INTEREST IN LOCATING WITHIN A BIOTECHNOLOGY PARK

This question assessed the overall interest of respondents in locating within a dedicated biotechnology park. The question was negatively worded.

Question	n	Mean	Std Error
18	36	2.0000	0.2520

Table 30: Descriptive statistics for question 18

Table 30 shows that the sample size was 36. The mean response was 2.0000 with a standard error of 0.2520. This suggested a negative response to question 18. The bar graph below gives a breakdown of responses obtained.

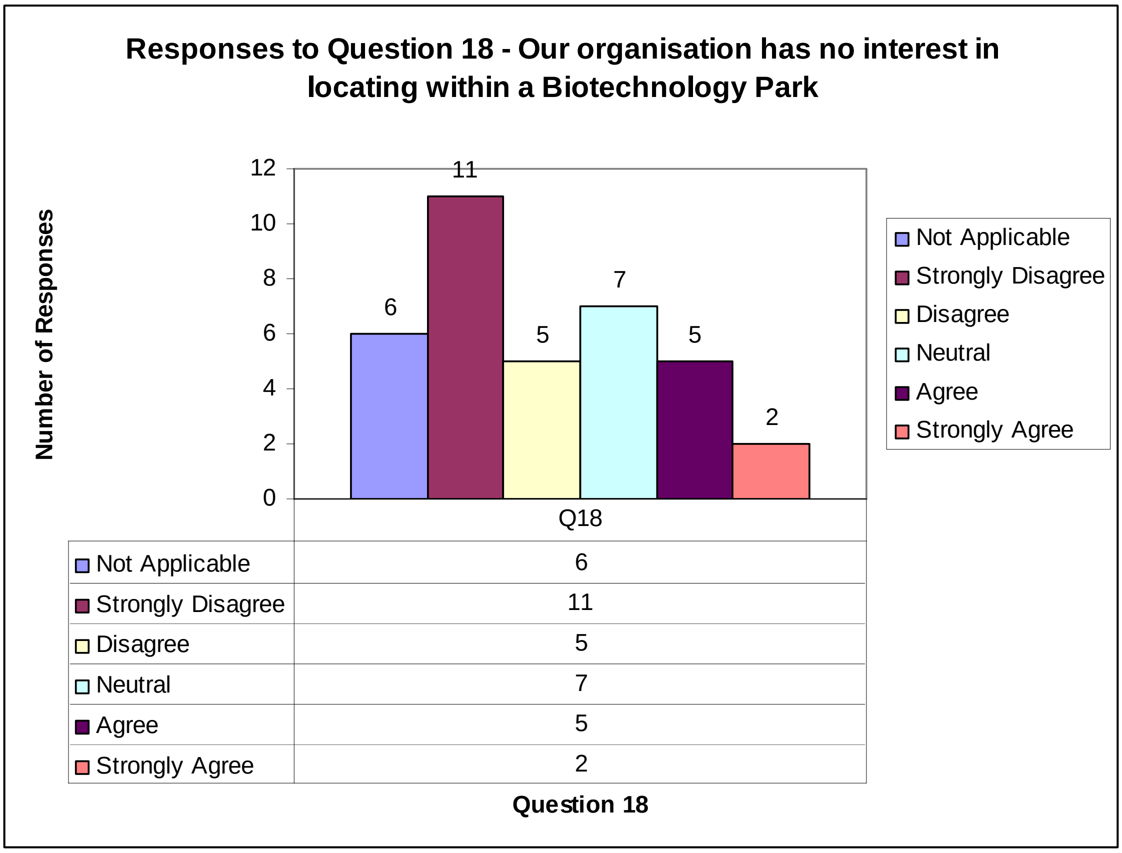


Figure 16: Bar chart showing responses to question 18

Figure 16 shows that 53% of respondents that considered this question relevant (i.e. excluding the “not applicable” responses) disagree with the statement that their organisations would not have any interest in locating within a dedicated biotechnology park. Twenty three percent agree with this statement and 23% were neutral. In order to test the significance of the above observation a one sample T-test was performed. The data below show the output.

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	0.9739	0.3301	Cannot reject normality
Kurtosis Normality	-1.7944	0.0728	Cannot reject normality
Omnibus Normality	4.1682	0.1244	Cannot reject normality

Table 31: One sample T-test results for tests of assumptions section

Table 31 shows that all three tests for a normal distribution of the sample cannot reject normality. The sample was thus normally distributed. The T-test section was thus used.

T-Test for Difference between Mean and Value (3.0) Section

Alternative Hypothesis	T-Value	Probability level	Decision (5%)	Power (alpha = 0.05)	Power (alpha = 0.01)
Q1<>3	-3.9686	0.000342	Reject Ho	0.971125	0.885368
Q1 < 3	**-3.9686**	**0.000171**	**Reject Ho**	**0.987630**	**0.931404**
Q1 > 3	-3.9686	0.999829	Accept Ho	0.000000	0.000000

Table 32: T-Test for Difference between Mean and Value (3.0) Section

The null hypothesis for table 32 was that the mean response to questions 18 was three. It was clear from table 32 that the null hypothesis was rejected where the mean equals three. Where the mean was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.000171. This result confirmed that the mean response was less than three and that the observation was statistically significant at the 0.05 level. The majority of respondents thus disagreed with the statement that their organization had no interest in locating within a dedicated biotechnology park.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. The analysis showed that all the means were equal for responses versus demographic variables. No group's answers were skewed in any significant way.

5.3.7.1. SUMMARY OF RESULTS FOR RESEARCH QUESTION 1

- The **primary motivation for South African biotechnology institutions or firms to relocate to a dedicated science park** (as measured by Chan and Lau's factors) is **increased access to funding**.
- Public perception of companies within the Park was considered the least important factor.
- Chan and Lau's factor rating is as follows (most to least important):

1. Increased access to funding
2. Subsidised rentals
3. Easier access to consulting advice on product development
4. Pool resources amongst tenants and lower training costs
5. Access to university knowledge
6. The public would view companies within the Park more favourably

- Question 18 showed that the majority of respondents disagreed with the statement that their organisation had no interest in locating within a biotechnology park. This result was shown to be statistically significant.

5.3.8. RESEARCH QUESTION 2

What is the single most critical factor for the success of the South African biotechnology industry?

QUESTION 19 – SOUTH AFRICA'S ABILITY TO DEVELOP A GLOBALLY COMPETITIVE BIOTECHNOLOGY INDUSTRY

This question sought the respondents' opinions on whether South Africa would be able to develop a globally competitive biotechnology industry. The results from this question were used to determine how valid the results of question 20 were.

Question	n	Mean	Std Error
19	36	1.8611	0.1499

Table 33: Descriptive statistics for question 19

Table 33 shows that the sample size was 36. The mean response was 1.8611 with a standard error of 0.1499. This suggests a negative response to question 19. The following bar graph shows the break down of responses obtained.

