LINKAGES BETWEEN PHARMACEUTICAL FIRMS AND UNIVERSITIES IN SOUTH AFRICA

Sechaba Bareetseng

A research report submitted to the Wits Business School, University of the Witwatersrand, in partial fulfillment of the requirements for the degree of Masters of Management in Innovation Studies

November 2014

SUMMARY

Technology-intensive industries such as the pharmaceutical industry have strong links with specialist providers of technological knowledge and receive inputs (e.g. advice, consultation and access to research equipment) from other actors such as universities. This study reports on the nature of the participating pharmaceutical firms' management decision making processes in forming linkages with universities.

The two research questions formulated for this study are -

i. What types of linkages do pharmaceutical firms operating in South Africa form with South African universities?
ii. How do South African pharmaceutical firms decide with which university/ies to form linkages?

In order to answer the research questions, a qualitative research methodology was employed to collect data from elite interviews with senior executives and senior managers from 20 pharmaceutical firms that participated in the study. The 20 pharmaceutical firms were represented by local and international firms operating in South Africa. Data was triangulated and entailed the collection of interviews from expert commentators drawn from universities and national government departments and government-owned scientific and technological knowledge-producing institutions.

The key findings are that these firms employ search and selection processes, and carry out evaluation processes when they seek external specialist providers of technological knowledge and other inputs, which have relevance for corporate decision making and policy development.

Declaration

I declare that this dissertation is my own, unaided work. It is submitted in partial fulfillment of the requirement of the degree of Master of Management in Innovation Studies at the Wits Business School at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any University.

_____

Sechaba Bareetseng

November 2014

Acknowledgements

I wish to express my gratitude **To Dr Diran Soumonni** for his supervision; **To my family,** for their amazing and undying support; and **To GOD**, whom **He** kept me strong and grounded during the period of my study

Table of Contents

1. CHAPTER 1: INTRODUCTION

1.1 Purpose of the research

The purpose of this research is to explore how the pharmaceutical firms operating in South Africa establish linkages with specialist providers of scientific and technological knowledge, such as universities.

1.2 Research questions

iii. What types of linkages do pharmaceutical firms operating in South Africa form with South African universities?
iv. How do pharmaceutical firms operating in South Africa decide on which university/ies to form linkages?

1.3 Problem statement

There is insufficient evidence about how pharmaceutical firms operating in South Africa establish linkages with universities and how they choose among alternative sources of specialised technological knowledge.

1.4 Context of the research

Linkages between firms in technology-intensive industries (such energy, telecommunication, steel and pharmaceutical) and universities contribute to the economic development of countries, as they are seen as key elements of innovation systems and have beneficial effects to firms' innovation processes (De Fuentes and Dutrénit 2012), and play an important role in fostering technology development (Cohen, Nelson and Walsh 2002) . For the purpose of this study, a linkage is an interaction between a firm and a university on research and technology development at the firm level, which may vary, depending on the needs of the firm. Linkages between firms and universities may include student training research programmes where students are placed in the firm to conduct a specific aspect of research (Meyer-Krahmer and Schmoch 1998; Bekkers and Freitas 2008), contract research

(Kingsley et al 1996; Monjon and Waelbroeck 2003) and university consultancy (Bekkers and Freitas 2008). In addition, firms have linkages with several sources of knowledge such as other firms, customers and suppliers. It is argued that these sources of technological knowledge can have a positive effect on management practices as well as overall firm innovation performance and productivity (Mol and Birkinshaw 2009). These types of linkages differ across technology industries and in their effectiveness to the firm innovation process and management, as well as the way in which knowledge is acquired by the firm from the university. According to Mowery and Sampat (2002), citing the Organisation of Economic Cooperation and Development publication of 2002, firms are involved in linkages with universities to acquire specific knowledge in order to improve their innovation performance and competitive advantage over their competitors. Thus, firms choose universities for various reasons to form linkages, such as providers of technological knowledge (Gunasekara 2006), as well as to reduce risks during the technology development process (Arranz and Arroyabe 2008), among other reasons. The latter authors mentioned that one of the advantages of the establishment of linkages between actors (e.g. universities and firms) within an innovation system is building of trust and enhancement of reputation for the actors concerned or involved (Arranz and Arroyabe 2008).

In order to understand how linkages improve technological and innovation performance of firms, several aspects of linkages were studied. These included the types, characteristics and nature of linkages (Arza and Lopez 2008; Schartinger, Schibany, Gassler 2001; Siyanbola et al 2012), the factors that facilitate the formation of linkages (Fontana, Geuna and Matt 2006; Giuliani and Arza 2009; Hamdan et al 2011) and the motivations and rationales for firms to form linkages with universities (Bayona, Garc´ıa-Marco, Huerta 2001; Brostrom 2008, 2010; Rasiah and Govindaraju 2009; Arza and Lopez 2011) and the benefits of linkages to firms (Leten, Landoni, Looy 2014; Buckley and Kafouros 2008), as well as the flow mechanisms of knowledge from universities to firms (Perkmann and Walsh 2009; Østergaard 2009; Hess and Rothaermel 2011; Zawislak and Dalmarco 2011; Fukugawa 2012; Erden et al 2014). The knowledge resource view literature suggests that firms' internal knowledge stock accumulated from knowledge flows and the

choices made by the management play an important role in increasing the innovation performance of firms (DeCarolis and Deeds 1999; Erden et al 2014).

These aspects of linkages were predominantly studied across technology-intensive industries using quantitative research methodologies within the context of developed countries, which are characterised by certain political, social, regulatory, legal and financial, as well as other socioeconomic attributes. There is a notable variation of linkages between firms and universities across technology-intensive industries. For example, a study in the British pharmaceutical industry indicated that the adoption of the research models for drug development and discovery have prompted firms to interact with universities in order to access new sources of innovation for novel drug therapies targeted for developing countries as well as to avoid high costs incurred by conducting basic research and the associated risks (Tralau-Stewart et al 2009).

In South Africa, pharmaceutical firms have options to choose from external specialist providers of technological knowledge. The South African life sciences industry, which includes pharmaceutical firms, has been shown to have strong linkages between firms and universities (Al-Bader et al 2009; Kruss 2012). These firms seek out interactions with universities in order to have access to scientific knowledge, know-how and research equipment to build capabilities for technology development and attain a competitive advantage over their competitors (Al-Bader et al 2009; Kruss 2012). These studies report that these firms experience a number of challenges when collaborating with universities, including a lack of commercial knowledge, prolonged intellectual property negotiations and unrealistic expectations in terms of royalties generated from the commercial exploitation of their research.

Previous work in the South African health biotechnology sector (Al-Bader et al 2009; Kruss 2012), which is similar to the pharmaceutical sector in terms of, for instance, the nature of research, technological challenges and technological knowledge requirements, suggests that several factors may play an influential role in firms forming linkages with universities. These include universities' contributions of technological knowledge and other inputs to firms' technological development and learning (Kruss 2012), through which firms could develop in-house capabilities required to manage the innovation process.

1.5 Significance of the research

The study adopted a qualitative research design to examine decision making processes within selected pharmaceutical firms operating in South Africa. The findings of this study present an underexplored aspect of the *university-industry linkage* in developing countries, like South Africa, especially from the management perspective, and have policy implications on how to promote linkages between the pharmaceutical industry and universities in South Africa.

1.6 Organisation of the research report

This research project is organised in six chapters as follows:
Chapter Two: The literature review presents key themes from academic and practitioner literature in line with this research. Chapter Three describes the exploratory nature of this study and the methodology, which includes design of the study, qualitative data collection, method and the analysis of data. The limitations of the research methodology are also outlined in this chapter. Chapter Four presents the findings. Chapter Five analyses the findings against findings obtained in the literature. Chapter Six presents conclusions and the recommendations for future research.

2. CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter establishes an analytical framework to assess the types of linkages, knowledge flows and benefits that exist between pharmaceutical firms and universities. The chapter includes a series of empirical literature studies on this subject and explores implications for management decision making and innovation. This is based on the literature.

The chapter is organised as follows: (1) the types of linkages and specialised knowledge flows from universities to the pharmaceutical industry; (2) linkages and innovation (3) how firms search for and select external specialist knowledge from providers; and pharmaceutical industry-university linkages and their benefits.

2.2 Types of linkages and specialised knowledge flows from universities to industries (firms)

Empirical studies on linkages between industries and universities are extensively documented: motivations and rationales for forming linkages with universities (Ramos-Vielba, Ferna´ndez-Esquinas and Espinosa-de-los-Monteros 2009; Bayona, Garcıa-Marco and Huerta 2000; Brostrom 2008, 2012; Ankrah, Burgess and Shaw 2013); types and nature (Arza and Lopez, 2011; Siyanbola et al. 2012; Fuentes and Dutrénit 2012); the mechanism of knowledge flows (Bekkers and Freitas 2008; Østergaard 2009; Purwaningrum, Evers and Yaniasih 2012; Awuor 2013) and benefits (Triulzi, Scholz and Pyka 2011; Fuentes and Dutrénit 2012). These studies, however, offer limited insights to understand how the linkages between firms and universities influence the management decision making processes within firms to transform knowledge into technologies and products that would yield financial gains for the business.

Universities are diverse in their missions, research activities, governance and performance, and carry out research through public funding in the innovation system (OECD 2010). Their performance varies across countries and industries, and while

some attract human capital needed for innovation, offer education and training services (OECD 2010), they usually only provide research and development support to firms through different interactions; and can also interpret the technological needs of the market (OECD 2011). Conversely, firms define the type of knowledge they wish to establish with universities relative to internal opportunities and knowledge needs (D'Este and Patel 2007), probably through various decision making processes. Various forms of linkages are country and industry-specific, and are related to the type of scientific knowledge required.

It has been estimated that about 10% of the world's products and processes in technological fields introduced by firms into their respective markets have been as a result of the contribution of specialised university knowledge inputs through linkages (Manfield 1998; Beise and Stahl 1999). Universities provide external specialist knowledge, which is scientific, and technological outputs (such as publications, patents and students) produced through a process of exploration in a laboratory-based setting in which the aim is to solve a science problem (Pavitt 2003; Moroz 2005 citing Popper 2000). Interactions between universities and industries form part of a system of innovation of a country, where the actors together create, diffuse and implement new knowledge (Innovation, Higher Education and Research for Development 2012).

However, to date it has not been determined how interactions between industries and universities evolve especially from management decisions of firms.

Firms involved in research and development (R&D) and technological activities benefit from linkages with universities on research and technology through a variety of specific channels (Intarakumnerd and Schiller 2009; Dutrénit, Fuentes and Torres 2010; Kruss 2012). The development of such channels is facilitated by personal contact and trust between the university and firm researchers and the geographical proximity of a university in relation to a firm (Luizo and Burcharth 2008; Araujo et al 2011). Public conferences, the mobility of students, collaborative research and development activities, patents and meetings are also regarded as important mechanisms or channels through which firms are able to access university specialist knowledge (Dutrénit, De Fuentes and Torres 2010; De Fuentes and Dutrénit 2012).

Technology licenses and personnel exchanges are, however, not found to be that important as channels of accessing university knowledge (Bekker and Bodas-Freitas 2008).

Universities play an important role in the economic performance of firms of high technology-intensive industries such as biotechnology, pharmaceutical and new materials in countries (Veugelersa and Cassimana 2005 citing Cockburn and Henderson, 2000; Mowery and Sampat, 2004). However, the role of universities differs across industries and countries, and is influenced by several factors such as structure and size of an industry and the structure of publicly-funded research performers (Mowery and Sampat 2004).

Bekker and co-authors assert that at the firm level, in the Netherlands, the more university knowledge is written down and published in scientific journals, it is searchable thereby making easier for firms to be aware of the R&D that is taking place in the academic environment and thus facilitating firms' decision-making processes for the establishment of linkages through informal contacts and collaborative and contract research with potential universities (Bekker and Bodas-Freitas 2008). Moreover, firms wishing to improve their innovation capability and business performance through the application of scientific published knowledge, both related to breakthroughs or to complex systems, need to favour scientific publications, informal contacts with university researchers and students as well as labour mobility (Bekker and Bodas-Freitas 2008). These types of knowledge transfer favour the combination of both scientific and technological knowledge, which is important to enable awareness and specification of scientific knowledge to the needs of firms and their markets (i.e. the adoption of that scientific knowledge by firms).

Firms operating in high knowledge and technology industries such as biotechnology and pharmaceuticals use a wide variety of linkages to access university knowledge, which was dependent on the firms' needs, industry type: knowledge type requirement and even the characteristics of researchers involved in producing the knowledge.

2.3 Linkages- Knowledge Flows-- and Innovation

The production of external specialist knowledge by universities is often aided by government or public funding and policies to address socioeconomic challenges; and the effects of external knowledge on firms' innovation capacity building have increased the attention of policy makers in developing countries to encourage linkages between universities and firms to bring technology change and develop a knowledge-based economy for economic growth (Slow 1957; Romer 1990).

Many countries recognise the fundamental role of knowledge in fostering economic growth and development of countries (OECD 1997), mainly through industrial innovation (Mowery, Oxyley and Solverman 1996; Wang 2009; Lim 2004; Furman and MacGarvie 2007), thereby contributing to helping governments to achieve socioeconomic development outcomes. Knowledge is an asset, both appearing as both input and output in the production processes and facilitates the learning capabilities of firms (Lundvall 2003) and stimulates innovation and competence building of firms (Lundvall 2004). Thus, knowledge is closely related to the economic performance of firms, measured by profit (Wolff and Pett 2006; Karakas and Yildiz 2012). Karakas and Yildiz (2012) further argue that external knowledge in relation to firms shapes the decision making process of multinational firms to enter new markets, including investment freedom, intellectual property rights and corruption.

According to the concept of a system of innovation, firms form complex networks with universities whose activities and roles initiate, import, modify and diffuse new technologies into the firm (Lundvall 2004 citing Freeman 1987). Lundvall (1992) suggests that the concept of national innovation system refers to relationships between firms and universities whose primary objective is the production, diffusion, and use of new knowledge to contribute to new institutional make-ups enabling for searching for new knowledge or technologies and building learning and technological capabilities.

Although, there are different perspectives of innovation at the firm level in practitioner literature, Marcelle (2011) offers another perspective of innovation which is related to the purpose of this study. The author describes innovation as a:

> *"process of generating, acquiring and applying knowledge for economically and socially beneficial purposes and takes place through efficient unfolding of various learning processes, rather than being determined by the mastery of science and technological knowledge"*.

While the author's perspective on innovation contradicts a perspective on innovation as science-based, and produced in a laboratory environment, it offers an understanding of the process of how firms acquire external specialist knowledge and apply the knowledge with the intention of improving their own innovation and gaining economic benefits. Furthermore, the definition of innovation according to Marcelle (2011) implies that firms acquire external specialist knowledge with the intention of developing learning and technological capabilities (Marcelle 2004; Bell 2009), which are required for technological innovation (product and process innovation) and overall firm's innovation performance (Atalay, Anafarta and Sarvae 2013). Firms with an innovation strategy based on linkages with external specialist knowledge providers such as universities have been shown to be more likely to survive in an environment where technology is changing rapidly than firms that do not have external linkages (Soh and Roberts 2003).

Firms, including those operating in pharmaceutical industry no longer rely solely on internal R&D activities to achieve innovation and are therefore necessary to form linkages with the universities to acquire, assimilate and integrate knowledge into production, technology and manufacturing processes to overcome such market pressures and sustain competitive advantage and improve performance (Santos 2003; Veugelers and Cassiman 2005; Jurado et al 2009). However, the challenge facing managers of most firms is how to search and identify the appropriate sources of external specialist knowledge in order to overcome the external business competitive environment and other pressures brought by government legislations and regulations.

Against this background, the concept of the national innovation system redefines the roles of universities as specialist producers and providers of knowledge and dictates how knowledge gets channeled to firms in a way that it will easily be adopted

(Mowery and Sampat 2000). Fu and Li (2009) add another dimension into the role of universities from a developing country's perspective, where they argued that universities should play a distinctive role in promoting the diffusion of frontier technology and the creation of new innovation outcomes at both the country and firm levels.

According to Eom and Lee (2010) citing Etzkowitz and Leydesdorff (1997) there are two divergent views concerning the role of universities within the innovation systems, namely the Triple Helix school of thought and the New Economics of Science school of thought. The two contradictory views emphasise an important role that universities could play in the national systems of innovation, both in social and economic development of countries (Etzkowitz and Leydesdorff 1997 cited by Eom and Lee (2010).

Thus, the Triple Helix School of thought refers to the industry-university-government linkages and it emphasises the social and economic value of universities in the national system of innovation (Eom and Lee 2010 citing Etzkowitz and Leydesdorff (1997). According to the Triple Helix perspective innovation takes place in a knowledge infrastructure where the linkages between firms, university and government play an important role in facilitating the conditions for innovation (Leydesdorff and Meyer 2013). The government creates an environment where the university and firms can become effective in knowledge production through policies, programmes and incentives (Etzkowitz and Leydesdorff (2000). The Triple Helix school of thought thus argues that the university needs to be directly linked to the firm through among other things formal meetings, joint research programmes, consultancy work commissioned by the industry, as well as licensing agreements of patents and purchasing of prototypes for industrialisation based on scientific and technological knowledge (Schartinger et al 2002; D'Este and Patel 2007). This then reiterates the third role of the university in the innovation system, which is serving for economic development aside from its traditional role of teaching and training (Etzkowitz and Leydesdorff 2000).

The New Economics of Science School of thought, on the other hand, emphasises education as a core function of universities (Dasgupta and David 1994). This view is

concerned with the relationship between university and industry becoming too close, arguing that it may be detrimental to the scientific potentials of a nation and that a proper division of labour between these actors is needed (Eom and Lee 2010 citing Etzkowitz and Leydesdorff (1997). Criticising the inappropriateness of the two in their applications to developing countries, Eun and co-authors suggested a contingent or context-specific perspective on the linkage between firms and universities (Eun et al 2006). Each country has its own national innovation system, and it is natural that the linkages between firms and universities in each country take various forms and assume different functions (OECD 1997).

Eom and Lee (2010) investigated the role of universities within the Korean national system of innovation, through the analysis of the Korean Innovation Survey data, with a particular reference to the determinants of the linkages between firms and government research organisations including the universities and their effect on the innovation performance of firms. The authors found that firm size and research and development intensity do not have a significant effect on the innovation performance of firms. Interestingly, Eom and Lee (2010) found that university research and development activities turn out to be the most important determinant to the innovation performance of firms. According to Eom and Lee (2010), this finding is, however, in contrast to the findings found in literature studies performed in European countries. Consequently, Eom and Lee (2010) emphasise that government policies and legislation should play important roles in promoting linkages between firms and public research organisations including universities in developing countries.