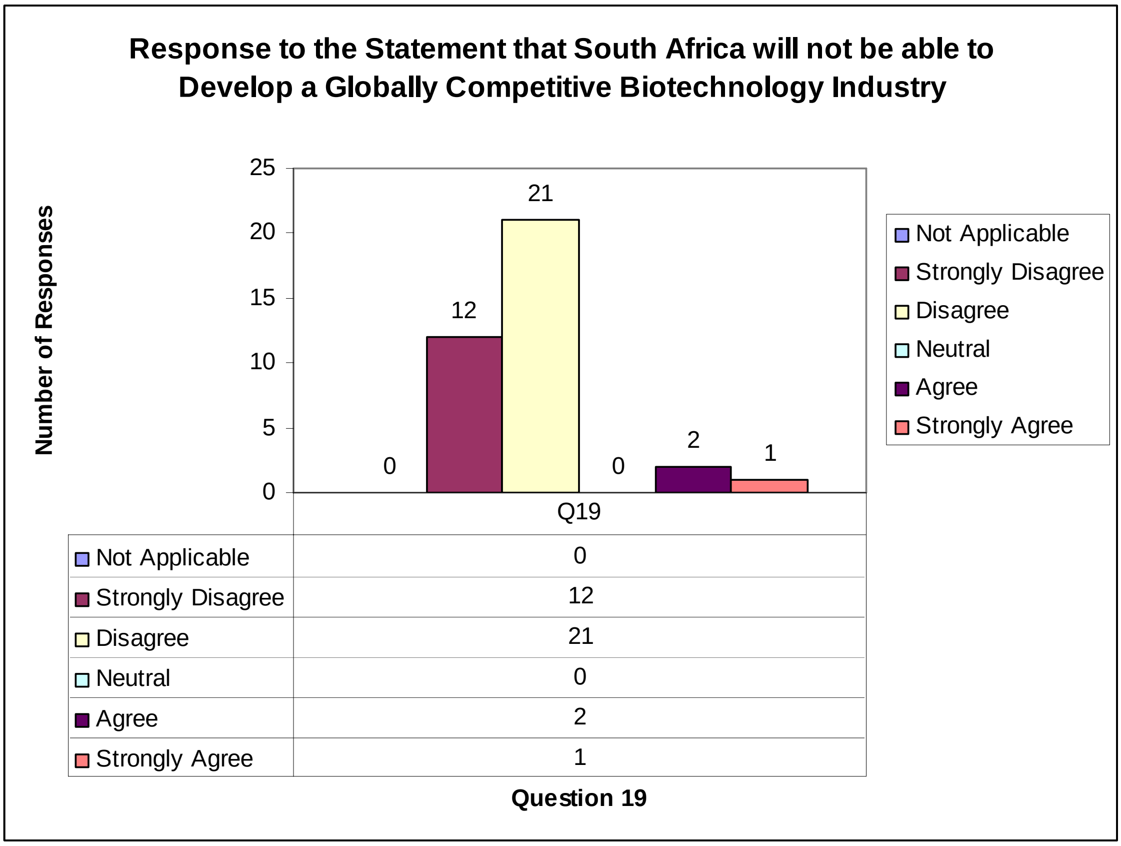


Figure 17: Bar chart showing responses to question 19

Figure 17 shows that 92% of respondents disagree with the statement that South Africa will not be able to develop a globally competitive Biotechnology industry. Only 8% agree with this statement. In order to test the significance of the above observation a one sample T-test was performed.

Tests of Assumptions Section

Assumption	Value	Probability	Decision (5%)
Skewness Normality	3.7528	0.000175	Reject normality
Kurtosis Normality	2.9803	0.002880	Reject normality
Omnibus Normality	22.9655	0.000010	Reject normality

Table 34: One sample T-test results for tests of assumptions section

The test for normality revealed that the sample was not normally distributed (highlighted in red). The data was thus assessed using the Wilcoxon signed-rank test for difference in medians.

Wilcoxon Signed-Rank Test for differences in medians

Alternative Hypothesis	**Z-Value**	**Probability level**	**Decision (5%)**
Median<>3	4.5542	0.000005	Reject Ho
Median < 3	**-4.5542**	**0.000003**	**Reject Ho**
Median > 3	-4.5542	0.999997	Accept Ho

Table 35: Wilcoxon Signed-Rank Test for differences in medians and Value (3.0) Section

The null hypothesis for table 35 was that the median response to questions 8 was three. It was clear from table 35 that the null hypothesis was rejected where the median equals three. Where the median was less than three (highlighted in red), the null hypothesis was also rejected with a probability level of 0.000003. This result confirmed that the median response was less than three and that the observation was statistically significant at the 0.05 level. Thus the majority of respondents disagreed with the statement that South Africa would not be able to develop a biotechnology sector that will compete globally.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. The analysis showed that all the means were equal for responses versus demographic variables. No group's answers were skewed in any significant way.

QUESTION 20 – THE SINGLE MOST CRITICAL FACTOR FOR THE SUCCESS OF THE SOUTH AFRICAN BIOTECHNOLOGY INDUSTRY

Respondents were asked to choose the factor they considered the most critical for the success of South Africa's biotechnology industry.

Question	n	Mean	Std Error
20	36	2.9167	0.3018

Table 36: Descriptive statistics for question 20

Table 36 shows that the sample number was 36. The mean was 2.9167 with a standard error of 0.3018. Because this question was a ranking question the mean and standard error are not particularly useful. The following bar graph gives a break down of the ranking of factors.

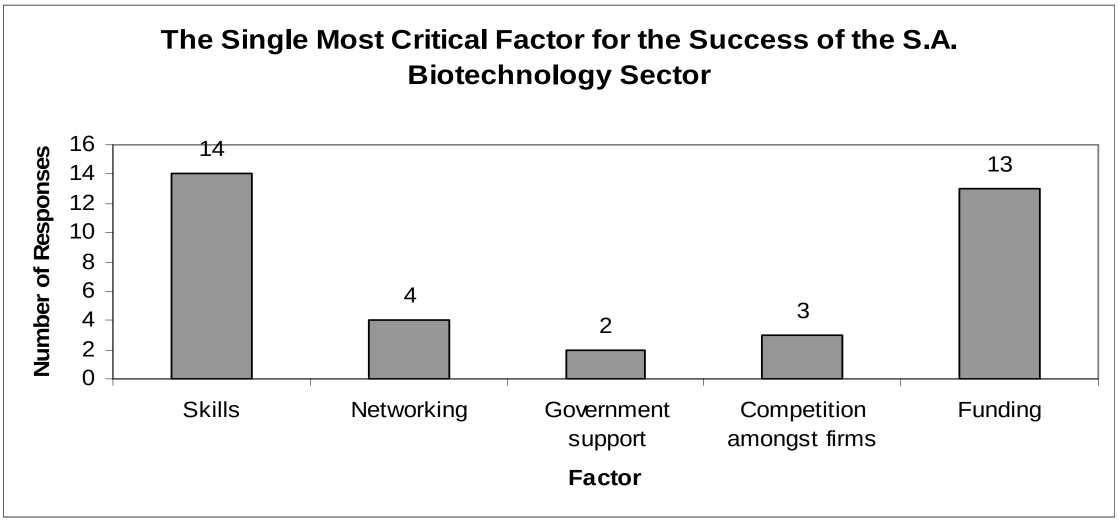


Figure 18: Bar chart showing responses to question 20

Figure 18 shows that skills and funding were considered the most important factors. The following table gives the forced rankings of the factors.