However, firm-university-government linkages on a firm’s innovation performance may influence the selection or direction of research projects of a firm (Etzkowitz and Leydesdorff 2000). When the analysis is limited to the innovation performance of firms, a positive effect of the firm-university-government linkages was observed in a study of Eom and Lee in 2010 on the number of patents produced from new product innovation due to external public research organisation and university research and development input into firm’s technological development process (Eom and Lee (2010). Although these findings were found from a study conducted in Korea by Eom and Lee (2010), the findings suggest that the nature of the innovation system and

knowledge inputs in developing countries would play an important role in firm's innovation performance and industrialisation.

2.4 Innovation management and external specialist knowledge

Interactions between different actors such as private firms, public research organisations (including universities) and government departments and their policies are the main features of the innovation system of any country, and promote learning, which can take place through formal education (Lundvall 2007; Parto et al 2006). Government interventions through policy measures play an important role in promoting and shaping interactions, as well as influencing the performance of national innovation systems (OECD 1997). Hence, government interventions (through policies and incentives) account in a major way for the process which the public and private producers of knowledge become linked and, in doing so, influence the market orientation of manufacturers, and research and development at firms.

Universities are seen as important agents in driving the economic and social agendas of countries (Innovation, Higher Education and Research for Development 2012). This is mainly through linkages with private firms in high technology sectors where scientific and technological knowledge form the basis for innovation at the firm level.

Hobday (2009) notes that innovation process models have implications for management decision making processes for alternative sources of specialist knowledge providers. Tidd and Bessant (2009) provide insights into how firms in developed countries manage innovation through interaction with external specialist knowledge providers, and how the process of innovation within firms influence management decision making and development.

Tidd and Bessant (2009) proposed the innovation process model shown in Figure 1, which provides an understanding of how firms make decisions on accessing specialist knowledge to trigger innovation, derive value, learn and build competitiveness in relation to their competitors. The model is comprised of four dimensions: search, select, implement and capture, which show the routines that

firms in developed countries utilise to stimulate innovation. However, it is not clear to what extent firms perform these routines in order to trigger the innovation process and the factors involved, and whether firms go through these routines simultaneously or perform one routine at a time. Tidd and Bessant (2009) argue that the challenge for firms in managing innovation is how to strike the balance between its internal complementary assets and what it needs outside its boundaries to innovate and to do with limited resources such as people and the budget for research and development.

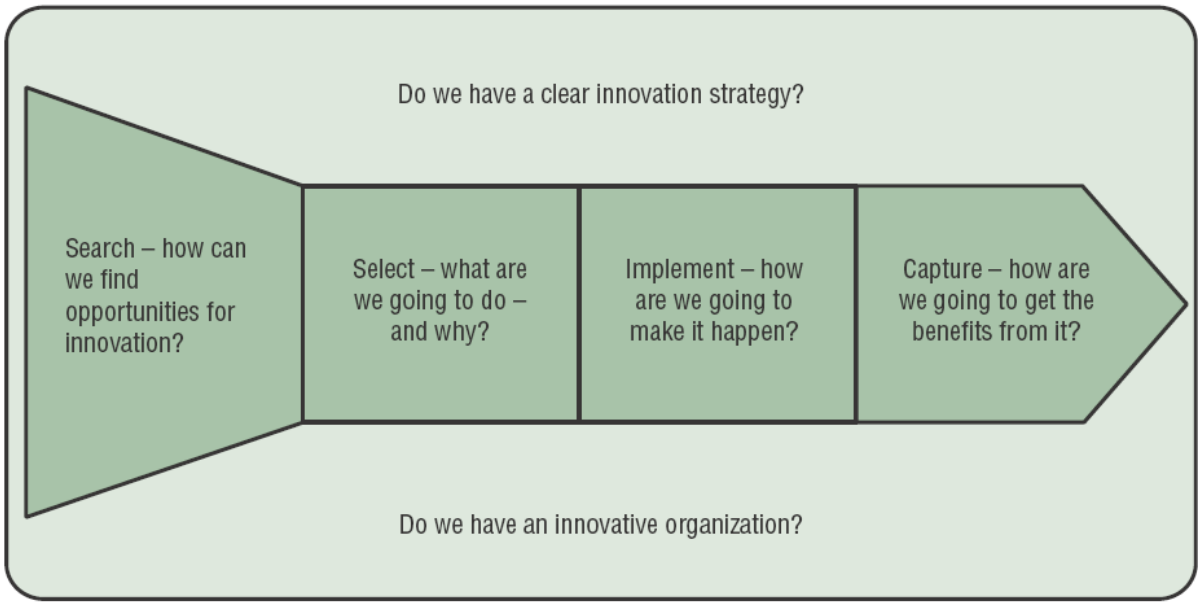

Figure 1: Firm level innovation management process (Source: Tidd and Bessant 2009)

Firms have different approaches to searching for, and identifying external specialist knowledge providers to trigger innovation (e.g. Tidd and Bessant 2009). They adopt a specific search approach or strategy based on the characteristics of the environment in which they are operating, such as organisational arrangements, institutional infrastructure, and the culture and legal and policy framework. These institutional frameworks influence how firms search for external specialist knowledge. Some firms can adopt different approaches of the search process simultaneously, thus creating more opportunities to identify potential sources of knowledge providers to form linkages with on knowledge development and production. However, it is not clear in the literature how firms choose among the different options of search for

external specialist knowledge and which option is more effective to enable a firm to identify relevant knowledge to trigger innovation.

Private firms search for specialist knowledge to trigger the innovation process and engage in a number of approaches or strategies to search for external specialist knowledge [e.g. Tidd and Bessant (2009, page 263)], as illustrated in Figure 2. According to Tidd and Bessant (2009) firms employ search strategies to establish linkages with external role players in the innovation system as potential sources for specialist knowledge to innovate. However, the challenge facing the management of many firms is how to recognise and choose among a variety of search options in order to maximise value from external knowledge requirements in so doing with limited resources (Tidd and Bessant 2009).

In the context of innovation management at the firm level, *search* is referred to as a process by which firms scan for innovation opportunities, as well as keep abreast of developments in their operating environment. A firm employs search strategies to identify signals in the marketplace to trigger innovation and bring technological change (Tidd and Bessant 2009). Hence, search strategies have been found to substantially impact on the innovation performance of firms (Sofka and Grimpe 2008). However, firms across industries differ on search depth and scope and these variations can lead to variations in their innovation performance, which suggests that some firms are able to engage in different search strategies or approaches simultaneously (Katila and Ahuja 2002). Firms should manage search approaches in a manner that would lead to the transformation of external knowledge into benefits (Tidd and Bessant 2009), such as new product technologies, manufacturing processes and services as well as market opportunities.

Search strategy	Mode of operation
Sending out scouts	Dispatch idea hunters to track down new innovation triggers
Exploring multiple futures	Use futures techniques to explore alternative possible futures; and then develop innovation options
Using the web	Harness the power of the web, through online communities, and virtual worlds, for example, to detect new trends
Working with active users	Team up with product and service users to see the ways in which they change and develop existing offerings
Deep diving	Study what people actually do, rather than what they say they do
Probe and learn	Use prototyping as a mechanism to explore emergent phenomena and act as boundary object to bring key stakeholders into the innovation process
Mobilize the mainstream	Bring mainstream actors into the product and service development process
Corporate venturing	Create and deploy venture units
Corporate entrepreneurship and intrapreneuring	Stimulate and nurture the entrepreneurial talent inside the organization
Use brokers and bridges	Cast the ideas net far and wide and connect with other industries
Deliberate diversity	Create diverse teams and a diverse workforce
Idea generators	Use creativity tools

Figure 2: Search strategies by firms (Source: Tidd and Bessant 2009)

Cohen and Levinthal (1990) emphasise that for firms to be effective in the search process, they must have internal resources that include competent staff with skills and knowledge to detect relevant market signals. Cohen and Levinthal (1990) refer these internal resources as absorptive capacity. The individuals with specialised knowledge and skills to conduct search processes often go out in the environment to locate and detect signals about the potential for change and bring back information to the firm for use in technological development (Pertuzé et al 2010; Hess and Rothaermel 2011).

Operating in highly intensive technology industries, which require external knowledge inputs for innovation and production processes, it is noted that firms differ in how they search for external specialist knowledge from universities. Laursen and Salter (2004), using a survey of firms drawn from the United Kingdom's manufacturing sector, found that these firms use external search breath and external search depth to access external specialist knowledge to trigger internal innovation process. These search strategies enable firms to be open to different options to access external knowledge. This correlates with Laursen and Salter (2004) on the influential role of the search process to firms' decisions on choosing universities and other research organisations.

There are various factors which influence firm's ability to choose from search options. These include the intensity of the internal firm research and development, the size of the firm and the nature of the industry (Laursen and Salter 2004). In their study, Laursen and Salter (2004) suggest that firms operating in high technology-intensive industries with small budgets for research and development have a high propensity to form linkages with universities on specialist knowledge.

Sofka and Grimpe (2008) argue that the characteristics of the innovation system in which a firm operates may influence a search process to seek external knowledge. Each country has unique conditions characterised in terms of combinations of organisations and institutional arrangements and infrastructure which determine a firm's ability to innovate (Sofka and Grimpe 2008). Such institutional infrastructure refers to public research organisations including universities involved in the generation and diffusing of technological knowledge, including other factors such as culture, legal and policy frameworks (Soka and Grimpe 2008). Firms operating in developed countries where innovation systems are functional and effective in terms of knowledge production processes, are more likely to find external knowledge requirements for innovation than firms operating in a developing country context. This implies that context matters on how firms undertake the process of search.

In summary, search is an important aspect of innovation management at the level of the firm and has been linked to the innovation performance of firms. However, firms across industries vary on how they search for external specialist knowledge and this

variation may lead to variations in the effect of search to a firm's innovation performance. Firms search for external specialist knowledge to supplement technological capabilities in order to gain competitive advantage in a specific technological niche (Stuart and Podolny 1996).

2.5 Firm-university linkages in the pharmaceutical industry and their benefits

The literature notes that firms that operate in industrial sectors that require external specialist technological knowledge such as biotechnology and pharmaceutical industries for innovation and enhanced business growth have linkages with universities to draw technological knowledge and other inputs (Laursen and Salter 2004; Loof and Brostrom 2008). The literature suggests that universities, through their technological knowledge and other inputs, offer firms an opportunity to develop their competitive advantage in the business environment they are operating in.

The industrialised sectors such as pharmaceutical industry are characterised by increased international competition, stiff regulatory requirements, technological evolution and technological complexities, and long lead timeframes for the commercial development of technology (Brostrom 2010 citing Gerybadze and Reger 1999; Druker 2001). Hence, firms across the highly intensive industries are finding it a necessary requirement to manage internal knowledge and resources, recognising and selecting appropriate sources of technological knowledge providers to form appropriate linkages that they would benefit from to overcome external environmental pressures and challenges (Escribano, Fosfuri and Tribó 2009).

Siyanbola et al (2012) showed that firms in the Nigerian pharmaceutical industry established linkages with local universities through consultancy services, staff exchange programmes and sponsored workshops for researchers. In contrast, Paranthos (2010) found that in the Brazilian pharmaceutical industry, firms and universities established linkages for joint collaboration, to produce knowledge and technologies, and mutually owned the intellectual property of their joint output. While both these cases occurred in similar socioeconomic contexts and innovation systems, the internal resources of firms, skills and hard equipment, likely contributed to management decisions on the nature of the linkages and the knowledge required.

2.6 The South African Pharmaceutical Industry

According to the South African Department of Trade and Industry official report, the pharmaceutical industry is among the strategic industrial sectors of the South African economic growth and development (Department of Trade and Industry 2011). The industry provides employment for up to 9 600 people, most of which are professionals with university qualifications and skilled workers in manufacturing, processing and product development of drug technologies in both local and international firms operating in South Africa.

The South African pharmaceutical industry consists of local and multinational firms operating in the areas of manufacturing, export, import, research and development, and clinical research, among others (Medicine Control Council 2011). The manufacturing industry focuses on generic drugs (Mahomedy 2010), which are medicines that have been taken off patents and are readily available for manufacturing (South African Healthcare Report 2009; Mahomedy 2010). In 2011, the MCC issued licenses to 438 pharmaceutical companies to operate in their respective areas of business, including firms operating in the wholesale industry (Medicine Control Council 2011). The MCC also issues a license to pharmaceutical firms performing clinical research in South Africa. Firms involved in clinical research often involve universities in their clinical research activities, such as patient recruitment and clinical protocol design (Academy of Science of South Africa 2009).

Key local pharmaceutical players include Adcock Ingram Ltd and Aspen Pharmacare, the largest generics manufacturer in the southern hemisphere. International pharmas— GSK (UK), Sanofi-Aventis (France), BMS (US), and Johnson & Johnson (US) have operations in the country (South African Healthcare Report 2009; Mahomedy 2010). US companies operating in South Africa lead the international firms, supplying over one fifth of the market, followed by German, British and Swiss firms (Business Monitor International 2009; Mahomedy 2010).

South African companies feature prominently in the pharmaceutical market share of most developed countries including the United States of America (USA), Switzerland, France, Germany, Great Britain, Denmark, India, Japan and Australia

(Business Monitor International 2009; Mahomedy 2010). Conversely, pharmaceutical companies from these countries are operating in South Africa. Thirty-nine percent of pharmaceutical firms in South Africa are local (Business Monitor International 2009); 21% from the USA, 11% from Switzerland, 9% France, 7% Germany, 6% Great Britain, 2% Denmark and India (each), and Japan and Australia 1% each.

It is reported that the size of the market for the pharmaceutical industry in South Africa has reduced, both in size and total income (Business Monitor International 2012). The reduction has subsequently affected the industry's ability to build the technological capability needed to delivery desirable health care in South Africa to patients especially those infected by HIV and AIDS and tuberculosis.

According to Malodney and Myburgh (2007), pharmaceutical firms are losing capabilities, especially in the area of innovation process value chain, such as in research and development and manufacturing activities due to limited human resources capacity and skills (Maloney and Myburgh 2007). According to the 2006 Global Competitive Report on the performance of developing countries in innovation within the pharmaceutical sector, South Africa scored poorly compared to Singapore, India, China and Brazil. Maloney and Myburgh (2007) suggest that innovative capacity can be improved within pharmaceutical firms operating in South Africa if the government offers fiscal and policy support for R&D and manufacturing capabilities. Moreover, Myburgh (2007) asserts that government support can be in the form of tax incentives, grants and the promotion of linkages with universities and science councils. Furthermore, these forms of government support for the private sector pharmaceutical firms could boost innovative capacity and capability and promote the innovation system within the sector, as a mechanism for encouraging specialists to remain in the country.

The leading pharmaceutical firms operating in South Africa in terms of manufacturing, research and development, and clinical research activities as well as profit revenue are indicated in Box 1:

Box 1: The leading pharmaceutical firms operating in South Africa

- Adcock Ingram Healthcare (Pty) Ltd
- Aspen Pharmacare Holdings Ltd
- Astrazeneca Pharmaceuticals (Pty) Ltd
- Cipla Medpro South Africa Ltd
- Eli Lilly (SA) (Pty) Ltd
- Glaxosmithkline South Africa (Pty) Ltd
- GM Pharmaceuticals (Pty) Ltd
- Gulf Drug Company (Pty) Ltd
- Ingelheim Pharmaceuticals (Pty) Ltd
- Johnson & Johnson (Pty) Ltd
- Merck Pharmaceutical Manufacturing (Pty) Ltd
- MSD (Pty) Ltd
- Novartis South Africa (Pty) Ltd
- Pfizer Laboratories (Pty) Ltd t/a Pfizer South Africa
- Pac-Con Pharmaceuticals (Pty) Ltd
- Ranbaxy (SA) (Pty) Ltd
- Roche Products (Pty) Ltd
- Sandoz South Africa (Pty) Ltd
- Sanofi-Aventis South Africa (Pty) Ltd

Source: Mahomedy (2011)

Research and development activities

Research and development are the backbone of the South African pharmaceutical industry and feeds into the innovation process for drug development and discovery. However, at any stage, the innovation process may have to be abandoned if it is not showing desired results both in terms of effectiveness and safety of drug technologies. Although the research and development expenditure by firms has shown a significant increase, research and development productivity has come down. All these factors have led to added pressure on the profit margin of the leading pharmaceutical firms and thus there is a pressing need to cut down the

costs. This suggests that pharmaceutical firms would opt to form linkages with universities as a way in which to lower the cost of research and development.

The South African research and development within the pharmaceutical industry has largely been restricted to product development issues such as the formulation and stability of drug technologies, although there are new drug discovery projects in a number of public-private partnerships and in public research institutions including universities (National Association of the Pharmaceutical Manufacturers 2011). According to Business Monitor International (2009), the South African pharmaceutical industry spent 2 billion Rand (US$ 0.2 billion) in 2009 in pharmaceutical R&D primarily towards clinical research centered on clinical trials of HIV/AIDS treatments due to the large HIV-positive population.

Clinical research activities

The South African clinical trial research sector is the best established as compared to the export and import markets of pharmaceuticals (Business Monitor International 2009 citing Academy of Science of South Africa 2009). This is mainly as a result of the high burden of infectious diseases, such as HIV and AIDS (Centre for the AIDS Programme of Research in South Africa 2007), followed by TB and non-infectious diseases, such as heart disease, diabetes respiratory diseases and cancer. In addition to population diversity in South Africa, a majority of multinational pharmaceutical firms find South Africa as the best choice to conduct clinical research.

According to a 2009 report by the Academy of Science of South Africa, clinical research refers to research primarily conducted with human participants (and on material derived from them, such as tissues, specimens and cognitive phenomena) during which clinical investigators examine the mechanisms, causation, detection, progression and reversal of human diseases (Academy of Science of South Africa 2009). Thus, clinical research contributes to health care at all levels by identifying the causes of problems, facilitating diagnosis, improving the efficiency and effectiveness of care, and promoting good policy-making.

Clinical research is regulated by the MCC in areas such as research ethics, academic and private research ethics committees in South Africa. The application for approvals to the regulatory authority and ethics committee is a parallel process. All clinical research conducted in South Africa must be registered in the South African National Clinical Trials register. Each clinical trial on the register is issued with a unique number.