Factor	Total score	Ranking (1 = most important factor; 5 = least important factor)
Skills	14	**1**
Funding	13	**2**
Networking	4	**3**
Competition amongst firms	3	**4**
Government Support (Tariffs, tax incentives)	2	**5**

Table 37: Forced factor rankings from question 20

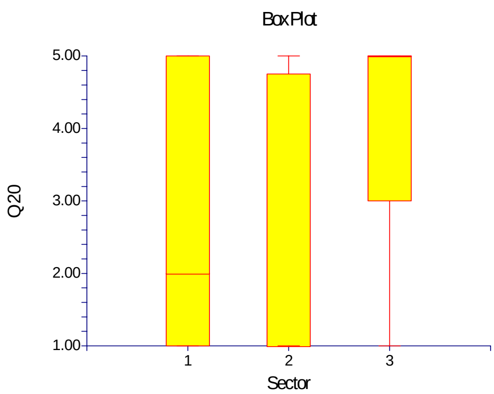
It is evident that Skills and funding were considered the most critical factors. Skills was given the ranking of one (most important) with funding getting the ranking of two although only one response separated the two factors. This was done in order to give rankings from one to five however it is highly likely that skills and funding are considered equally important. Networking, competition amongst firms and government support all received much lower responses and hence were given lower rankings.

One-way ANOVA analysis was performed to determine if there was any correlation between any of the demographic variables and response. The analysis showed that the means were not equal for the sector group.

Kruskal-Wallis One-Way ANOVA on Ranks				
Hypotheses Ho: All medians are equal. Ha: At least two medians are different.				
Test Results				
Method	**DF Decision (0.05)**	**Chi-Square (H)**	**Probability Level**	
Not Corrected for Ties	2	5.5372	0.0628	Accept Ho
Corrected for Ties	2	6.2030	**0.0450**	**Reject Ho**

<u>Table 38: ANOVA Output showing Kruskal-Wallis Test Results for Sector vs Question 20</u>

Table 38 shows that the null hypothesis (all medians between the sector groups and response to question 20 are equal) was rejected when corrected for ties at the 0.05 level and at the 0.07 level for not corrected for ties. The following box plots assessed which groups are responding differently.



<u>Figure 19: Box plot for responses to question 20 versus sector</u>
<u>(1 = Government, 2 = Industry and 3 = Academia)</u>

The box plot, figure 19, revealed that the mean response for government and industry are relatively close however academia generally answered higher up the scale (closer to 5). This suggests a focus on funding by academia.

5.3.8.1. SUMMARY OF RESULTS FOR RESEARCH QUESTION 2

- **Skills and funding were considered most critical factors** for the success of the South African biotechnology industry.
- Question 19 had mean responses statistically significantly less than 3 (neutral) showing that the majority (92%) of respondents disagreed with the statement that South Africa would not be able to develop a globally competitive biotechnology industry.
- No demographic variable was shown to be linked to response for question 19.
- The ranking of the critical factor from question 20 is as follows:

1. Skills
2. Funding
3. Networking
4. Competition amongst firms
5. Government support

- Academia rated funding most highly. There was no difference in the other demographic groupings versus responses.

5.3.9. SUMMARY OF FINDINGS

Proposition 1:

Factor Conditions are a problem for South African biotechnology institutions or firms.

The results support this proposition.

Proposition 2:

There is a deficiency in Related and Supporting Industries for biotechnology institutions or firms in South Africa.

The results support this proposition.

Proposition 3:

Demand Conditions within the South African Biotechnology sector are poorly developed.

The results are mixed with respect to this proposition.

Proposition 4:

Firm Strategy and Rivalry is poorly developed in the South African biotechnology industry.

The results neither support nor refute this proposition.

Proposition 5:

South African biotechnology institutions or firms have no interest in the establishment of a dedicated biotechnology (science) park.

The results refute this proposition.

Research Question 1:

What is the primary motivation for South African biotechnology institutions or firms to relocate to a dedicated science park?

The primary motivation was increased access to funding. The least important motivation was public perception.

Research Question 2:

What is the single most critical factor for the success of the South African biotechnology industry?

Two critical factors were identified namely skills and funding.

CHAPTER 6: DISCUSSION

6.1. INTRODUCTION

This chapter will discuss the research findings from Chapter 5 in terms of Porter's Diamond of National Competitiveness (1990a) and will address the strengths and weaknesses of the biotechnology industry in South Africa that have been identified. The discussion is presented under the same headings as the Results Chapter with each Proposition and Research Question being discussed individually.

6.2. DEMOGRAPHIC DATA

Four sets of demographic data were considered important in terms of an accurate assessment of the biotechnology industry in South Africa. The first demographic group was Sector. The major role players in the biotechnology industry in South Africa were identified as belonging to one of three broad sectors namely government, industry or academia. Although the sample size was small it is key that the sample did included representatives from all three sectors with industry represented by the greatest number of respondents. This was important considering that the research focussed on the industry specifically.

The second demographic group was years involved in biotechnology. This demographic was used to gather information relating to the relevant experience in the biotechnology industry of the sample. The results showed that the majority of respondents have been involved in biotechnology for only one to five years. This is interesting and illustrates the relative youthfulness of the biotechnology industry in South Africa which is, for the most part, still in its infancy. There are both positive and negative implications of this observation.

On the positive side, the biotechnology industry is attracting people in South Africa and these people bring with them new energy and perhaps innovative thinking. On the negative side, there are relatively few people in the biotechnology industry with years of experience who can act as mentors to newcomers. This could lead to frustration and people looking to overseas countries for opportunities and mentorship.

The third demographic group was company employees. This gave an indication of the size of the organisations in the biotechnology industry. The data showed that the majority of respondents came from small organisations (less than 20 employees). Interestingly the organisation sizes were generally either less than 20 employees or greater than 50 employees. The industry respondents almost exclusively had less than 20 employees in their organisations and this shows that the biotechnology industry is dominated by small enterprises. This is one of the reasons it is a key area of development for government because biotechnology has the potential to provide jobs and grow the economy.