To provide high quality clinical research and to protect clinical trials and human participants, pharmaceutical firms go to great lengths to identify suitable researchers at universities and research sites that meet both ethical and regulatory criteria. Pharmaceutical firms conduct intensive feasibility assessments prior to the selection of universities to collaborate on clinical research. According to the South African Clinical Research Association, there are seven good reasons to conduct clinical research in South Africa, namely, good infrastructure; high standard of medical care and practice; experienced researchers; robust regulatory system; stringent ethics oversight for research participant protection; international acceptability of data; diverse population and disease profiles (Academy of Science of South Africa 2009).

Clinical research is important because it can improve health outcomes by establishing the effects of health care interventions, and because it promotes and facilitates best-possible health care practices. It is, therefore, a crucial element in building capacity, building appropriate human resources and providing training and education to deliver effective clinical services. Revitalising the clinical research environment is thus important for the interest of South Africa to stimulate new drug development technologies to reduce the burden of diseases. Delivering on efficient clinical research requires effective and supportive management decision-making at all levels with pharmaceutical firms.

The Academy of Science of South Africa (2009) report mentions the two critical perspectives in clinical research. The first perspective is about the application of clinical research to epidemiological methods in the search for valid answers to questions regarding diagnosis, prevention, therapy, prognosis, etiology and other issues relevant to patient care. The second perspective, which is encountered in the pharmaceutical industry, is part of the research and development (R&D), drug

technology development and innovation process aimed at establishing the risks and benefits associated with new pharmaceutical products.

South Africa has a long history of conducting clinical research and a reputation for good study conduct, and as an ideal clinical trial destination. It is ranked 20 out of 40 leading countries according to the number of sites/population such as China, India, US and United Kingdom (Academy of Science of South Africa 2009). Although South Africa has been regarded as the best place to conduct clinical research investigation (due to diverse demographics and high burden of diseases) by the multinational pharmaceutical firms around the world, it is emphasised that the country displays its competitiveness through high quality clinical research performance (Academy of Science of South Africa (2009).

2.7 Linkages between firms and universities in the South African Pharmaceutical industry

The pharmaceutical firms operating in South Africa enter into linkages with public research organisations including universities mainly to overcome technological competition and fulfil a demand for local supply of technological drugs, among other reasons (Kruss, Adeoti and Nabudere 2009). The major pharmaceutical firms are currently attempting to use their cost advantage to access knowledge from public research organisations including universities. Strong compliance with global standards and elaborate in-house research and development activities, both of which are encouraged by public policies, make pharmaceuticals a preferred partner for contract research with public research organisations. Along with public research institutions, they are creating a high profile for outsourcing research and development activities and manufacturing for both the local and international market.

Firms' motivation to form linkages with universities is to have access to scientific knowledge, know-how, and research equipment in order to build their capabilities for technology development and attain a competitive advantage relative to their competitors (Al-Bader et al 2009). However, they experienced a number of challenges collaborating with universities, which included a lack of commercial

knowledge, prolonged intellectual property negotiations and unrealistic expectations in terms of royalties generated from the commercial exploitation of their research.

Case studies that Kruss, Adeoti and Nabudere (2009) focused on, revealed a mismatch between university and local firm capabilities. The first case study example was located at the University of Western Cape with a strong biotechnology expertise and capability. Cooperation between biotechnology firms and this university primarily takes the form of university-based spinoff micro-enterprises offering bioinformatics consultancy services to foreign customers and clients. The main beneficiaries are the individual academics who are permitted to increase their salaries, but there are few academic or financial benefits to the university.

The second case study was based at the University of Cape Town with a strong scientific research capability and reputation locally and globally (Kruss, Adeoti and Nabudere 2009). The case frontier scientific research, new to the world, but directly oriented to the human development health needs of South Africa and sub-Saharan Africa. The research has potentially significant social value, whether in relation to HIV/AIDS vaccines, tuberculosis or hypertension. The university benefited in terms of publications, students and evidence of its contribution to address national health priorities, and drug, vaccine and device development is proceeding at various stages through trials to the market. All of the firms involved are foreign, whether interacting in the role of sponsor, customer, supplier of services, or partner in a start-up company. Key gaps in the local supply chain drive co-operation with foreign firms: local capacity for producing vaccines, even for trial quantities, has been eroded; few internationally compliant and certified laboratory facilities for monitoring trials exist; the lack of local venture capital means that investment partners are sought abroad; and the small size of local demand drives the search for foreign partners to assist with access to global markets.

Yet it is significant that universities do have levels of scientific production that are sufficiently strong to attract global firms as business or research partners. From the two case studies, it can be deduced that the challenges of developing conditions and capacity for science-led firm selection within the health biotechnology (including

pharmaceutical firms), and for creating emergent new products innovations, need to mature further, given the fragile links within the national system of innovation.

The South African pharmaceutical industry, especially in the area of health, is not able to take advantage of the latent opportunity inherent in existing scientific research and knowledge generation capability, but it is unlikely that university-led commercial ventures can drive the process without a core local productive sector with key capabilities along the innovation value chain.

According to the article in the July/August Magazine on Science and Technology of 2014 published by the South African National Department of Science and Technology, the multinational pharmaceutical firm - Pfizer and North-West University have established a linkage on pre-clinical research – a field regarded as important in the development of new drug technologies (Viljoen 2014). Although, it is not clear how a linkage was established, a Memorandum of Understanding between Pfizer and North-West University was signed to initiate the process for the establishment of linkages on potential scientific research projects in the area of pre-clinical research, as well as on Pfizer's genetically modified animal models for the evaluation of the safety and efficacy profiles of drug technologies that would be developed by North-West University (Viljoen 2014). The article reports that the linkage between Pfizer and North-West University would focus on developing drug technologies to address infectious and chronic diseases that are relevant to South Africa, as well as in the rest of African continent.

The North-West University is equipped with trained researchers in pre-clinical research, as well as the pre-clinical research infrastructure such as facilities that serve as national study and supply infrastructure for qualitative and quantitative pre-clinical studies for researchers across South Africa. The pre-clinical research infrastructure was established through funding from the South African National Department of Science and Technology. The pre-clinical research infrastructure of the North-West University uses safety models, in combination with bioanalytical expertise to speed up research and development, and drug technology development processes. It may be deduced that Pfizer has selected North-West University on the

basis of availability of skilled and experienced researchers coupled to the infrastructure in pre-clinical research.

According to the article of Viljoen 2014 (2014) published in the Department of Science and Technology magazine, the research that is able to advance science and innovation and patient health is one of the key research and innovation strategies of Pfizer, to produce scientific technologies for patients in South Africa as well as the in the rest of the African continent (Viljoen 2014). Furthermore, the article mentions that Pfizer believes that its linakges with the North-West University is a key to expediting the translation of science into technologies for patients' health. This will be also be enabled by the creativity, flexibility and openness, as well as talent and resources to innovate where it matters to improve patient health. The article further mentions that the innovation strategy of Pfizer thus entails interacting and collaborating with patients foundations, patients, government, funders, health care professionals, academia and other leading firms in biopharmaceutical and biotechnology to ultimately produce drug technologies that are relevant to improving the health of patients.

The Department of Science and Technology has classified the linkage between the University of North West and Pfizer as among the initiatives of the South African government to contribute to the growth and development of the South African Bioeconomy sector of South Africa (Viljoen 2014). The Bioeconomy Strategy of South Africa, which was launched during 2014, seeks to create an environment that encourages the establishment of linkages between pharmaceutical firms and universities in South Africa to develop and produce drug technologies that can be introduced on the market to improve patient health (Bioeconomy Strategy 2014).

3. CHAPTER 3: RESEARCH STRATEGY AND METHODOLOGY

This chapter presents the research methodology and strategy used in this study in order to answer the two research questions formulated for the study. The chapter introduces triangulation to validate the perspectives of the pharmaceutical firms that participated in this study.

3.1 Qualitative research

This study employed qualitative research methodology instead of quantitative research methodology due to the small sample size of the 20 pharmaceutical firms operating South Africa that participated in the study. According to Van Maanen (1979), who is cited by Carcary (2009):

> *"A qualitative research includes an array of interpretative techniques which seek to describe, decode, translate, and otherwise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world"*

In qualitative research, the researcher seeks to achieve an in-depth understanding of the different meanings that people hold and place on their perspectives (Cooper and Schindler 2011). Hence, this study used qualitative research to explore the perspectives of these firms and their linkages with universities.

3.2 A qualitative research process

3.2.1 Development of the interview questions and interview protocol

The broad academic and practitioner literature used in this study facilitated the development of a framework from which open-ended and closed interview questions were formulated. Open-ended questions enabled the researcher to understand the innovation profile of the pharmaceutical firms as well as of the respondents. They further allowed the respondents to express their views without time limitations placed on them other than depicting abstract generalisations. The advantage of open-ended

questions is the full richness and complexity of the views provided by the respondents. The disadvantage is the unlimited time that the respondents can have to express their views (Denscombe 2003), which may cause them to become unwilling to participate in the research (Denscombe 2003). This was experienced in one case in this study when a respondent from a pharmaceutical firm terminated the interview due to other commitments, after spending a lot of time expressing himself in response to a question.

The development of closed and open-ended questions led to the design of the interview protocol which comprised of the different sections. The interview protocol directed to the pharmaceutical firms participated the study is indicated in Appendix A.

The interview protocol consisted of Part 1 and Part 2 questions. Part 1 questions elicited a general overview of the firm as well as of the individual respondents. Part 2 questions drew out a general understanding of the internal activities of the firm from the innovation perspective. It was divided into four sections:

First section: **"Searching for universities for collaboration and innovation."** This section explored how the firms searched for technological knowledge and other inputs from the universities; and how they operationalised the search function.

Second section: **"Selection criteria for choosing among knowledge providers".** This section explored the factors that influenced the firms' selection processes of choosing universities. The section further explored the characteristics of the universities that captured firms' interest in forming linkages.

Third section: **"Types of knowledge and learning from the university knowledge".** This section explored the types of university knowledge that the firms sought from the universities and how/what they learned from those knowledge inputs.

Fourth section: **"Value".** This section explored how the firms derive value from linkages with the universities; and how they capture that value.

3.3 Research strategy

3.3.1 Sampling frame

Denscomber (2007) defines a sampling frame as an objective list of the population from which the researcher can make a selection of the participants to be involved in the study. A sampling frame allows the researcher to choose elements relevant for the study; and to determine possible answers to the central questions formulated for research. The sampling frame for this study is presented in Appendix B. It consists of the pharmaceutical firms operating in South Africa. The sample frame was identified from the website of the South Africa's Medicine Control Council (Medicine Control Council 2011). The Medicine Control Council (MCC) is the government institution responsible for regulating clinical trials, to test new drug candidates, and to issue licenses to pharmaceutical firms wishing to operate in South Africa in various business activities, such as manufacturing, export and import of drugs and medicines. The sample frame study excluded the pharmaceutical firms involved in the retail and distribution of drugs and medicines because they are unlikely to form linkages with universities.

Table 1 shows the number of pharmaceutical firms found in each South African province. As of 2011, there are 263 pharmaceutical firms licensed to operate in South Africa (Medicine Control Council 2011). These pharmaceutical firms represent the sample frame for the study at the time of the research was undertaken.

Table 1: The sample frame of the pharmaceutical firms for this study

South African Provinces	Number of pharmaceutical companies
1. Gauteng	196
2. Western Cape	24
3: KwaZulu Natal	20
4. Eastern Cape	13
5. North West	5
6. Free State	3
7. Mpumalanga	1
8. Northern Cape	1
TOTAL	**263**

Sub-population represents a Province in South Africa. No pharmaceutical firms are present in the Northern Province.

3.3.2 Selecting the pharmaceutical firms and identifying the respondents

Pharmaceutical firms were selected following a review of their websites to ascertain whether their involvement in research and development activities, clinical research and technology development. Firms that showed involvement were identified for inclusion in this study and assumed to have linkages with universities.

The identified pharmaceutical firms were contacted via email and or telephone requesting them to participate in this study. Eleven international and nine local pharmaceuticals operating in South Africa emerged from the sample frame and participated in the study (Table 2). These firms represent the sample size and interviews for this study. The pharmaceutical firms are located in the Gauteng, Western Cape and KwaZulu Natal provinces participated in the study.

Table 2: The pharmaceutical firms operating in South Africa that participated in the study

Firm	Firm core activity	Location	International	Local (South Africa)
1	Manufacturing; Clinical research; & Research and Development	Gauteng		X
2	Clinical research	Gauteng		X
3	Manufacturing; and Packaging	Western Cape		X
4	Research and Development	Gauteng		X
5	Manufacturing; & Export	Gauteng		X
6	Import; Clinical research; and Quality control	Gauteng	X	
7	Manufacturing	KwaZulu Natal		X
8	Clinical research	Gauteng	X	
9	Manufacturing; and Distribution	Gauteng	X	
10	Manufacturing; Export; Import; Marketing; and Distribution	Gauteng	X	
11 (a)	Clinical research	Gauteng	X	
12 (b)	Clinical research	Gauteng	X	
13	Clinical research; Import and Quality control	Gauteng	X	
14	Manufacturing; Export; and Research and Development	Gauteng	X	
15	Manufacturing	Gauteng		X
16	Manufacturing; Research and Development	Gauteng	X	
17	Manufacturing; Clinical research	Gauteng	X	
18	Manufacturing; Export; Import; Packaging	Western Cape	X	
19	Manufacturing; Import; and Clinical research	Western Cape		X
20	Import; Research and Development; and Distribution	Gauteng		X
	Number of the international and local pharmaceutical firms participated		**11**	**9**
TOTAL NUMBER OF THE PHARMACEUTICAL FIRM PARTICIPATED			**20**	

NOTE: Firm 11 (a) and 12 (b) represent the same firm; Location denotes a Province of South Africa

3.3.3 Convenient sampling of the respondents

Initially, the researcher had planned to conduct proportional sampling of the respondents from the pharmaceutical firms, holding positions such as Managers of Research and Development, Commercialisation, Intellectual Property, Strategic Collaboration, Senior Technology Acquisition and general Project Managers. The assumption was that these respondents were involved in projects with linkages with the universities and thus would provide insights.

Additionally, the researcher encountered challenges to increasing the number of respondents and pharmaceutical firms that participated in the study; hence a convenience sampling technique was adopted. Denscomber (2007) defines convenience sampling as a selection of research participants based on the convenience of the researcher from which the researcher has easy access to conduct qualitative research.

Subsequently, convenience sampling resulted in the nature of the respondents for the study, with the exception of two respondents who held positions as Managers for Research and Development and Technology Transfer Pharmacist (Table 2). The respondents represented senior managers and executives. It is noted that two respondents from the same pharmaceutical firm participated in the study and hence there were 20 respondents in total (Table 3).

Table 3: The respondents from the pharmaceutical firms

Firms	Respondents	Position in the company
1	1	Operations
2	2	Managing Director
3	3	Research and Development Manager
4	4	CEO
5	5	Technology Development Manager
6	6	Medical Director
7	7	Business development; Marketing and Sales, Drug Information, Procurement of Active Pharmaceutical Ingredients
8	8	International Clinical Research Operations
9	9	Senior Executive, Strategic Trade Development
10	10	Managing Director
11 (a)	11	Operation Lead
12 (b)	12	Head of Clinical Research
13	13	Clinical Research Manager
14	14	Technology Transfer Pharmacist
15	15	CEO
16	16	Business Unit Manager Pharmaceuticals
17	17	Compliance Oversight – Translational Lead – Africa
18	18	CEO
19	19	General Manager
20	20	CEO

NOTE: 11 (a) and 12 (b) represent one pharmaceutical company. Two individuals holding positions of Operational Lead and Head of Clinical Research participated in the study, respectively

3.3.4 Conducting the interviews

The researcher explained the purpose of the interview to each respondent. Interviews were conducted by telephone and face-to-face with the respondents who held managerial and executive positions at their firms. Seventeen telephonic and four face-to-face interviews were conducted. The primary reason for including a telephonic interview was because of the difficulty of securing an appointment on the calendars of most respondents who were otherwise willing to participate.

Face-to-face interviews were conducted with respondents who were willing to meet with the researcher in person. Unfortunately, respondents did not allow their interview to be tape recorded. This was probably due the competitive nature of the South African pharmaceutical industry as the respondents did not want to be quoted or have their identity revealed.

A systematic approach to interviewing was adopted to keep the interview sessions on schedule, and focus the respondent on answering the questions. However, in some interviews the respondents favoured a more flexible approach. For example, at the request of some respondents, the interview protocol was sent to them a week in advance so that they could familiarise themselves with the questions, and prepare their responses. This probably created bias since the respondents had time to prepare for the responses prior the research interview. The researcher may assume that the bias had resulted in the type of findings obtained.

A weakness of sending an interview protocol in advance to the respondents was the lack of questions directed to solutions that the respondents could describe. While the respondents expressed several solutions to issues, the lack of specific solution to questions reduced the richness of the findings. In addition, when using semi-structured interviews, a bias may be introduced by the interviewer or the interviewee. The comments and questions may shape the responses in a way that imposes the interviewer’s opinion. Some interviewees asked for the opinion of the researcher but the researcher clarified terms or the meaning(s) of a question but refrained from giving an opinion.

The structured interview approach was adopted to gain control of the interview process and used as a means to identify the factors emerging from linkages with universities. This technique subsequently enabled the researcher to focus the respondents on the relevant issues.

Depending on the respondents' innovation and business experience background and interest, some questions were explored in greater detail whereas other questions were not dealt with at all. The advantage of the semi-structured approach to the interview is that it enables the interviewer to probe and clarify answers in order to understand the reasons for decisions, attitudes and opinions (Denscomber 2007). It provided the researcher the opportunity to pursue issues that may surface instead of restricting the matter of the researcher's preconceived ideas. The interviews took on average 45 - 60 minutes.

3.3.5 Triangulation

Due to the limited sample size of the pharmaceutical firms, multiple sources of data were collected for triangulation. This strategy of data collection reduced the risk that the research conclusions reflected only the systematic biases or limitations of the interviews. Thus, triangulation allows the researcher to seek convergence and corroboration of research findings from methods designed for the study seeking to understand the same phenomenon (Muskat et al 2012).

Interviews were conducted with expert commentators drawn from universities (five respondents) and government departments and government knowledge generation institutions (five respondents). There were therefore 10 respondents interviewed in this study. Interviewing both groups of expert commentators provided a wider range of information about the perceptions of the pharmaceutical firm linkages with the universities. Each interview took a maximum of 30-45 minutes. The interview protocol directed at expert commentators is indicated at Appendix C.

3.3.6 Qualitative data analysis

The raw data from the interview responses were collated, summarised and organised in an Excel spreadsheet. This helped the researcher to create meaning, identify possible common ideas that emerged from all the respondents, and to begin the analysis.

The data were coded in an Excel spreadsheet using the selective coding as suggested by Cooper and Schindler (2011). This process involved the selection of various categories and sub-categories, which were captured on the Excel spreadsheet and compiled into units of analysis. In the analysis of the data, open coding was used. The aim of open coding is to develop categories in terms of their properties and dimensions (Denscombe 2003). The coding assisted the researcher to identify patterns in the responses and new insights.

Notes were open-coded by assigning conceptual labels to each identified unit of data. Open coding enables the investigators to break through subjectivity because fracturing the data forces preconceived notions and ideas to be examined against the data itself (Cooper and Schindler 2011). During the coding process comparison and contrasting took place. This ongoing process of data units with one another and with the named codes and categories, observing what is similar and different, allowed for the clarification of what happened to be uniform and stable in the data (Cooper and Schindler 2011).

A type of axial coding was also used to determine the relationships between data. This was followed then by selective coding to determine relationships and themes between categories of data that had emerged from open coding. The relationships and themes between categories of data were identified and rearranged in a hierarchical order with the emergence of subcategories. Creation of subcategories was used particularly when a category was over populated with data. In this way, phenomena could be explored and explained by identifying what was happening and why, and what the outcomes are of the action that had been taken (Cooper and Schindler 2011). The theoretical categories were compared to clarify the relationships and themes between them. As emphasised by Denscombe (2003), this

process was repeated in order to refine the explanation to which the researcher in the present study was working.

Due to the small sample size of the pharmaceutical firms that were interviewed, it was not envisaged that saturation of the data could have been reached in each of the categories. In other words, a point during the data collection when it ceases to reveal new data that are relevant to a category, where categories have become well developed and understood (Cooper and Schindler 2011). When all the insights that emerged from the data were identified and coded, frequency tables and graphs were used to present the findings. The data from triangulation was also analysed in the same way.

3.4 Limitation of the study

- Sampling limitations are present as the research makes use of convenience sampling. Convenience sampling does not attempt to sample in such a way as to be representative of the population (Patel, Tang and Elliot 2005). A generalisation of the population can only be made if the sample is representative of the population (Patel et al 2005). The research focused only on the pharmaceutical firms that have R&D programmes in-house and are involved in clinical research activities with universities. Additionally, telephonic interviews were only considered for the firms that became a challenge to secure a face-to-face interview but were willing to participate. Face-to-face interviews were conducted with the pharmaceutical firms that could meet the researcher in person. A fairly low number of firms were included in the sample. The results are therefore reported tentatively, to be treated as indicative and not conclusive.
- Extensive firm knowledge of respondents may be limited due to recent employment or a narrow scope of their function. Data obtained from these respondents may not represent the firm perspective.
- The research considered the decision-making approaches such as the search and the selection functions in so far as they are considered by firms operating in high-intensive technologies industries like the pharmaceutical industry.

3.4.1 Summary: Chapter 3

The present research employed a qualitative research methodology instead of a quantitative research to answer the two central questions developed for the study. The use of qualitative research in the study was due to the small sample from the sample frame of the pharmaceutical firms operating in South Africa.

Triangulation was included in the study by interviewing expert commentators drawn from the South African universities as well as from government departments and government knowledge-generating institutions. The aim of including triangulation was to validate the views and perspectives of the pharmaceutical firms obtained from earlier interviews and get additional insights. In total, 10 expert commentators were interviewed.

Twenty pharmaceutical firms participated in the study to investigate their linkages with the universities. The research findings from the pharmaceutical firms, universities, government departments and government knowledge-generating institutions were obtained, and later organised, coded and analysed. The detailed presentation of the research findings is in Chapter 4.

4. CHAPTER 4: RESULTS

4.1 Introduction

The present research concerns linkages between the pharmaceutical firms operating in South Africa interviewed and universities in South Africa, with particular reference to innovation management and decision making processes by the firms. The chapter presents the research findings in detail, obtained from elite interviews with the pharmaceutical firms and the findings obtained from interviews with expert commentators drawn from South African universities and government departments and government knowledge generation institutions during the triangulation stage of this research. This qualitative data has been represented in a simple quantitative format in this chapter in order to provide a sense of the relative preference for certain instruments or practices as articulated by the respondents. A more critical and reflexive explanation of these findings and their relationship to the reviewed literature is later given in Chapter 5.

4.2 The profile of the pharmaceutical firms

The pharmaceutical firms interviewed comprised of both international firms (also referred to as multinationals) and local (South African) firms operating in South Africa. Figure 3 depicts the percentage of the pharmaceutical firms in different provinces of South Africa. The pharmaceutical firms that participated in the study are located in Gauteng, Western Cape and KwaZulu Natal.

The majority of pharmaceutical firms were from the Gauteng province (80%), 15% from the Western Cape and 5% from KwaZulu Natal. There were no pharmaceutical firms from the other provinces that participated in this study.

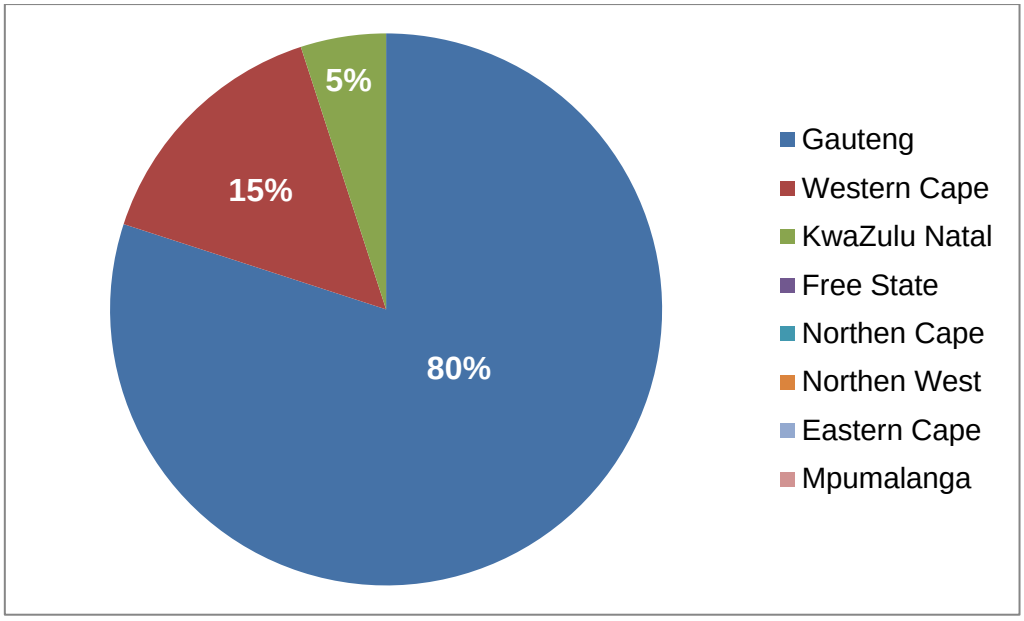

Figure 3: The percentage of the pharmaceutical firms participated in this study according to the provinces of South Africa

In the study, 55% of the local and 45% of the international pharmaceutical firms operating in South Africa participated (Figure 4). The firms were interviewed to explore the perspectives of senior and executive managers on the formation of linkages with South African universities and the decision making process.

Figure 4: The percentage of the international and South African pharmaceutical firms operating in South Africa participated in the study

In total 28% of the firms are involved in manufacturing generic drugs, 21% are involved in clinical research activities, 12% in research and development (R&D) and the importation of drugs manufactured elsewhere in the world and 9% in export activities of generic drugs (Figure 5). The firms were involved in more than one business and innovation activity. The professional profile of the respondents is provided in Table 3 in Chapter 3 of this report.

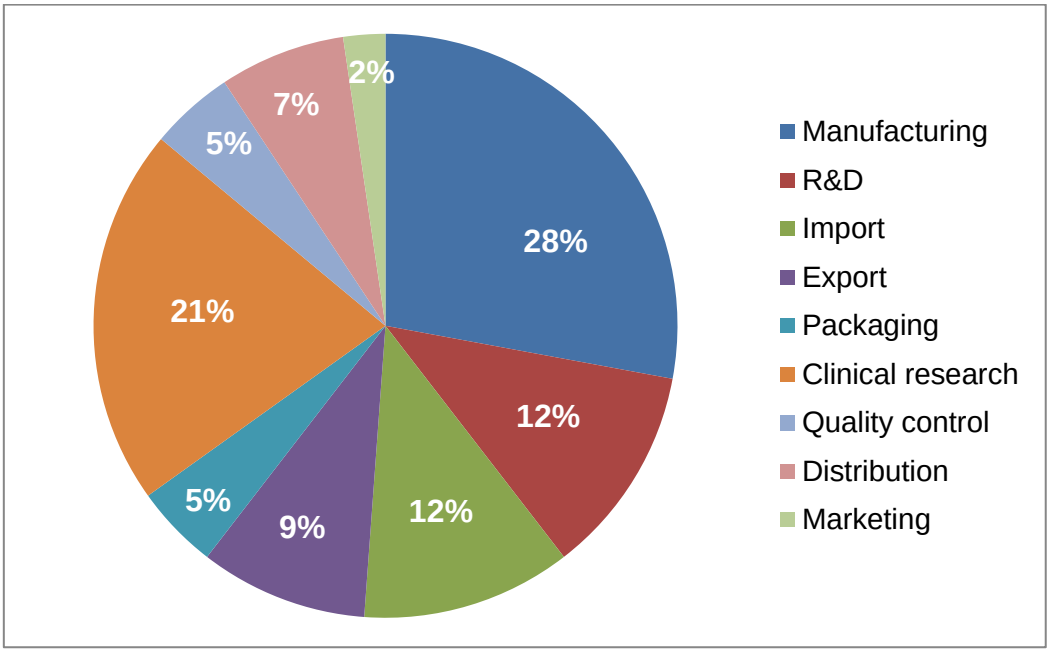

Figure 5: The percentages of the pharmaceutical firms involved in different business activities in South Africa

4.3 The innovation activities of the pharmaceutical firms

This section provides a background of the innovation activities of the pharmaceutical firms that participated in the study, with particular reference to the collaboration activities of the pharmaceutical firms participated, the nature of the firm collaboration with the universities and in-house firm R&D activities. These innovation activities are presented here because they are closely related to the research questions formulated for this study. A detailed account of the innovation activities of the pharmaceutical firms is presented in Appendix D.

4.3.1 Collaboration between the pharmaceutical firms and universities

Ninety-five percent of firms indicated that they have had collaborations with universities. This is illustrated in Figure 6.

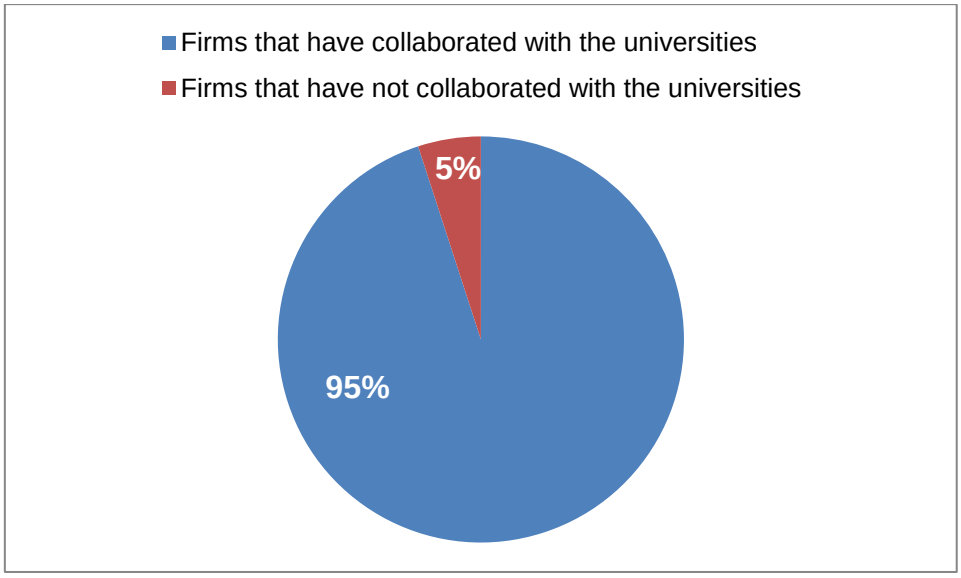

Figure 6: The percentage of the pharmaceutical firms in terms of collaboration with universities

4.3.2 Nature of knowledge collaboration

The nature of collaborations of the pharmaceutical firms with universities is illustrated in Figure 7.

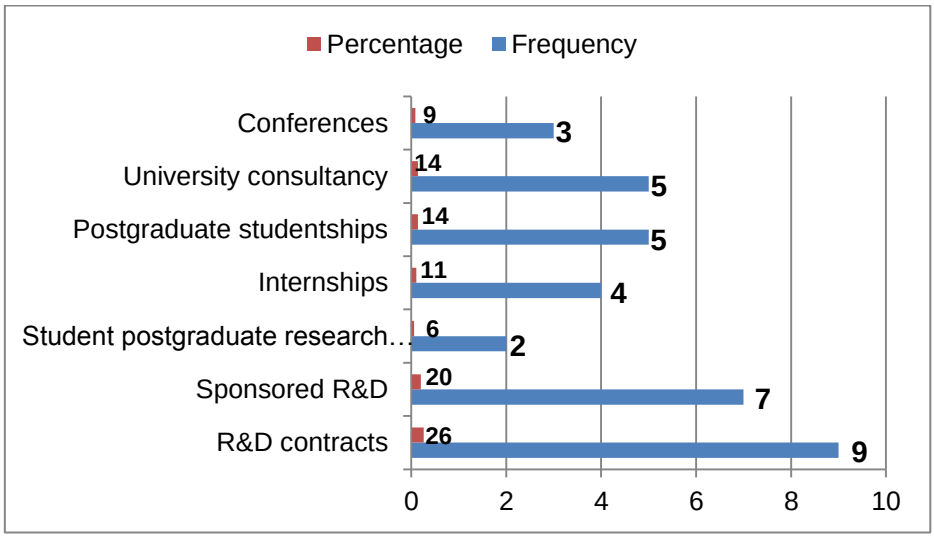

Figure 7: Nature of the knowledge collaboration between the pharmaceutical firms and universities, *(n = 35)*

4.3.3 Firm-university collaboration for technology development and innovation

The percentage of pharmaceutical firms' collaboration with universities for technological development and innovation is indicated in the graph in Figure 8. Sixty percent viewed university collaboration as important for the development of technologies and innovation. All agreed that they have derived value from collaboration with the universities.

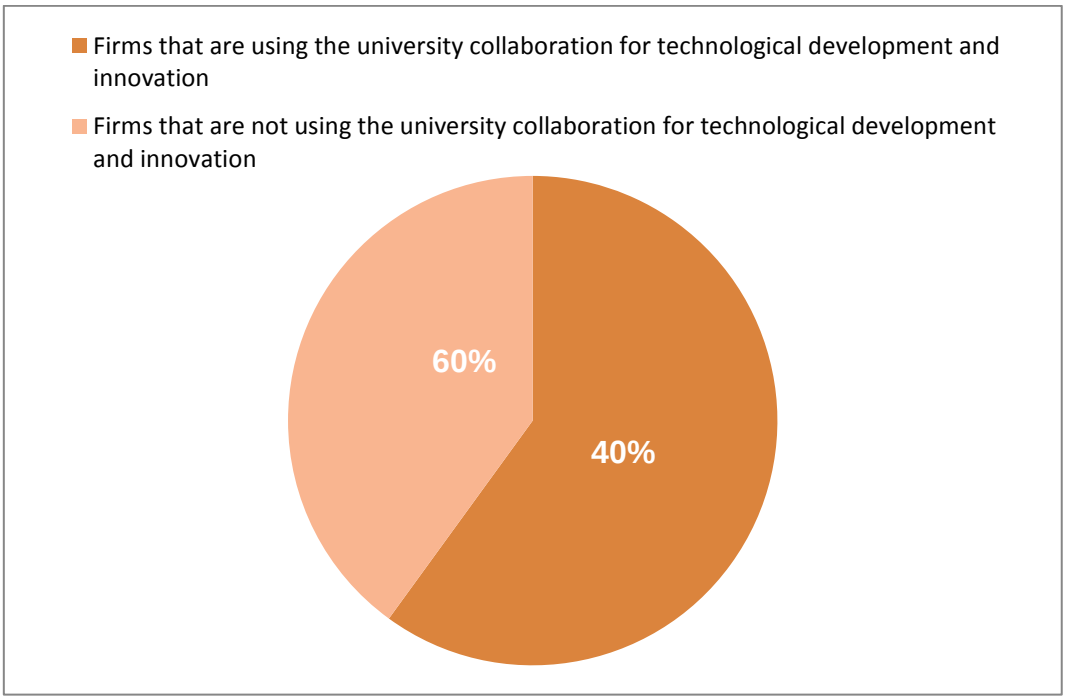

Figure 8: Percentage of the firms in terms of university collaboration for technology development and innovation

4.3.4 Intention of the firms to collaborate with universities

Eighty-five percent of firms said they intend to enter into research collaboration with universities in the near future. This is illustrated in Figure 9.

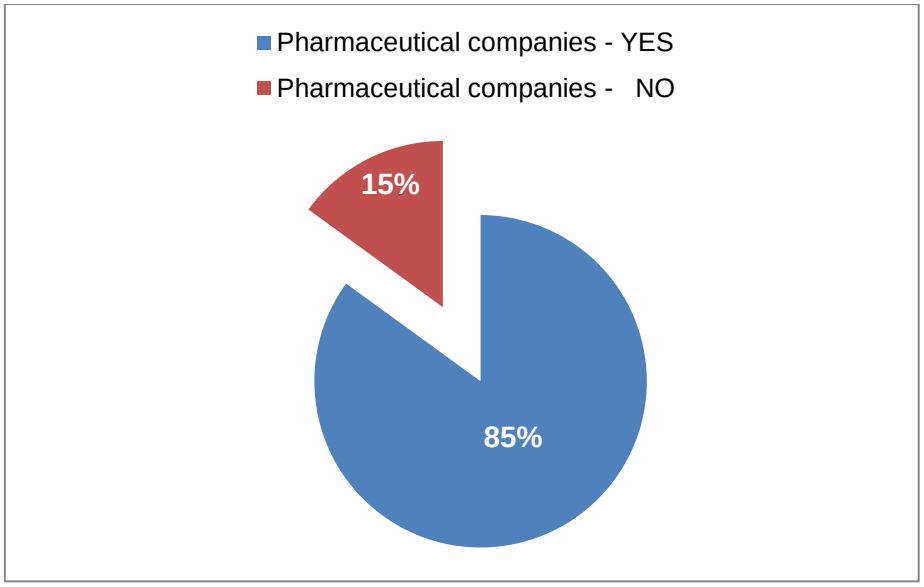

Figure 9: Percentage of the pharmaceutical firms that intend to enter into research collaboration with the universities in the near future

4.3.5 In-house research and development activities performance within firms

Fifty-seven percent of firms are involved in ongoing in-house R&D activities, 24% have occasional involvement and 19% have never had in-house R&D activities (Figure 10).