The final demographic group was company product on the market. The inclusion of this demographic was to assess the extent of respondents' exposure to the forces of the market and to competition. This was of course key in terms of the theoretical framework of this study. Only 47% of respondents indicated that their organisations had product on the market while 36% responded that the question was not applicable.

Exposure to market forces impact heavily on two attributes of Porter's Diamond namely demand conditions and firm strategy and rivalry. It is not surprising then that these two attributes gave inconclusive results as assessed by this study. A concern is the high percentage of respondents who considered this question to be not applicable to them. The very essence of the biotechnology industry is to commercialise life sciences research and processes. Without this commercial focus it is very difficult to see what purpose one would play in the industry.

6.3. PROPOSITION 1

Factor conditions are a problem for South African biotechnology institutions or firms.

As discussed in Chapter 2, Porter (1990b) states that nations succeed in industries where they are particularly good at factor creation. The results show that this attribute of Porter's Diamond model is a problem in South Africa. Skills, capital and infrastructure were all shown to be difficult to obtain in the biotechnology industry.

The deficiency in skills and funding was a recurring theme in the research. Not only were these factors identified under direct testing but also in assessing Chan and Lau's (2005) factors and in the question regarding the single most critical factor for the success of the biotechnology industry. This supports the conclusion that Factor Conditions are definitely a problem for biotechnology organisations in South Africa.

The deficiencies in Factor Conditions are a critical stumbling block to success of the South African biotechnology industry. Without concerted efforts to address this attribute of the Diamond there can be little to be optimistic about. South Africa has excellent Life Sciences training and professionals. What is needed is industry training and experience. The skills employed in industry are obviously very different from those employed in research.

6.4. PROPOSITION 2

There is a deficiency in related and supporting industries for biotechnology institutions or firms in South Africa.

The biotechnology industry is a highly specialised industry requiring specialised inputs. The 2003 survey conducted by Mulder (2003) noted that most of the large international life sciences materials suppliers have agencies in South Africa. Despite this the research has shown that organisations consider supplies and equipment difficult to source.

The South African biotechnology industry is small and this must translate into small volumes (compared to countries such as the USA) of supplies and equipment being provided into the industry. Suppliers may even only provide catalogues and equipment is then ordered from the parent company when a firm order is received. This slows down the supply chain and makes South African companies very susceptible to the currency fluctuations of the Rand.

Networking with related companies and within the industry appears to be seen within the government sector. This is perhaps not surprising given the fact that the strategy mandates the BRICs to develop such relationships. Industry however does not appear to be developing relationships with other biotechnology companies or related companies within South Africa. Mulder (2003) observed that the industry appears fragmented and that companies regard information as highly sensitive. While this is very true for the biotechnology industry, a greater flow of ideas and communication should be encouraged. This flow of ideas and knowledge is, after all, the very essence of the Network Economy.

Forums for sharing ideas are not strongly promoted among the industry sector. Intellectual property would obviously not be shared however general concepts and information could be networked.

6.5. PROPOSITION 3

Demand conditions within the South African Biotechnology sector are poorly developed.

The results of this study showed that the majority of respondents considered there to be a poor understanding of biotechnology amongst the general public in South Africa. Porter (1998a) argues that a nation's companies gain a competitive advantage where the local customers or domestic buyers are the world's most sophisticated and demanding. This pressure from customers forces companies to innovate and become competitive if they are to exist. The issue of sophisticated local buyers is clearly a problem for South African biotechnology companies.

Overseas customers may be more important to the South African biotechnology industry in the short to medium-term while locally customer information and education on biotechnology should be a priority. While it is commendable that many respondents agreed that their customers are mainly South African based, Porter's theories on demand conditions may justify companies looking further afield if they are to find more sophisticated customers and learn to compete globally.

The observation that the majority of organisations had local customers could be considered a positive in terms of local demand however further assessment of this observation is required. The reason could be that there is strong demand in

South Africa. However it could be that South African firms are not globally competitive or are too small to exploit global markets.

Certain demand forces are influencing the biotechnology industry, not just in South Africa but globally, and there may be an opportunity for South African companies. Governments all over the world are pushing for lower cost medicines. Biotechnology has the potential to provide medicines at costs lower than traditional pharma companies can. South African biotechnology companies in the health biotechnology sector have a cost base advantage over traditionally first world countries. Diseases specific to developing world countries like malaria, tuberculosis and HIV are candidates where South African health biotechnology companies should be able to develop a competitive advantage if they focus their resources.

While demand conditions do appear to be poorly developed as assessed by this study there is potential.

6.6. PROPOSITION 4

Firm strategy and rivalry is poorly developed in the South African biotechnology industry.

Porter (1998) considers this attribute of the Diamond the most important because rivalry has a powerfully stimulating effect on all the other attributes. O'Connell and Clancy (1999) on the other hand argue that these factors may be less important in the Ireland context. South Africa has a small biotechnology industry and yet the national survey in 2003 identified 106 companies involved in biotechnology (both core and non-core).

The survey also noted that the industry is fragmented, a point-of-view shared by some of the respondents to this study. Porter (1998) also maintains that geographic concentration magnifies the power of domestic rivalry. The BRIC strategy is an attempt to spawn geographic cluster in the four regions where the BRICs are located. While this is a noteworthy aim the question has to be asked whether four BRICs are necessary or whether it would be more appropriate to try and stimulate the industry in a single geographic location in order to create a critical mass. This would concentrate not only the biotechnology companies but also suppliers and other supporting industries. Fragmentation by definition is the antithesis of clustering, a fact which should be carefully considered.

The results did not support or refute this proposition however one must suppose, based on the results for the other attributes and the general view points of the respondents, that it is likely that firm strategy and rivalry is poorly developed in the South African biotechnology industry.

6.7. PROPOSITION 5

South African biotechnology institutions or firms have no interest in the establishment of a dedicated biotechnology (science) park.

Science parks have been used, with mixed success, throughout the world as a strategy to stimulate (or fast track) cluster development. The main industries targeted for these parks have been high technology industries like Information Technology and also Biotechnology. The aim of the science park is to aggregate like businesses in order to stimulate networking and competition and also to provide structural support to start-ups.

Some refer to these parks as incubators and South Africa has some examples of incubators. These incubators, however, have not been shown to be successful as yet. The majority of respondents were of the opinion that such parks may be useful in growing the biotechnology industry. This observation suggests that South African biotechnology organisations do have an interest in geographic concentration.