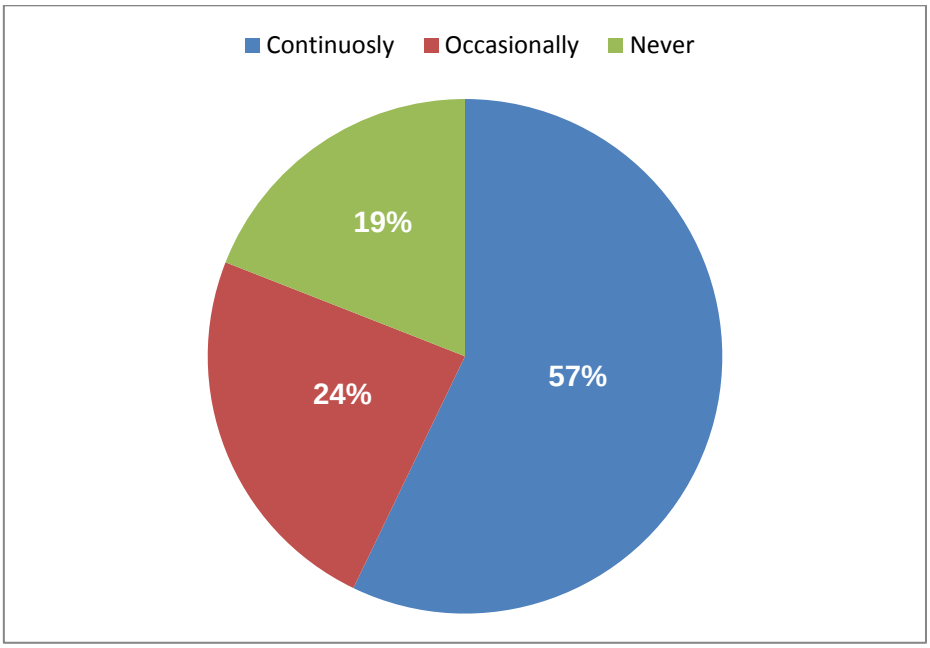

Figure 10: Percentage of the pharmaceutical firms in terms of the R&D activities performed in-house

4.4 Innovation Management

This section presents the innovation management practices at the level of the pharmaceutical firms, in order to understand the process that the management personnel of these firms undertake to make decisions to form linkages with universities.

4.5 Search

The pharmaceutical firms conduct the process of search for university specialist knowledge (Figure 11). Thirty-four percent of the respondents mentioned that they undertake the search process by approaching the universities directly to seek scientific knowledge; while 26% conduct the search process through searching for existing patents and research publications and attending conferences (26%). The remaining respondents noted that that the search process is undertaken by using the firm's knowledge brokers (9%) and conducting feasibility and market studies (6%).

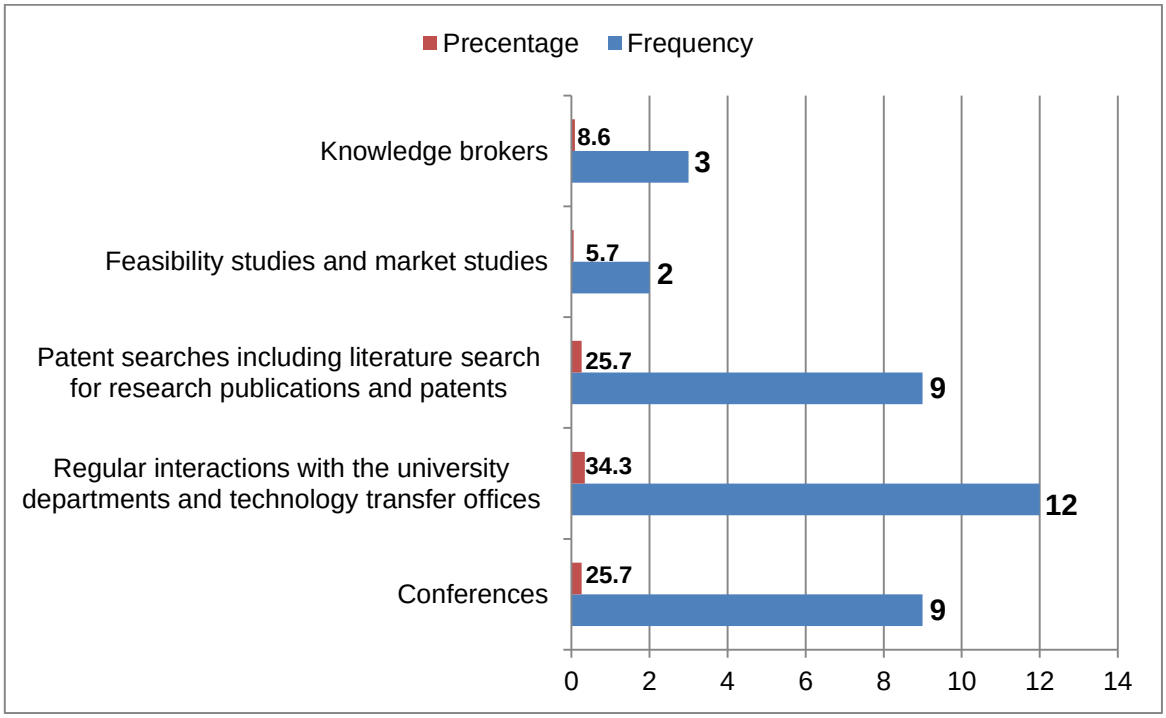

Figure 11: The scan and search process by the pharmaceutical firms participated in the study, *(n = 35)*

4.5.1 Value of search

The pharmaceutical firms were asked if the search process adds value to their value for creation. Eighty-six percent indicated that the search process adds value to what they would want to create within their firms (Figure 12).

The summary of the reasons from the respondents who indicated that the search process adds value for creation is shown in Table 4.

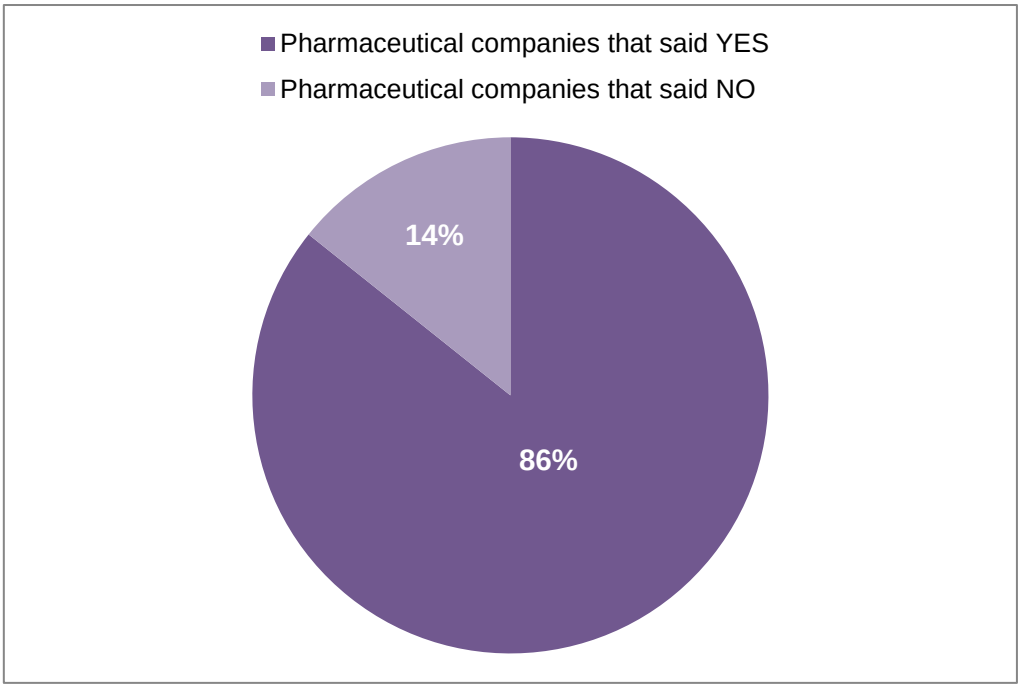

Figure 12: Proportion of the pharmaceutical firms whose search process does/does not add value to their value creation

Table 4: Summary of the reasons from the pharmaceutical firms for conducting the search process, *(n = 22)*

Reasons	Frequency	Relative frequency	%
Knowledge important to the company – develops expertise to become competitive relative to their competitors	4	0.18	18
Identify universities with relevant expertise	8	0.37	36
To familiarise with what is happening in the research environment – to identify opportunities for collaboration and derive value	7	0.32	32
Build company's internal database of the universities in order to inform strategy	3	0.14	14

4.5.2 Use of staff with specialised competencies for search process

Pharmaceutical firms were asked if they use staff with specialised competencies to undertake the process of search. Seventy-six percent indicated that they use staff with specialised competencies to undertake the search process (Figure 13).

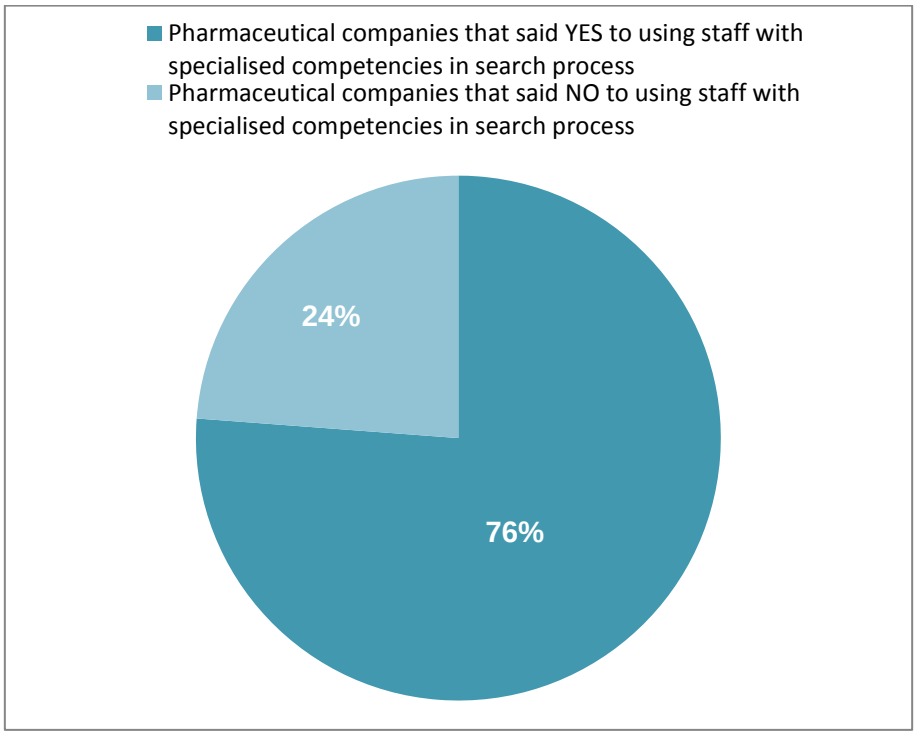

Figure 13: Proportion of the pharmaceutical firms using and not using staff with special competencies to undertake the process of search

4.5.3 Factors considered in the search process

This study explored an array of factors considered by the pharmaceutical firms in the search process. The summary of the factors as expressed in the order of importance is shown in Table 5. The most important and prioritized factors that the respondents noted were availability of resources at universities and the reputation of the university; university research complementarity to the firms and alignment to the company's strategy; university research with commercial potential and IP (intellectual property) confidentiality by universities; and cost implication for knowledge acquisition and public good.

Table 5: Factors considered in the search process, *(n = 44)*

Factors	Frequency	Relative frequencies	Relative ranking
Resource availability at universities for research and clinical research	14	0.318	1
Reputation of the university in the research frontier for doing and producing quality research including commitment to deliver	8	0.182	2
University research complementarity to the firms and alignment to the company's strategy	11	0.25	3
University research with commercial potential and IP confidentiality by universities	7	0.159	4
Other factors including cost implications for knowledge acquisition and public good	4	0.09	5

4.5.4 Types of projects

Figure 14 represents the views of the respondents on the type of projects considered when conducting the search process. Thirty-four percent considered R&D projects with commercial potential, 31% indicated translational projects; clinical research projects (14.3%), research projects relevant to the market and are cost effective (11%) and projects with proof of concept (8%) when conducting search.

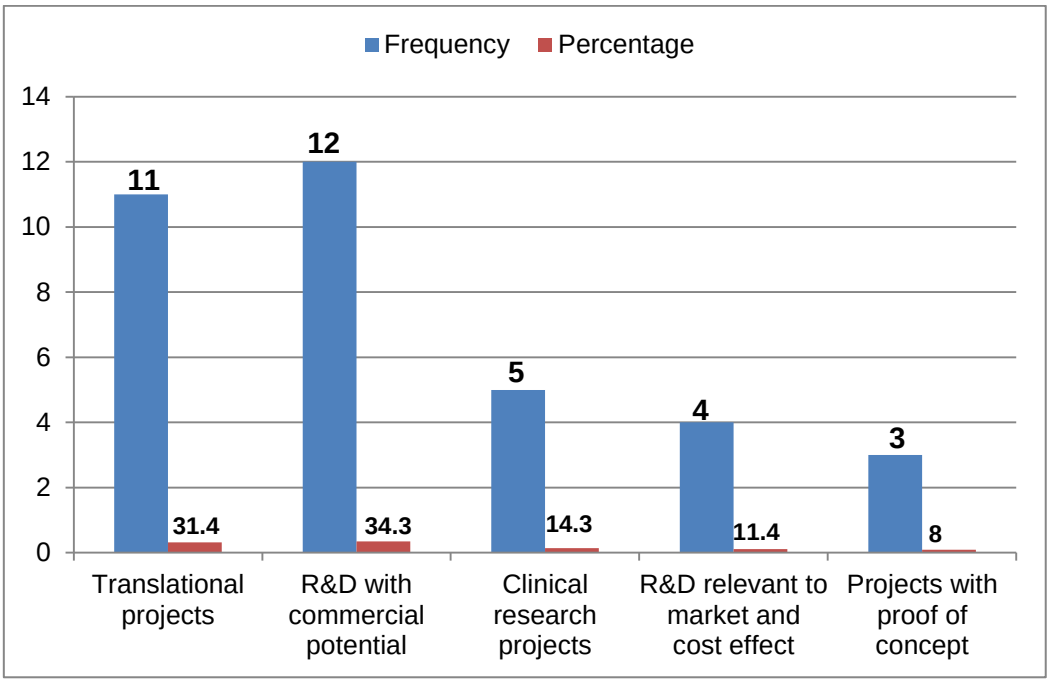

Figure 14: Types of projects considered by firms in the search process, *(n = 35)*

4.6 Selection process

4.6.1 Factors influencing the selection process

Several factors influenced the selection process for choosing universities other than other knowledge providers. Twenty-eight percent of firms agreed that expertise and experienced scientific know-how influenced their selection of the universities rather than other knowledge providers; and 15% said that reputation was an influencing factor. Conversely, 13% of firms agreed that the relevance and alignment of the university knowledge to firms' research and innovation activities influenced their

selection process, while the other firms said that distance of the university in relation to firm's location (at 11%), quality of the university research (at 11%), and infrastructure (e.g. research equipment) and a Technology Transfer Office availability (at 11%) at universities influenced their selection process. The remaining firms indicated that cost for knowledge acquisition (at 7%) and public utility (at 4%) also influenced their selection process. This is illustrated in Figure 15.

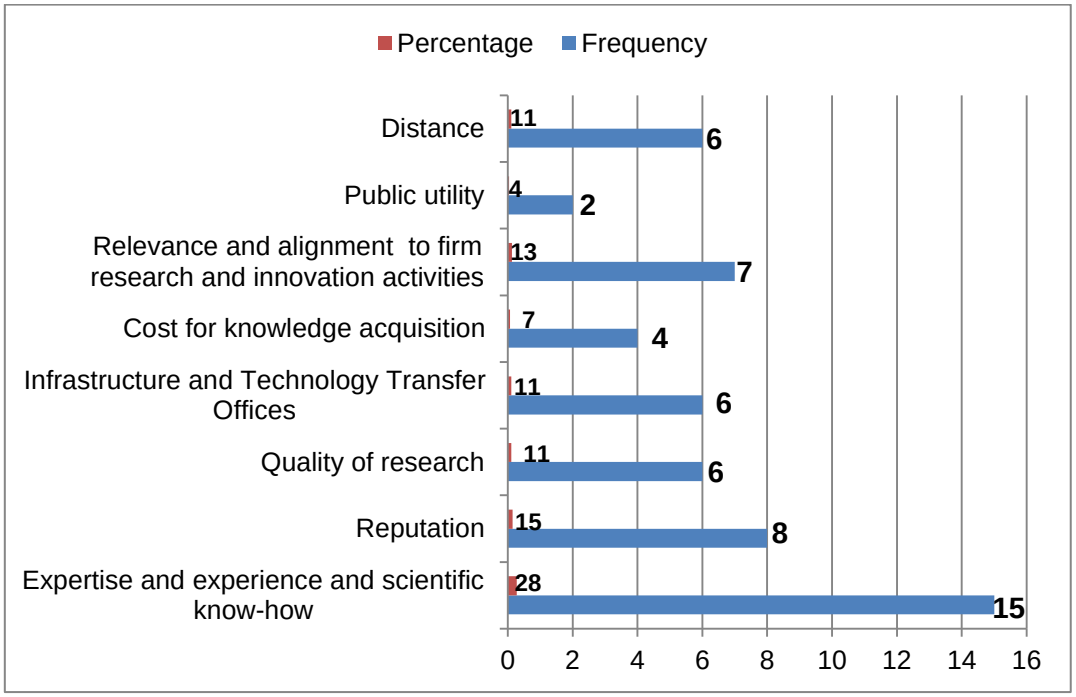

Figure 15: Factors influencing the selection process, *(n = 54)*

4.6.2 Characteristics of universities

The characteristics of the universities influenced the selection process (Figure 16). Thirty-two percent of the firms agreed that universities with trained, experienced researchers with research expertise facilitate the selection process, while 20% of the firms indicated that universities with international exposure and standing among their research peers facilitate their selection process. Other firms noted that universities whose research is relevant to the firm, with technology platform infrastructure and are accessible to the firm, facilitate the selection process.

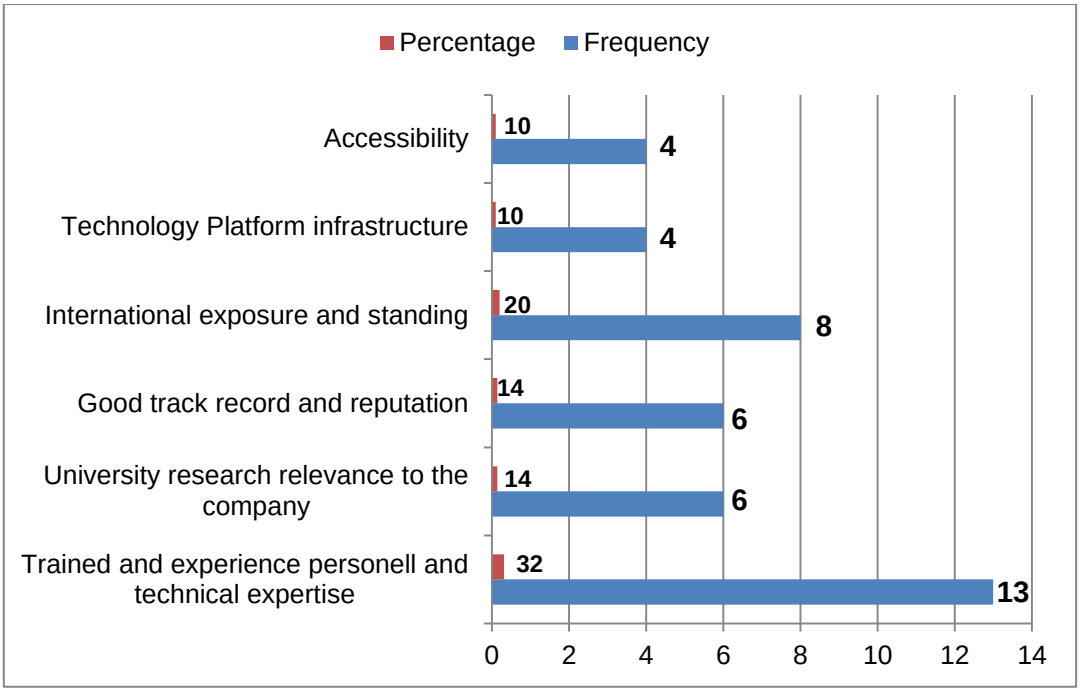

Figure 16: Characteristics of universities, *(n = 41)*

4.7 Decision making

4.7.1 Firm management level

Figure 17 indicates the views of the firms on management level decisions on how knowledge collaboration with universities was taken. The graph reveals that 43% of decisions were taken by senior management, 40% were at Executive Level, which includes the CEO and 17% at Board Level.

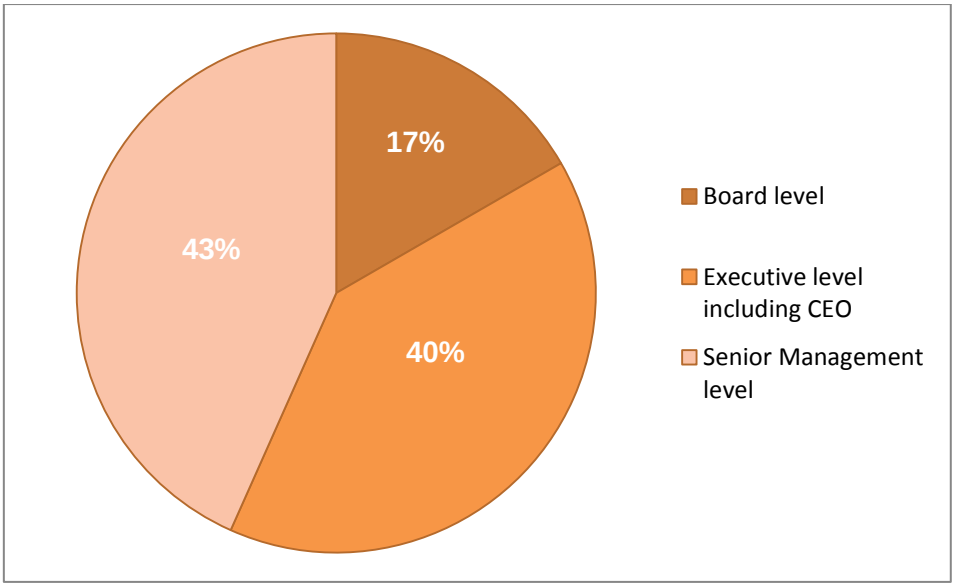

Figure 17: Firm management level of decision making

4.7.2 Investment committee

Fifty-seven percent indicated that decision making involved participation of their investment committee (Figure 18).

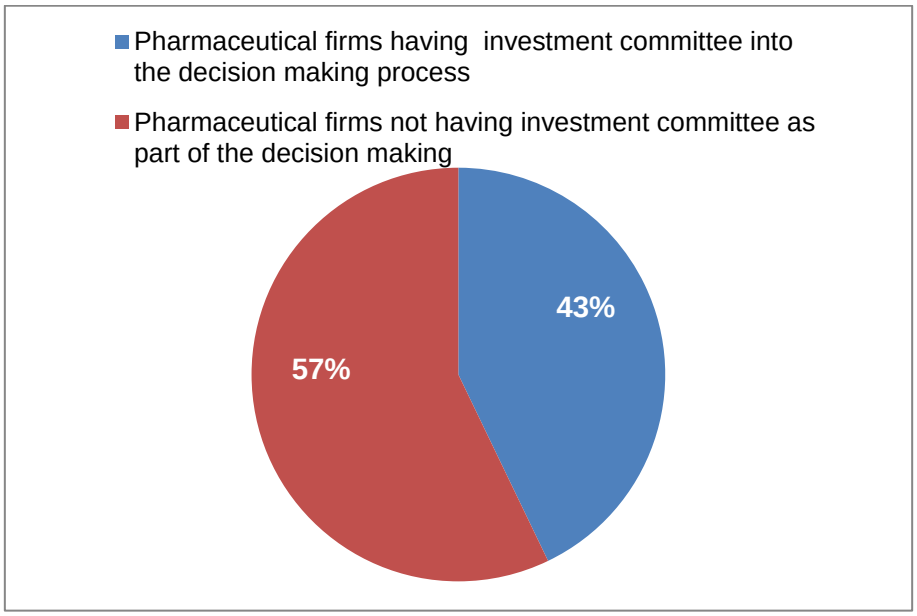

Figure 18: Proportion of the pharmaceutical firms with investment committee involvement in the decision-making process

4.7.3 Decision making process

The pharmaceutical firms were asked to describe the process for making decisions on knowledge collaboration with universities. The summary of the decision making process is shown in Box 2.

Box 2: Summary of the decision making process within the firms participated in the study

- Process of iterative reasoning - for instance, is the knowledge aligned to the company's vision and is it cost effective? Gathering of all the data or information about universities' scientific expertise and capabilities and patient population and reviewing universities' past performance
- Senior management providing inputs into strategic decisions
- Thought process that goes into deciding which technologies to pursue for development and what knowledge inputs are required
- Discussing the available treatments on markets such as their effects and demand, leading to decisions on projects to undertake
- Discussing the commercial viability of the knowledge to the firm or whether the knowledge is commercially viable
- Deciding what they require from universities and making decisions based on their requirements
- Performing feasibility studies to determine which universities are potential collaborators. Also sending out questionnaires to universities to ask about the research they perform and the available expertise and if they would be interested in partnering on R&D
- Discussing R&D strategy with project managers to determine whether knowledge is aligned to the company strategy
- The CEO makes contact with universities about the research and then makes the final approval
- Reviewing the firm's past relationship with universities
- Through collective efforts within different levels of the company
- Consultation among different levels of the company

4.7.4 Decision approval

Of the international firms operating in South Africa that were interviewed, 67% noted that the decisions are taken at their Head office overseas, 33% indicated that decisions are taken at the regional office in South Africa (Figure 19).

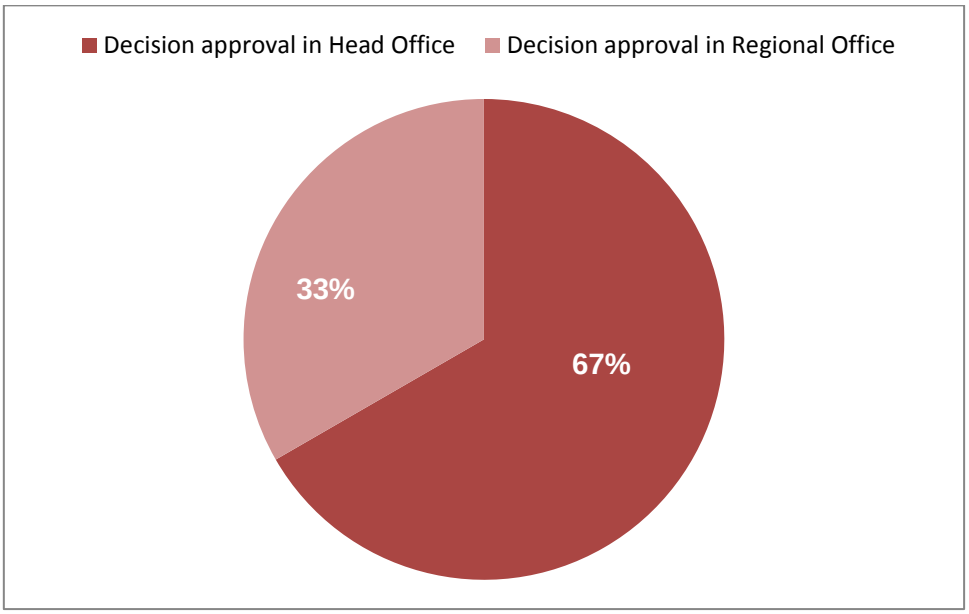

Figure 19: Decision approval within the international pharmaceutical firms operating in South Africa participated

In terms of where the operational aspect of knowledge collaboration is taking place, 81% of the international firms noted that they had a Regional Office in South Africa, which was involved in operationalising the knowledge collaboration with the universities, while 19% said that their International Office got involved (Figure 20).

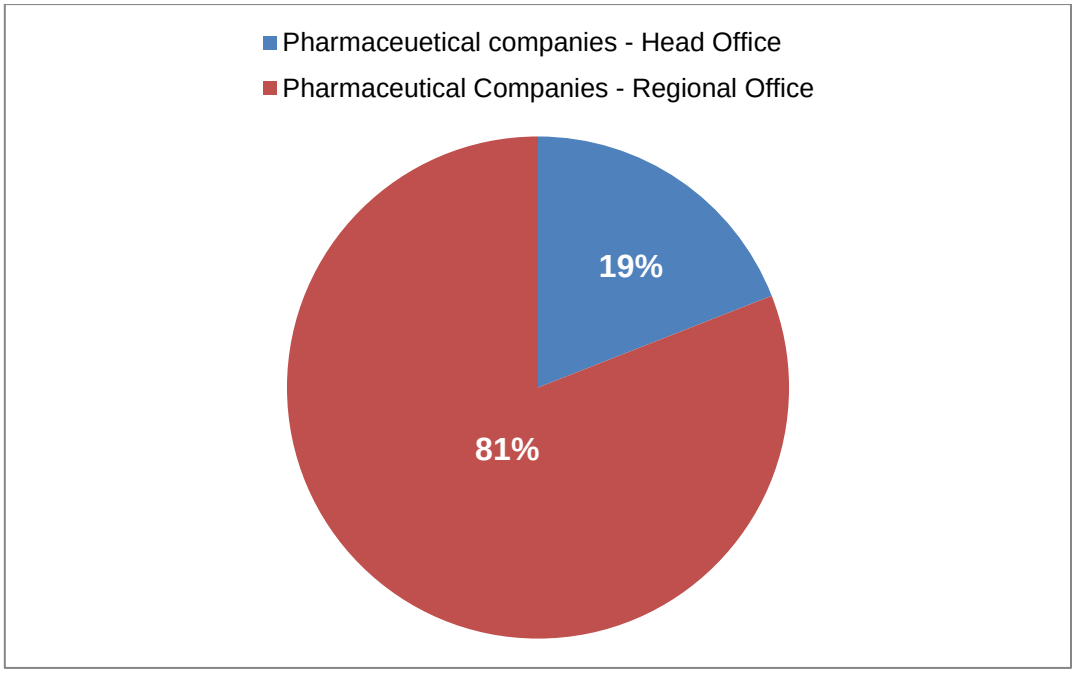

Figure 20: Operational aspect of multinational pharmaceutical firms for knowledge collaboration with the universities

4.7.5 R&D projects decision making process

A percentage of how the R&D projects were decided upon by all the pharmaceutical firms is indicated in Figure 21. Forty-one percent said that the outcome of market studies influenced which R&D projects or technologies were explored, and 22% noted that the decisions on which R&D projects to explore resulted from extensive discussions among the different departments within firms. Fifteen percent agreed that population studies dictated the decisions on which type and design of clinical research studies needed to be undertaken in collaboration with a university, and 11% of the firms said that interaction with the relevant university department through a process of enquiry and a request from their overseas Head Office resulted in their decisions on which research projects to explore.

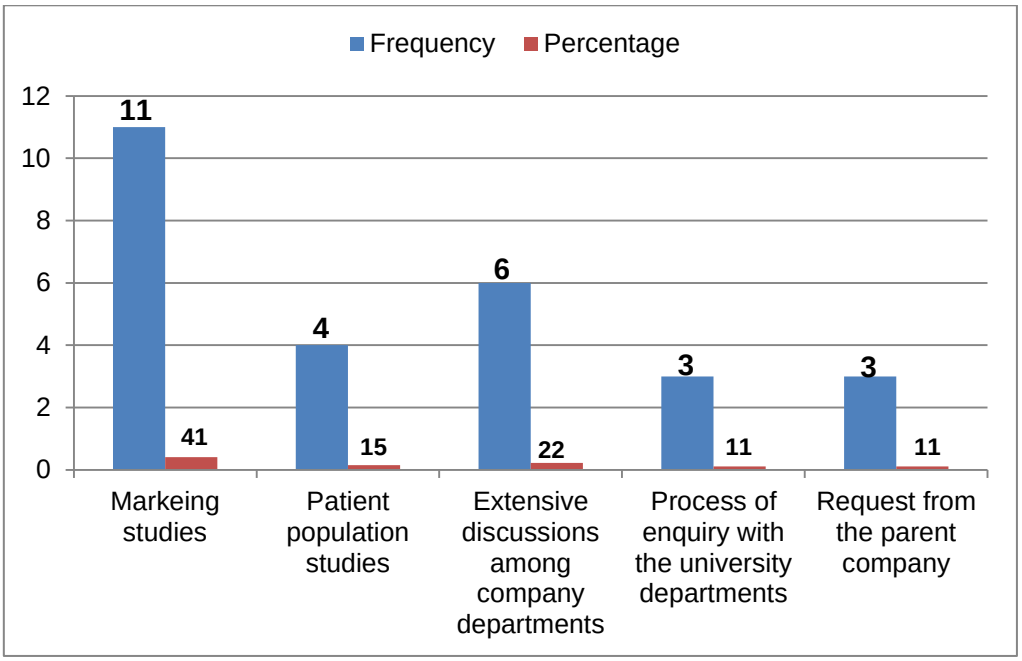

Figure 21: Decision making processes on R&D projects to explore, *(n = 27)*

4.7.6 Management and improvement collaboration with universities

Of all the pharmaceutical firms that participated in the study and indicated collaboration with universities (refer to Figure 4), 26% agreed that they managed improving collaboration with universities through capacity building and problem solving ability. This was followed by 15% of the firms that highlighted a commitment, sponsorships of conferences and constant searching for new and experienced people at universities and science councils to collaborate with the firm. Eleven percent all mentioned the mutual interest and benefits of collaboration, and search for new technical expertise, respectively, as important in managing improvement in collaboration with these technological knowledge providers. The remaining 7% mentioned that a constant communication helped to manage improving collaboration. This is indicated in Table 6.

Table 6: Managing knowledge collaboration with universities *(n = 27)*

Managing knowledge collaboration	Frequencies	Relative frequency	Percentage
Capacity building and problem solving ability	7	0.26	26
Commitment to collaboration and relationships with Heads of Department.	4	0.15	15
Sponsoring and attending academic conferences	4	0.15	15
Looking for new people with expertise	4	0.15	15
Mutual interests and benefits	3	0.11	11
Constantly looking for new technical expertise	3	0.11	11
Constant communication	2	0.07	7

4.7.7 Value of collaboration with universities

All the pharmaceutical firms that collaborated with universities agreed that they had derived value from collaborating with universities (Table 7).

Table 7: Views of the firms regarding value derived from knowledge collaboration with universities

Universities
Universities have much broader contracts which allow firm the freedom to collaborate with other actors.
There are always students available in projects involving a firm collaboration. This is mainly facilitated by government funding programmes.
Universities specializes in performing basic research, development and training of skilled human capital to support pharmaceutical firms research and technology development and have highly experienced researchers who understands markets needs for technologies.
Conditions at universities are favourable for conducting clinical research activities by

firms, such as universities are connected to hospitals, enabling to have easy access to patients information and cooperation, and recruitment of quality patients to participate in clinical research.
Universities understand markets and technology constraints as well as the South African regulatory requirements for clinical research.

4.8 Types of specialised university knowledge inputs

Figure 22 below indicates that 35% of the respondents from the pharmaceutical firms that participated agreed that research and related expertise is their knowledge requirement from the university to solve technology problems and constraints. Twenty-three percent of the respondents require research expertise that would improve production and manufacturing processes in order to increase their competitive advantage. Sixteen percent indicated they would require expertise to design a credible clinical research protocol that is cost effective. The remaining 3% require universities that would assist them in understanding the South African regulatory requirements for clinical research as well as on how to overcome such regulatory requirements.