Another strategy that has been used successfully is the establishment of a Biotechnology Institute such as Cuba and Taiwan have done (Ferrer, 2004; Zhenzhen, 2004). This strategy is slightly different because it does not focus on aggregating a number of like firms. Rather there is a focussed development of a single institute which is setup and run as a business. The institute provides industry training to the staff as well as employment. Visiting professionals are involved in skills transfer to local professionals. While this approach does not directly address clustering, it does dramatically and quickly address factor conditions such as skills development. Clustering may occur as spin-off companies are established out of the institute.

As discussed above Porter (1998) suggests that geographic concentration magnifies the power of domestic rivalry and a local willingness amongst biotechnology organisations to consider this possibility is encouraging and suggests a path forward.

6.8. RESEARCH QUESTION 1

What is the primary motivation for South African biotechnology institutions or firms to relocate to a dedicated science park?

Chan and Lau (2005) suggested a list of seven factors which they considered important in assessing the success of Information Technology science parks in Hong Kong. There are no established, successful Biotechnology parks as yet in South Africa and the primary reason for this research question was to assess which of Chan and Lau's factors would be the most important in the minds of South African biotechnology industry stake holders for locating within such a park.

The research showed that access to funding was considered the most critical factor. Interestingly but perhaps not surprisingly public perception was the factor considered least important. This finding ties in with what was mentioned earlier regarding commercialising product and the high response rate of "not applicable". Of all the factors identified by Chan and Lau (2005) only public perception is externally focussed. All the other factors address what is good for the company itself (internally focussed) rather than what is good for the customer or what contributes towards a positive customer relationship. The only conclusion that can be drawn from these observations is that South African biotechnology stakeholders are not focussed enough on the market and are exceptionally internally focussed.

The other four of Chan and Lau's factors showed no clear ranking order which suggests that either the other four factors are not suitable assessment factors in the South African context or that they carry equal importance in the minds of the respondents.

6.9. RESEARCH QUESTION 2

What is the single most critical factor for the success of the South African biotechnology industry?

The research revealed that skills and funding were considered the most critical factors for the success of the biotechnology industry in South Africa. Both of these factors can be located in the Factor Condition attribute of Porter's Diamond. Skills are critical to biotechnology globally, not specifically in South Africa, but there is clearly a deficiency in industry related skills in South Africa. There are a number of ways to go about addressing the issue of skills creation.

South Africa has a well developed Life Sciences training programme at tertiary institutions. This is necessary for a successful biotechnology industry but not enough on its own. Life science graduates who are interested in pursuing a career in biotechnology have very few choices in South Africa at present. Porter (1990b) states that nations succeed in industries where they are particularly good at factor creation. Porter (1998) goes further by saying that the presence of world-class institutions that first create specialised factors and then continually work to upgrade them creates competitive advantage. South Africa has no biotechnology specific institution to create these factors. Cuba and Taiwan created an institute as described earlier and perhaps this is the route to follow if South Africa is to succeed.

Biotechnology is not simply good life sciences research; that is Research and Development (R & D). Biotechnology takes R & D one step further by using the R & D for commercial gain. Biotechnology is business not science and this is where a fundamental misunderstanding occurs in South Africa. Life sciences research is an input for biotechnology, much like timber is an input for furniture. One could conceivably sell a log as a couch however in order to be successful in the market converting the log into a leather and wood lounge suite would make good business sense. It is these business skills that are so critical to the success of the biotechnology industry.

6.10. CONCLUSIONS

The research has shown that the South African biotechnology industry is weak on virtually all attributes of Porter's Diamond of National Competition.

Factor Conditions

Skills and access to capital were identified as the factors most lacking in South Africa in terms of biotechnology. These are both critical Factor inputs and must be addressed urgently. On the positive side South Africa has good life sciences training. Life sciences graduates however need to find opportunities in industry in order to develop the skills necessary for a career in biotechnology.

Related and Supporting Industries

Although life sciences materials suppliers are represented by agents in South Africa, most still source stock from overseas. This leads to long delays for raw materials and equipment if the local agent is out of stock. South African biotechnology companies are also exposed to currency fluctuations by this situation. Economies of scale brought about by a larger biotechnology industry would force suppliers to carry more stock or even manufacture in South Africa. It is thus in the interest of all stakeholders in the biotechnology industry to work towards growing the industry as a whole.

Demand Conditions

The understanding of biotechnology in South Africa amongst the general population is poor. Although many respondents said that their customers are

South African based the impression is that local demand is not sophisticated. A great concern is the general disregard of market factors amongst respondents. Biotechnology is all about commercialising life sciences research and thus a heavy focus needs to be placed on education with respect to markets and market forces.

Firm Strategy and Rivalry

Porter argues that this is the most critical driver of competitiveness. The South African biotechnology industry is fragmented and small. Local rivalry does not appear to be a significant feature of the industry at present. Bringing companies into close proximity by the formation of a dedicated biotechnology park may stimulate rivalry and thus advance competitiveness. The majority of respondents agreed that the establishment of a dedicated biotechnology park could help grow the South African biotechnology industry.

Porter (1998) suggests that it is possible to turn a disadvantage in a particular attribute of the Diamond into an advantage by forcing companies to innovate. He says that while this is true it is dependent on favourable circumstances elsewhere in the Diamond. Finding these favourable circumstances will be the key to the success of the biotechnology industry in South Africa.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1. INTRODUCTION

This chapter will present the findings of the study and make recommendations to policy makers, academics and industry stakeholders.

7.2. MAIN FINDINGS

South Africa, at the present, has a relatively poorly developed biotechnology industry. The industry is fragmented and the national strategy, while commendable in its intentions, does not appear to have delivered the desired results since its adoption in 2001. More time may be needed to assess the impact of the national strategy however serious deficiencies exist in the industry as identified in this assessment.

The three most serious deficiencies are a skills shortage, funding and a poor understanding regarding the nature of biotechnology even amongst stakeholders.

7.2.1. SKILLS

Biotechnology skills are highly specialised and are not the same as Life Sciences skills. South Africa has a long history of producing world-class life sciences researchers and professionals. While this is certainly something to be proud of there has been a complete lack of training with respect to the industry and business requirements for biotechnology. The skills needed for research and business are quite different. Neither is more important than the other: they are equally essential for success.

Life sciences graduates who have an interest in biotechnology have few choices in South Africa. If they are lucky they can perhaps find employment in a small biotechnology company. Most probably they will become frustrated at the lack of opportunity and either leave the biotechnology field or leave the country and seek opportunities elsewhere. This issue needs to be urgently addressed.

7.2.1.1. RECOMMENDATIONS REGARDING SKILLS

Recommendations to Industry:

Business and industry skills are probably best learned in the field. Companies involved in biotechnology should assess the feasibility of offering mentorship programmes in-house for promising life sciences graduates who are interested in biotechnology. These programmes could be run in conjunction with tertiary academic institutions.

Recommendations to Academia:

Biotechnology requires an understanding of business. Life sciences and biotechnology courses should be run jointly between business and science faculties. If this is not feasible at an undergraduate level then perhaps it should be considered at the post-graduate level.