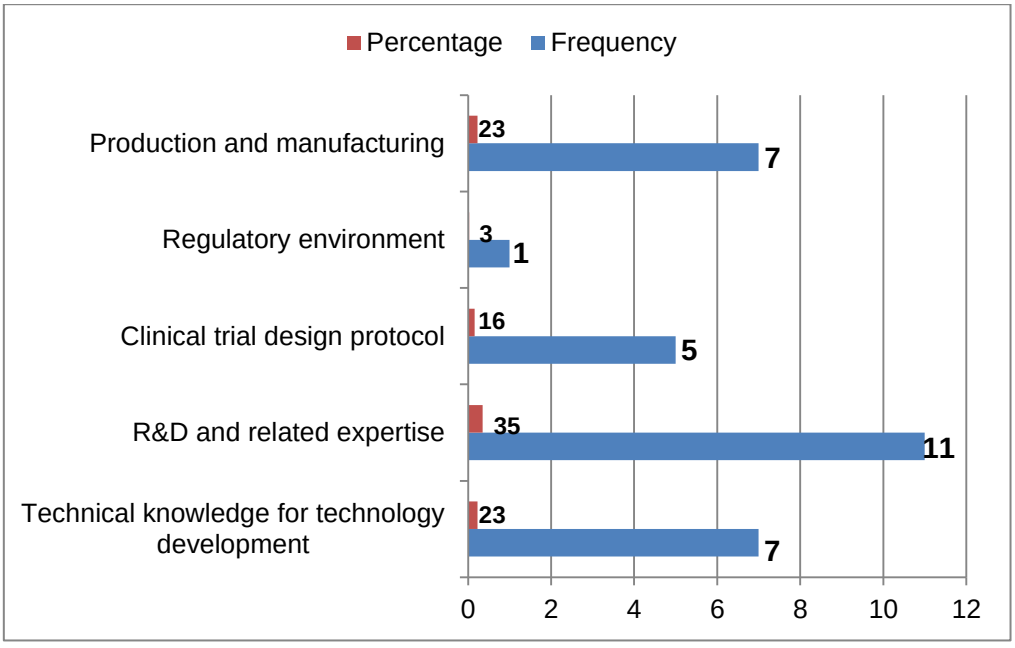

Figure 22: Types of university knowledge inputs required by the pharmaceutical firms that participated in the study, *(n = 31)*

4.8.1 Knowledge capture

Figure 23 indicates the views of respondents from the pharmaceutical firms on ways their firms capture external technological knowledge inputs from universities to improve innovation process and deliver on projects. Fifty percent of the respondents capture technological knowledge on documentation of physical hard copies and 25% on electronic databases. Ten percent highlighted project management systems and technology transfer agreements to capture knowledge to improve collaboration experiences, respectively and 5% indicated that mentoring programmes assist in capturing knowledge for future projects.

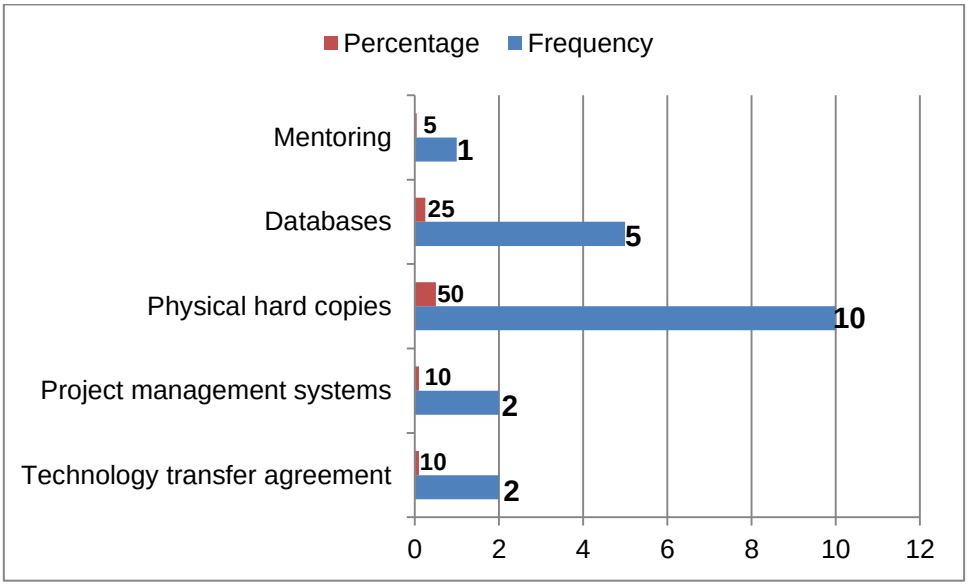

Figure 23: Capturing mechanisms for specialised knowledge inputs, *(n = 20)*

4.8.2 Codification of external university knowledge

Figure 24 shows the ways in which the firms codify external specialist knowledge from universities on physical and electronic base systems in order to benefit the innovation process of the firm.

Thirty-eight percent of the respondents use electronic document systems, 33% use physical hard copies, 14% use training initiatives connected to manuals, and 10% and 5% used employment contracts and minutes of the meetings, respectively.

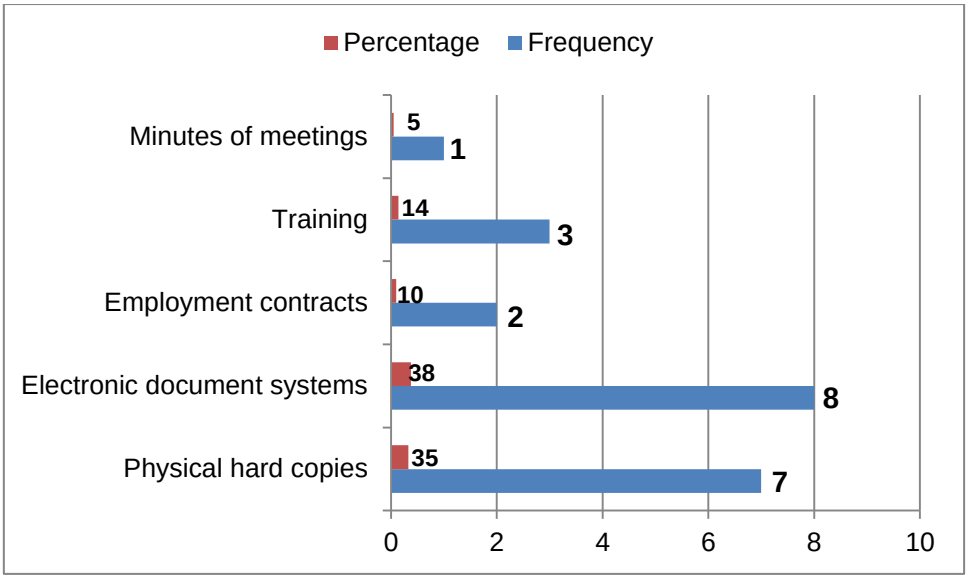

Figure 24: Codification of the external specialist knowledge from universities, *(n = 21)*

4.9 Learning from university knowledge inputs

Figure 25 shows how firms learn from external specialist university knowledge. Thirty-seven percent indicated that they learn from published research articles of interest during the search process of specialist knowledge, while 25% said that reviewing past research collaboration contracts with universities enable their learning experiences for future collaborations with external technology partners. Nineteen percent mentioned reviewing their firms' internal databases of lists of universities including other electronic document management systems to facilitate learning. The remaining 13% and 6% agreed that mentoring of the firms' researchers by university researchers on specific technologies and various training provided by the universities' initiatives facilitate learning within firms.

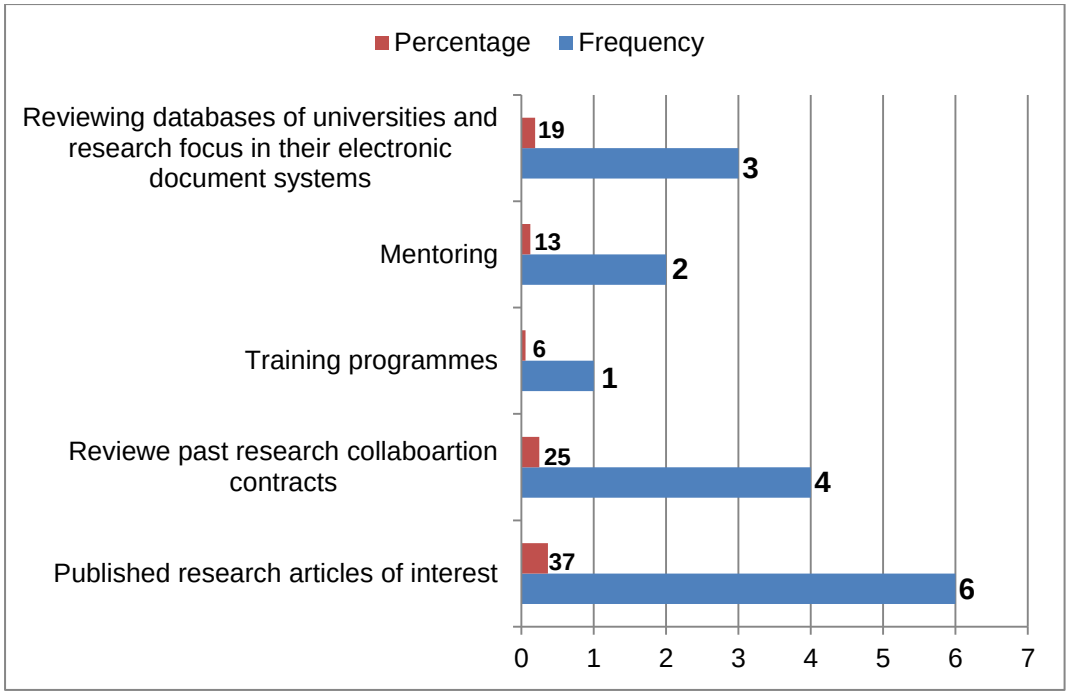

Figure 25: Ways to improve learning from external university knowledge according to the pharmaceutical firms participated in the study, *(n = 16)*

4.10 Value of the university knowledge

4.10.1 Resource allocation to knowledge collaboration

This section presents data on why the pharmaceutical firms dedicate resources to knowledge collaboration with universities. Thirty seven percent indicated that resource allocation to technological collaboration with universities helps to acquire knowledge in order to develop internal expertise on specific technologies for development and 33% spoke about the need to develop unique and competitive technologies (Figure 26). The remaining 30% collectively mentioned the need to develop their networks; to stay abreast of their competitors; to promote their company's brand; part of the firm innovation strategy to form external collaborations; and to reduce costs for research and development, all at 5%.

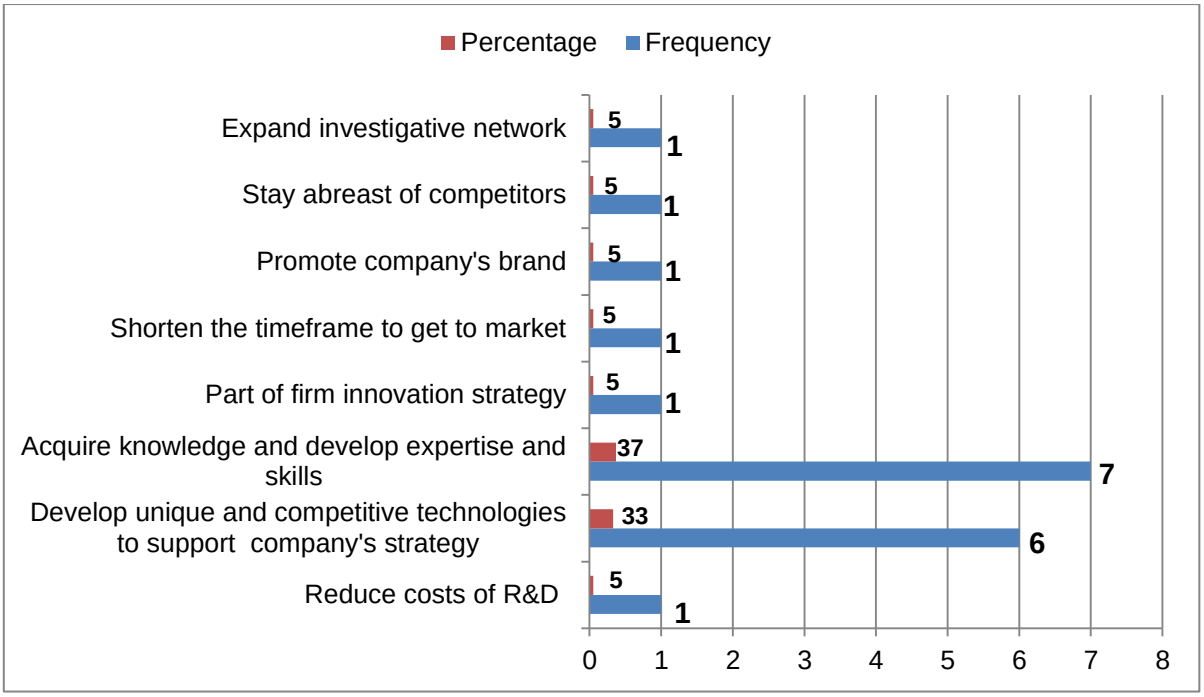

Figure 26: Reasons of the firms for dedicating the resources to knowledge collaboration with universities, *(n = 19)*

4.10.2 Effects of university knowledge on firm technologies

Figure 27 summarizes the effects of how university knowledge has an effect on pharmaceutical firm research and technology development that participated in the study. University knowledge has an effect on pharmaceutical research and technology development. According to the below graph, 30% of the respondents mentioned that university knowledge helped to commercialise technologies faster; 22% said that the effect of university knowledge was evident in increasing a firm's technological knowledge and 17% mentioned the effect helped to conduct a highly competitive clinical research and enhanced the quality of the research, respectively. The remaining 4% agreed that university knowledge had an effect on making predictions of technology trends.

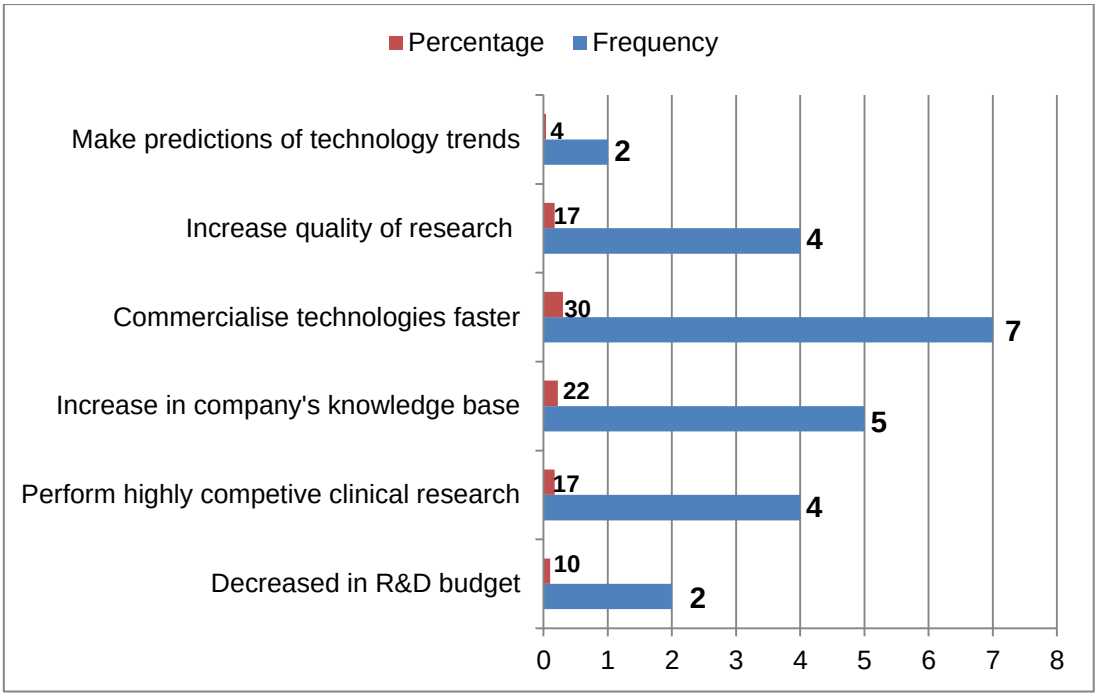

Figure 27: Effects of university knowledge on firms' research and technology development, *(n = 23)*

4.10.3 Effects of university knowledge on firm's innovation

Table 8 indicates the views of the firms on the effects of university knowledge on their firms' innovation activities. Thirty-five percent agreed that university knowledge did not have any effect 18% said that it helped to increase a firm's internal knowledge base, commercialised product technologies and designed clinical research protocols, 6% agreed that the university knowledge improved innovation on production and manufacturing processes for generic drug technologies, and effected the establishment of technology platforms at universities to focus on drug development initiatives.

Table 8: Effects of university knowledge on pharmaceutical firm's innovation activities, *(n=17)*

Effects of university knowledge on firm's innovation activities	**Frequency**	**Relative frequency**	**%**
No effect	6	0.35	35
Increases firm's internal knowledge base to innovate	3	0.18	18
To commercialise product technologies faster through licensing	3	0.18	18
To design quality protocols to conduct clinical research	3	0.18	18
Improve innovation capability in manufacturing processes	1	0.06	6
Establish drug technology delivery programmes at universities	1	0.06	6

4.11 Summary of the key findings

4.11.1 Search process

The pharmaceutical firms operating in South Africa that participated in this study employ a number of approaches to search for specialist technological knowledge from universities. These are: regular academic conference attendance; interactions with the relevant universities' departments and technology transfer offices; patents and research publications; market studies and knowledge brokers. In addition, the pharmaceutical firms appear to search for external technological knowledge through student employment programmes which they had established, and use competent staff to search for specialist knowledge inputs from universities. They go out to the universities to find out which technologies are available that their firm can acquire and adopt.

Although search adds value to the pharmaceutical firms, it seems to not be organised. It does not happen sequentially and is an "*ad hoc*" activity which is neither planned nor budgeted for. However, the study suggests that search is effective and adds value to the firms as these are able to find the external specialist knowledge input from universities for their technology development and innovation activities. Search, therefore, adds value to the firm.