Recommendations to Government:

The establishment of a biotechnology institute would provide opportunities for life sciences graduates to apprentice in the biotechnology industry. They would learn the relevant skills necessary and may even start their own companies. A dedicated biotechnology park would bring together a large number of firms, promote clustering and facilitate the transfer of skills through networking.

Government and academia (and industry if possible) could explore the possibility of offering interested graduates bursaries to gain work experience with overseas biotechnology companies or institutes however this may be difficult practically due to intellectual property concerns.

7.2.2. FUNDING

Access to funding was repeatedly identified as a deficiency. Biotechnology companies throughout the world are funded initially by venture capital groups and then some raise capital listing on a stock exchange. There are no publicly traded biotechnology companies in South Africa. Venture capital is also difficult to secure due to a very risk averse venture capital market in South Africa.

Government is trying to address this issue by making funds available through the BRIC system however the BRICs do not provide seed capital.

7.2.2.1. RECOMMENDATIONS REGARDING FUNDING

Recommendations to Industry:

Companies need to ensure that they develop very professional business plans and present these to venture capital groups. Giving up equity is a part of venture funding and should be thought through carefully.

Recommendations to Government:

In order to increase funding of biotechnology companies a novel strategy would be to allow individuals to donate a small proportion of their income to biotechnology companies tax-free. This could increase the flow of capital into the biotechnology industry and ultimately generate a greater tax return for government because the companies would use the money to employ people who pay tax. If the company is successful then more tax revenue is generated. Government should also look at measures to decrease the costs and red tape involved in setting up small businesses.

7.2.3. UNDERSTANDING BIOTECHNOLOGY

Without a clear understanding of the biotechnology industry it is very difficult to see how the industry will be able to survive in South Africa. Responses to certain of this study's questions raise serious concerns regarding the understanding of biotechnology in South Africa.

The Biotechnology industry is about commercialising products or process that have been created or modified by living organisms. Commercialisation is the key word here. Biotechnology stakeholders should be preoccupied with markets, customers and the company's or organisation's product. The biotechnology industry is an industry just like any other. It requires inputs such as skills, capital and raw materials and provides an output which is sold to generate revenue. In the case of biotechnology, life sciences research is a raw material. The process of creating a clone expressing a gene will not give rise to a biotechnology industry alone. Selling or licensing the clone or using it to produce the cloned protein which can then be sold is the start of an industry

7.2.3.1. RECOMMENDATIONS TO PROMOTE THE UNDERSTANDING OF BIOTECHNOLOGY

Recommendations to Industry:

Industry should consider becoming more involved in promoting biotechnology amongst the public but also amongst students and scholars. This may help sow the seeds of entrepreneurship and stimulate interest in the industry.

Recommendations to Academia:

The business and commercialisation side of the biotechnology industry needs more focus. Academia/industry partnerships in terms of lectures, vacation jobs and internships should be considered.

Recommendations to Government:

National meetings (road shows) such as Bio2Biz are essential in promoting biotechnology and creating awareness of the biotechnology industry.

7.3. ASSESSING THE BIOTECHNOLOGY INDUSTRY

Using Porter's Diamond of National Competitiveness as a framework this study showed that all the attributes of the Diamond are weak when applied to the South African biotechnology industry at present. An obvious assessment tool going forward would be to use the Diamond in future assessments and compare the results to see if progress has been made.

The results of this study have shown some very specific areas which could be singled out and focussed upon in future assessments. The areas can be divided into those that should be focussed on by government, by industry and by academia and those that overlap sectors. The ultimate measure of the success of the biotechnology industry is new product registrations or new markets entered. The figure below shows the assessment framework.

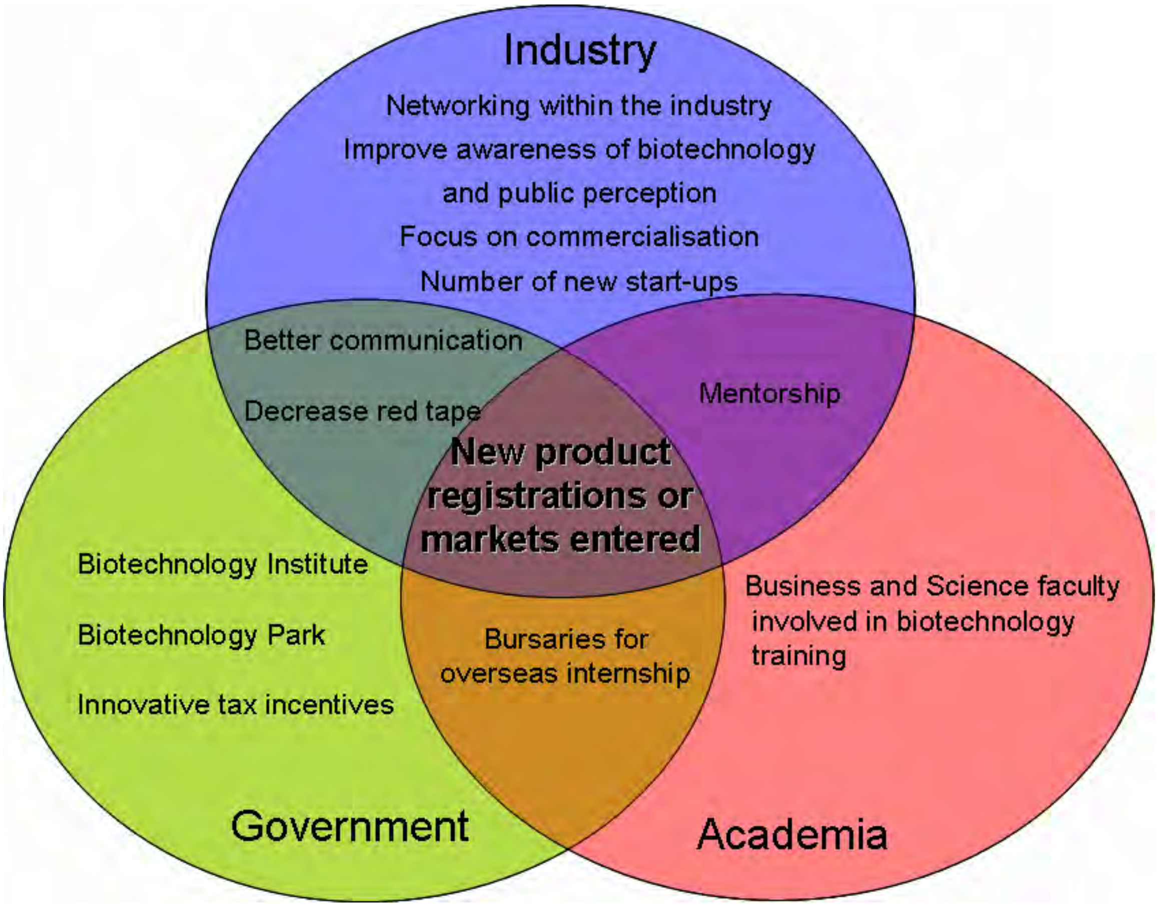


Figure 20: An Assessment Framework for the South African Biotechnology Industry

Figure 20 shows a framework for assessing the biotechnology industry in South Africa based on the findings of this study. Each oval represents a sector as labelled; Government, Academia and Industry. The three ovals overlap in an area labelled “new product registrations or markets entered”. This is the ultimate aim of the industry and would signal competitiveness if new product is registered or if new markets are entered.

Each sector has areas of focus specific to that sector alone. Progress in these areas can be assessed in the future. Where areas of focus overlap sector these are shown in overlapping ovals. Here both sectors would need to be studied in order to assess the progress.

Industry:

Industry should focus on developing networks within the industry. Networking will accelerate knowledge transfer and perhaps skills transfer. It would also promote rivalry and cooperation. Creating awareness of biotechnology could increase local demand and improve customer sophistication. Industry needs to be highly focussed on commercialising products. The number of new start-ups can be monitored to gauge activity. This could indirectly assess funding because it is unlikely that a company could be formed without sufficient funding.

Academia:

Academia should try and focus on biotechnology skills training. This does not mean a course on biotechnology which is already being offered at most Universities of Technology and Universities. It means focusing on the business and industry side of biotechnology, perhaps only at the post-graduate level.

Government:

Government's task is to facilitate industry development, regardless of the industry. In terms of biotechnology government should look into the establishment of a biotechnology institute (like Cuba or Taiwan) or possibly a more concerted effort into establishing viable biotechnology parks. Innovative tax incentives like allowing individuals to invest in biotechnology companies tax-free should be encouraged.

The above framework would allow an assessment going forward of one, two or all three sectors or a combination of sectors.

7.4. FUTURE RESEARCH

The purpose of doing an assessment is to use the analysis as a basis for future assessments. The obvious future research is thus a repeat assessment to gauge the level of progress or otherwise. This study has revealed a number of observations which warrant further research in their own right.

1. Skills were identified as a major deficiency for the biotechnology industry. A study to determine exactly which skills are in short supply would be useful. For example does the industry require quality assurance managers, cell culture technicians, business development managers or process engineers, to name a few? A study of this sort could be performed via a questionnaire to industry or by interviewing senior managers of biotechnology companies.
2. Funding was also identified as a major deficiency. A study assessing sources of funding should be undertaken and the results made available

to all stakeholders. Contact details of funding vehicles should be supplied.

3. As mentioned earlier a study should be considered to assess the nature of local demand. Many respondents stated that their organisations' customers were mainly South African-based. The question raised was: Is this a positive in terms of local demand or does it show that South African companies are not competitive internationally?
4. Tying in with the issue of local demand would be a study to assess the nature of current products on the market. This may reveal a particular strength in South Africa and may help to identify new markets for these products.
5. The BRICs and government, as enablers of industry, should become more involved in gathering information relevant to the biotechnology industry. Overseas government agencies frequently commission studies into areas of interest to industry and then make available the results of these studies. Areas to consider would be reviews of current trends in HIV research, market sizes for various disease treatments or the number of new biotechnology companies started in South Africa each year and the number that have closed down. These are just some examples, but information and knowledge are key to biotechnology.

7.5. IN CLOSING

South Africa's biotechnology industry is in its infancy. Many deficiencies have been identified using Porter's Diamond of National Competitiveness model and yet some positives exist. Global trends towards cheaper medication, a more secure food supply and environmental issues offer South African companies an attractive window of opportunity. South Africa's good science training, combined with a reasonable entrepreneurial spirit and relatively lower cost base, provides the platform for what could be a successful and globally competitive biotechnology industry.

The challenges however are great. Skills creation is not an issue which can be addressed overnight and yet the biotechnology industry is one where time is never on your side. Bold initiatives are required immediately, if not sooner, if South Africa is serious about developing a globally competitive biotechnology industry.

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Appendix 1

The Questionnaire used for the quantitative analysis

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

THE BIOTECHNOLOGY INDUSTRY IN SOUTH AFRICA QUESTIONNAIRE

Thank you for taking the time to complete this questionnaire. It should take less than ten minutes of your time. If you are using Microsoft Word simply "click" on the box you wish to check. For Questions 12 to 17 please click on the down arrow for numbers 1 to 6.

Demographics (please check the relevant box)			
Sector	Government ☐	Industry ☐	Academia ☐
Years involved in Biotechnology	1-5 ☐	6-10 ☐	>10 ☐
Company Employees	<20 ☐	20-50 ☐	> 50 ☐
Company Product on the market	Yes ☐	No ☐	Not applicable ☐

Question (please check the relevant box)	**Not Applicable**	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1. South Africa has a successful Biotechnology industry.	☐	☐	☐	☐	☐	☐
Comment why you think so:						
2. It is easy to recruit workers with the required biotechnology skills into our organisation.	☐	☐	☐	☐	☐	☐
3. Funding for biotechnology projects is difficult to obtain in South Africa	☐	☐	☐	☐	☐	☐
4. Physical infrastructure, for example facilities and equipment, are easy to locate and access within South Africa.	☐	☐	☐	☐	☐	☐
5. Our organisation has a strong network of relationships with other Biotechnology companies in South Africa.	☐	☐	☐	☐	☐	☐
6. Equipment is difficult to source because we have to import most of it.	☐	☐	☐	☐	☐	☐
7. Our customers are mainly South African-based.	☐	☐	☐	☐	☐	☐
8. There is a good understanding of the biotechnology industry in South Africa among the "lay person".	☐	☐	☐	☐	☐	☐
	Not Applicable	**No**	**Yes**			
9. Our organisation has many competitors in South Africa.	☐	☐	☐			
10. Our organisation has few, if any overseas competitors.	☐	☐	☐			

Question (please check the relevant box)	Not Applicable	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
11. Dedicated "Biotechnology Parks" where every tenant is involved in the Biotechnology sector would not help grow the Biotechnology Industry in South Africa.	☐	☐	☐	☐	☐	☐
For Questions 12 to 17: Please rate the following factors, assuming they were present, in order of importance when considering whether to locate your organisation within, or for establishing, a dedicated "Biotechnology Park" (most important factor = 1 and least important factor = 6).						
12. Increased access to funding.	0	**NOTE** **1 = MOST IMPORTANT** **6 = LEAST IMPORTANT**				
13. Access to University knowledge.	0					
14. Subsidised rentals.	0					
15. Pool resources amongst tenants and lower training costs.	0					
16. Easier access to consulting advice on product development.	0					
17. The public would view companies within the Park more favourably.	0					
18. Our organisation has no interest in locating within a dedicated "Biotechnology Park".	☐	☐	☐	☐	☐	☐
19. South Africa will not be able to develop a Biotechnology sector that will compete globally.	☐	☐	☐	☐	☐	☐
Comment why you think so:						
20. The single most critical factor for the success of the South African biotechnology industry is: **(please choose only the factor you consider MOST critical)**						
Skills	☐					
Networking	☐					
Government support (tariffs, tax incentives)	☐					
Competition amongst firms	☐					
Funding	☐					

Any other comments you feel are relevant:

Please return by fax to 011-656-9703 or Email to raymond@bioclones.co.za by **20 September 2006**

Appendix 2

The Coding Sheet Used for the Responses to the Questionnaire

Coding Sheet for Biotechnology Questionnaire

Question	Coding	Min-Max	Range	Measurement level
Sector	1=Gov, 2=Ind, 3=Academic	1-3	3	Nominal /categorical
Yrs	1=1to5, 2=6to10, 3=>10	1-3	3	Nominal /categorical
Employees	1=<20, 2=20-50, 3=>50	1-3	3	Nominal /categorical
Product	1=yes, 2=no, 3=N/a	1-3	3	Nominal /categorical
1	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
2	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
3	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
4	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal

Question	Coding	Min-Max	Range	Measurement level
5	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
6	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
7	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
8	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
9	1=yes, 2=no, 3=N/a	1-3	3	Nominal /categorical
10	1=yes, 2=no, 3=N/a	1-3	3	Nominal /categorical
11	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
12	1 = Most NB	1-6	6	Categorical
13		1-6	6	Categorical
14		1-6	6	Categorical
15		1-6	6	Categorical
16		1-6	6	Categorical
17	6 = Least NB	1-6	6	Categorical

Question	Coding	Min-Max	Range	Measurement level
18	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
19	1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree, 0=N/App	0-5	6	Ordinal
20	Skills = 1 Networking = 2 Gov Support = 3 Competition = 4 Funding = 5	1-5	5	Categorical

Appendix 3

Excel Database of Responses

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R30	R31	R32	R33	R34	R35	R36
Sector	2	3	3	3	1	1	2	3	2	1	2	1	2	2	2	3	2	1	1	2	1	3	1	1	2	2	2	3	3	2	2	3	1	1	2	2
Years	1	3	1	2	1	1	1	2	2	1	1	3	1	1	1	2	3	1	1	1	2	2	1	3	3	1	3	2	1	2	1	3	1	1	1	3
Employees	1	3	1	1	1	1	1	1	1	1	1	3	1	1	1	3	1	1	3	1	3	3	3	1	1	1	1	3	3	1	2	3	3	3	1	1
Product	3	3	1	1	3	3	3	2	2	3	1	1	1	2	1	3	1	2	1	1	1	3	2	1	1	1	1	3	3	2	1	3	3	3	1	1
Q1	4	2	2	2	3	2	2	4	2	2	4	2	2	3	2	2	3	3	2	2	2	4	3	2	2	1	2	3	2	1	2	1	1	2	1	1
Q2	2	2	2	1	4	1	1	2	3	1	2	2	3	1	2	2	4	2	2	2	2	3	2	2	1	1	2	2	4	2	1	1	4	1	2	1
Q3	2	1	1	2	4	4	2	3	4	2	2	2	5	4	1	4	2	4	2	1	3	2	3	2	3	2	2	2	1	1	2	1	3	2	2	2
Q4	2	2	3	3	3	3	2	2	2	2	2	2	2	4	5	2	2	1	2	2	3	2	4	2	2	3	2	3	2	1	2	2	4	2	2	1
Q5	4	2	2	4	4	4	1	4	3	4	2	5	2	4	4	3	2	3	5	4	4	5	4	2	1	1	2	3	2	2	2	3	2	3	2	1
Q6	3	2	4	4	0	3	0	2	2	0	2	5	1	4	2	3	2	2	2	2	3	1	3	2	2	1	1	1	2	1	2	2	1	3	1	1
Q7	4	3	4	4	4	4	2	4	4	5	2	2	1	4	4	0	4	4	4	5	3	4	3	4	4	4	5	4	4	4	2	4	5	5	4	1
Q8	3	1	1	2	2	1	1	2	1	1	1	1	1	1	1	2	1	2	2	2	1	1	2	5	1	1	1	2	2	2	1	2	1	1	1	1
Q9	2	1	2	2	0	2	1	2	2	0	1	1	2	2	2	1	1	0	2	1	2	0	1	0	2	2	1	2	2	1	2	2	2	2	2	2
Q10	2	1	1	0	1	1	2	2	2	0	2	2	1	2	2	2	2	1	2	2	2	0	2	0	1	1	2	1	1	2	2	2	0	0	2	2
Q11	1	2	4	3	3	4	1	1	2	2	3	3	2	2	1	2	2	1	1	3	3	4	2	2	4	2	2	2	2	4	1	2	1	2	1	5
Q12	2		1	1	3	1	6	2	3	2	1	1	1	3	1	4	4	3	1	3	5	4	2	3	6	1	3	1	1	1	1	2	3	5	1	6
Q13	4		5	5	5	3	2	1	1	5	3	3	6	4	3	1	3	5	2	2	4	5	1	6	2	3	4	4	3	5	3	1	2	4	6	4
Q14	6		3	2	4	4	5	4	4	3	5	4	2	5	5	5	2	4	3	1	6	2	3	2	5	2	5	2	2	3	2	3	1	1	2	1
Q15	3		2	4	1	2	3	5	2	6	4	5	3	1	4	2	5	2	4	5	2	6	4	4	3	4	1	3	5	4	6	5	5	3	3	2
Q16	1		4	3	2	5	4	3	5	4	2	2	4	2	2	3	1	1	5	6	1	3	5	1	4	5	2	6	4	2	5	6	4	2	4	3
Q17	5		6	6	6	6	1	6	6	1	6	6	5	6	6	6	6	6	6	4	3	1	6	5	1	6	6	5	6	6	4	4	6	6	5	5
Q18	3	5	4	4	1	3	3	2	1	1	3	3	2	2	1	1	0	1	4	0	3	5	4	1	3	2	1	0	0	1	1	0	2	0	1	4
Q19	1	5	2	2	1	2	2	2	1	2	1	2	1	2	2	1	1	2	1	2	2	2	2	1	2	4	2	2	2	2	2	1	4	2	1	1
Q20	5	5	5	5	2	1	5	2	1	1	5	5	4	1	5	1	1	1	5	1	2	4	3	5	1	1	3	5	5	1	1	5	2	4	1	1

Excel Database of Responses