The pharmaceutical firms consider an array of factors when conducting the search process. The key factors in the order of importance are: resource (experienced researchers and infrastructure linked to the research) availability to undertake the research; reputation of the university and commitment to produce deliverables within set timeframes and relevance of the university to firm strategy. It is also notable that upholding confidentiality of the intellectual property generated is also considered an important factor by firms when undertaking the search process. However, the cost implications to acquire university knowledge do not appear to be an important factor in the search process for external specialist knowledge; it was less frequently mentioned by the respondents compared to the other factors.

4.11.2 Selection process

The pharmaceutical firms consider multiple factors to select universities among other technological knowledge providers. These are: expertise; experience, scientific know-how; relevance and alignment of the university knowledge to firms' research and innovation activities; distance of the university in relation to the firm's location; quality of the university research; and research equipment and Technology Transfer Office. Cost for knowledge acquisition and public utility play a minor role in the firm selection process.

On the other hand, firms also take certain university characteristics into account when making their selection such as technology expertise, experience and know-how, infrastructure and technology transfer office availability. The study suggests that these factors as well as the university's characteristics may have influenced the selection criteria of firms for choosing the particular university among other technological knowledge providers, and ultimately the firm's decisions in forming linkages with universities.

4.11.3 Types of specialist knowledge inputs

The pharmaceutical firms prefer university knowledge packaged in a commercial framework. This includes research related to the market and translational research leading to technology development. These firms seek out specialist knowledge related to the production and manufacturing processes. It is also noted that the pharmaceutical firms are interested in university knowledge that can assist them in understanding the regulatory environment for clinical research and for overcoming hurdles for new drug technologies approvals. The effects of these knowledge inputs could lead to the firms' ability to commercialise their technologies faster and improve their competitiveness.

The pharmaceutical firms capture the university knowledge inputs in internal knowledge management systems such as databases and programmes. These facilitate the firms' learning process, which includes reviewing past research contracts with universities. Mentorship, i.e. working alongside highly experienced

researchers seems an important aspect of the learning experience in production and manufacturing processes as well as in designing clinical research protocols. Knowledge also flows to firms through licensing agreements and contract outsourcing.

4.11.4 Decision-making and process

In all the pharmaceutical firms that participated in the study, the decision to link with universities on research and development and technology development are taken at senior and executive management levels. Only a few decisions are taken at the company's board level. However, the decision making process does not involve one individual, but is a participatory process involving a team of individuals from different business units within a firm. Decision making is iterative-- it is a thought process which is usually informed by feasibility studies, market information and patient population studies as well as interaction with universities to identify knowledge requirements. The decision-making process also involves investment committee inputs.

In the case of international pharmaceutical firms operating in South Africa, the major and final decisions on knowledge collaborations, as well as clinical research based on new drug technologies, are approved at their Head Offices based overseas. The regional offices based in South Africa are mainly involved in the operational aspects of knowledge collaboration with universities, such as identifying the appropriate universities for collaboration on technology development and clinical research. They are, however, not necessarily involved in company policy and strategy decisions which are taken by the Head Office. Regional offices are required to provide regular feedback to the Head Office overseas regarding the progress of the research.

4.12 Triangulation

The researcher also interviewed individuals from the South African universities and expert commentators that were drawn from the South African national government departments and government knowledge producing institutions. The individuals and expert commentators collectively will be referred to as participants in this section when presenting the data. The interviews were mainly to validate the views of the pharmaceutical firms that participated in the study from earlier interviews regarding linkages with universities on scientific and technological knowledge.

This section, therefore, presents the combined views and opinions of the expert commentators separately in order to be able to assess their degree of congruence with those of the primary respondents, as well as any deviations from those views. The data is presented in tables of summary and graphs.

4.12.1 Search

All the participants agreed that the pharmaceutical firms perform the search function to ensure access to relevant specialised knowledge from universities. The views of the individuals and expert commentators with regards to search functions employed by pharmaceutical firms operating in South Africa for external specialist knowledge from universities is illustrated in Figure 28.

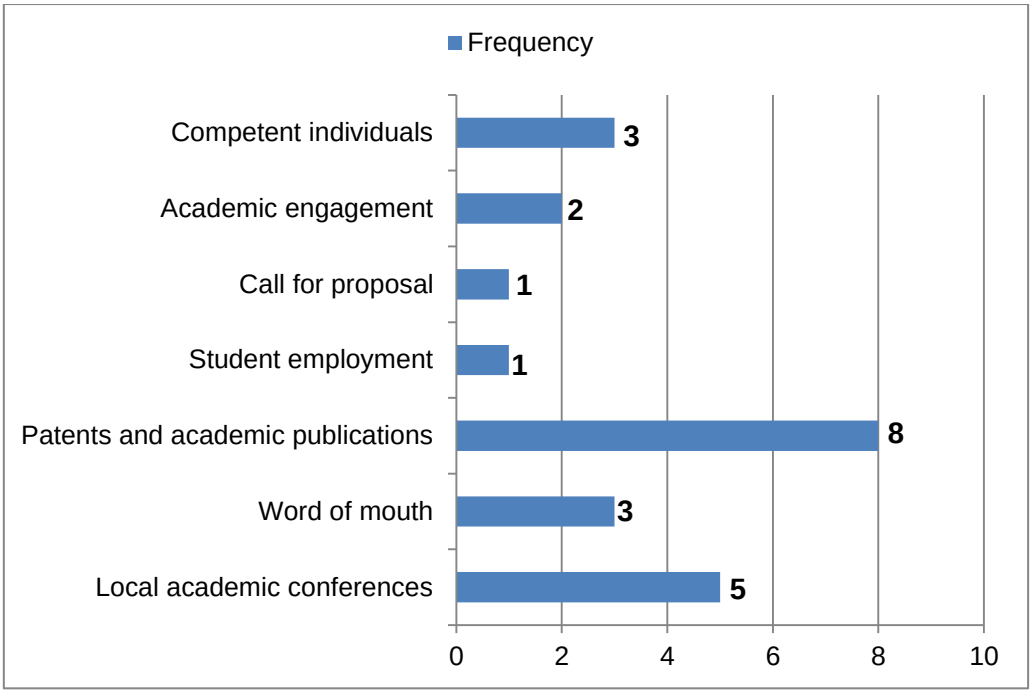

Figure 28: Search function by pharmaceutical firms operating in South Africa, *(n = 23)*

4.12.2 Search process

All the participants agreed that the process of search by pharmaceutical firms operating in South Africa is not organised but effective. Box 3 indicates the search process by pharmaceutical firms.

Box 3: The search process in terms of the views of the expert commentators from universities and government departments and government knowledge generation institutions

- Identifying a potential university partner on R&D at a local academic university conferences and then follow up to set up meetings for further discussions
- Some pharmaceutical firms have in-house research programmes, therefore it becomes easier for them to engage the universities (which they have identified through on-line search for patents and academic publications and even at conferences) on potential collaborative research projects that would address their needs
- Engaging the relevant universities that they had identified at conferences

- Pharmaceutical companies know their research needs and approach the relevant university they believe would address these
- Keeping abreast of the research developments at universities can be achieved through conference attendance, academic publications and patents. Pharmaceutical firms have governance structures comprising of scientific research board and stakeholders who provide advice.

4.12.3 Sources of knowledge

All the participants agreed that pharmaceutical firms have sources of knowledge to draw from. Table 9 indicates the typical sources of knowledge of pharmaceutical firms operating in South Africa in terms of the views of the expert commentators drawn from universities and government departments and government knowledge generation institutions who participated in the study.

Table 9: Typical sources of knowledge of pharmaceutical firms, *(n = 23)*

Source of knowledge	Frequency	Relative frequency	%	Ranking
Publications and patents (prior art search)	7	0.30	30	1
Visits to universities	5	0.22	22	2
Specialised university department and engagement	4	0.17	17	3
Conference proceedings	3	0.13	13	4
Networks (word of mouth)	2	0.09		5
Historical relationships with universities	1	0.09	9	6
University websites	1	0.09	9	

4.12.4 Selection

4.12.4.1 Selection criteria

All the participants agree that pharmaceutical firms have criteria for choosing universities among other knowledge providers as opposed to science councils. Figure 29 reveals the criteria used by pharmaceutical firms to select universities for scientific and technological knowledge in the order of ranking.

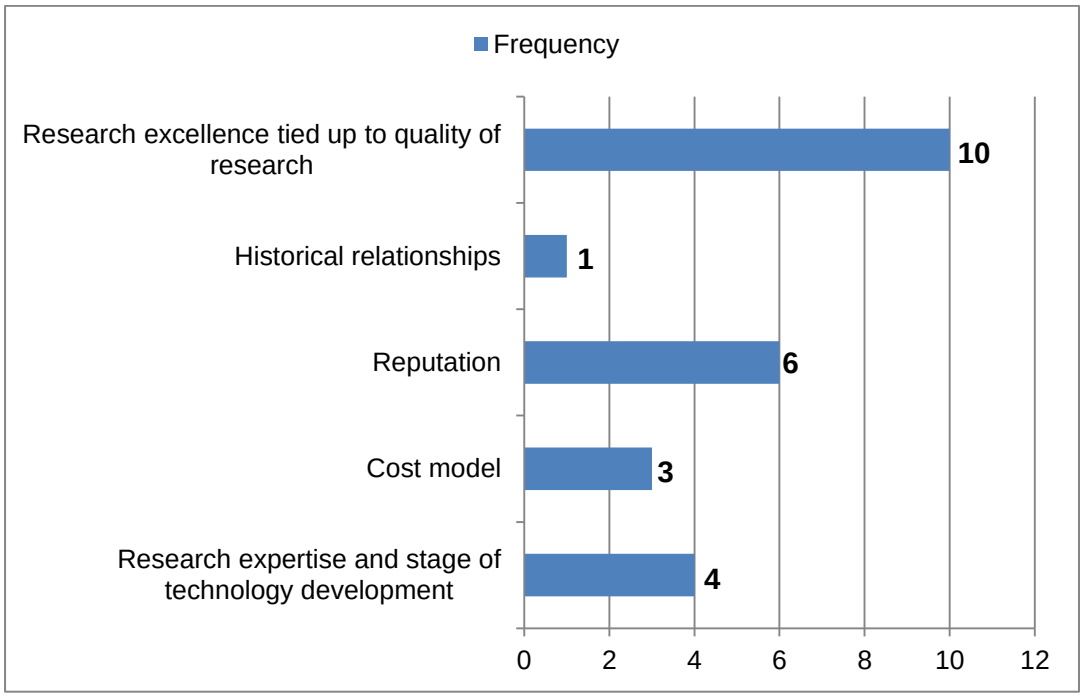

Figure 29: Selection criteria used by pharmaceutical firms for choosing universities among other technological knowledge providers, *(n=24)*

4.12.4.2 The characteristics of universities

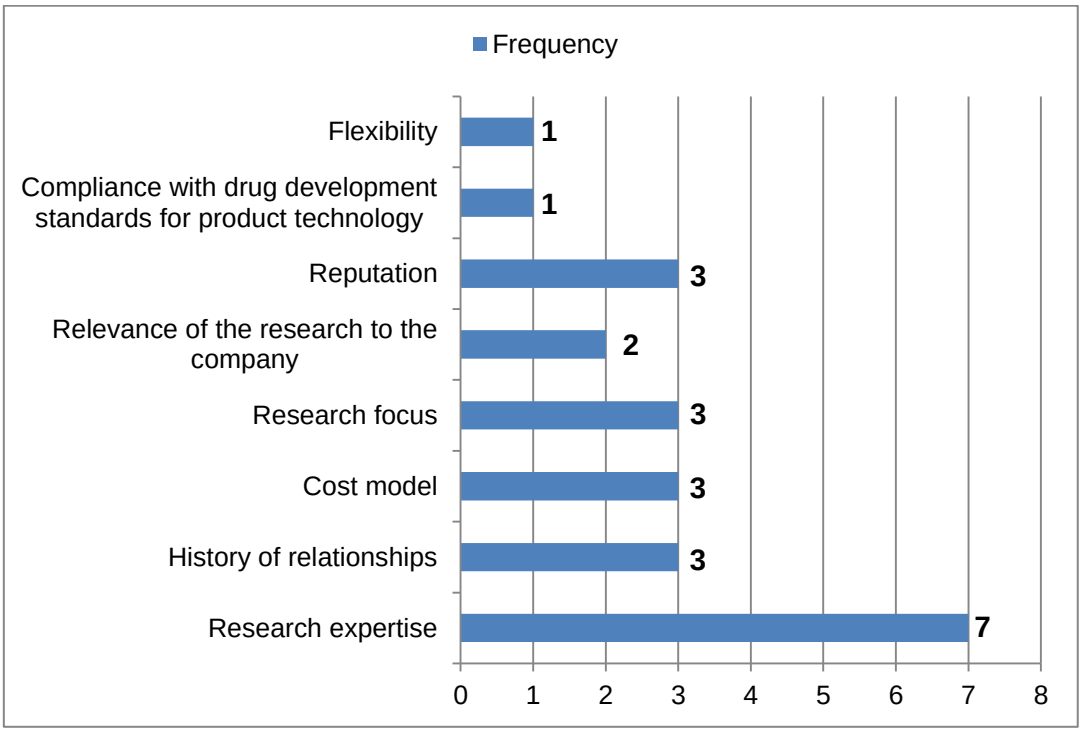

Figure 30: Characteristics of universities considered by pharmaceutical firms in the selection process, *(n = 23)*

4.12.5 Types of linkages between firms and universities

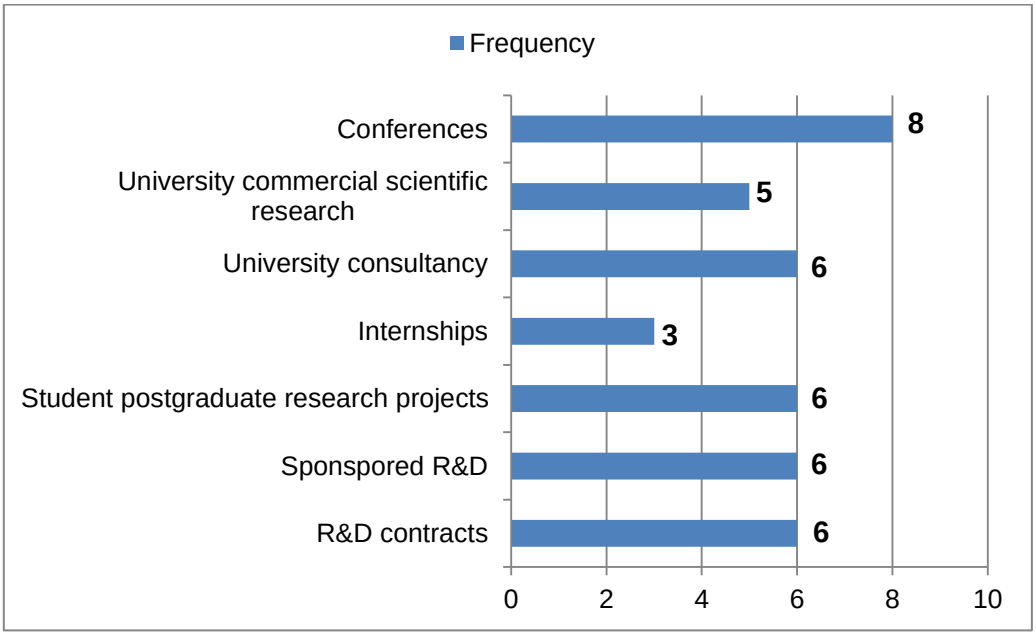

Figure 31: Types of linkages between firms and universities in South African pharmaceutical industry, *(n = 40)*

4.12.6 Nature of university scientific knowledge outputs

The percentage of the participants who indicated the nature of scientific knowledge inputs needed by pharmaceutical firms operating in South Africa is indicated in Figure 32. Eighty percent said that pharmaceutical firms require scientific basic knowledge from universities packaged in a commercial framework and 20% said that firms require basic scientific knowledge from universities.

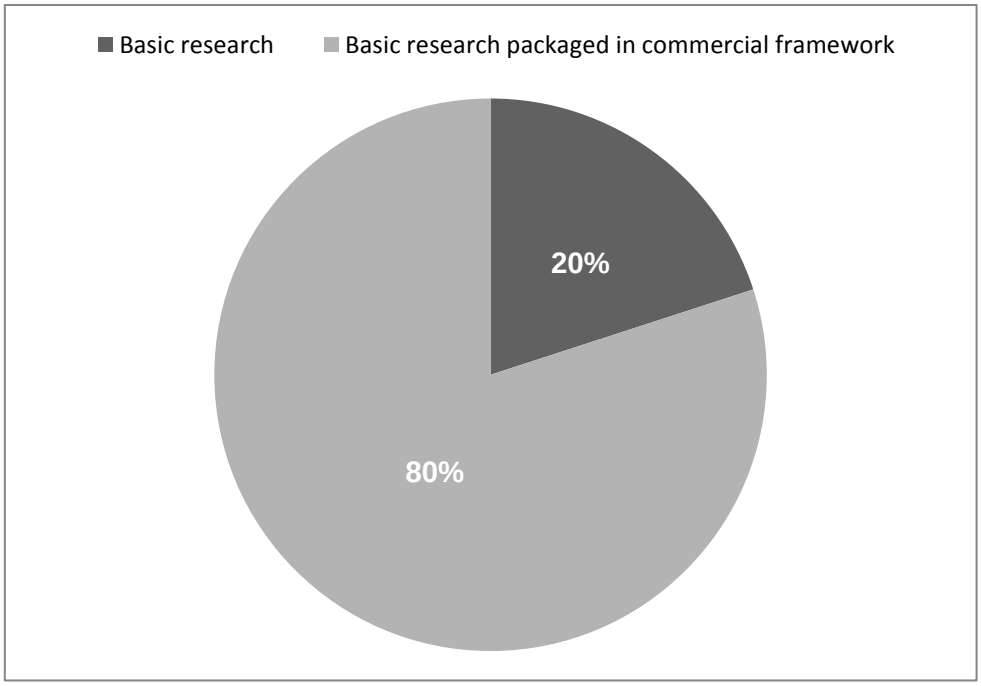

Figure 32: Nature of university scientific knowledge outputs

4.12.7 Types of knowledge flows

All participants agreed that knowledge flows from universities to pharmaceutical firms through a variety of channels or flows as indicated in Figure 33. These include contract research (frequency = 1), outsourcing (frequency = 1), employment of experienced researchers (frequency = 2), as well as interactions or engagement with the university research departments (frequency = 4) and license agreements (frequency = 2).

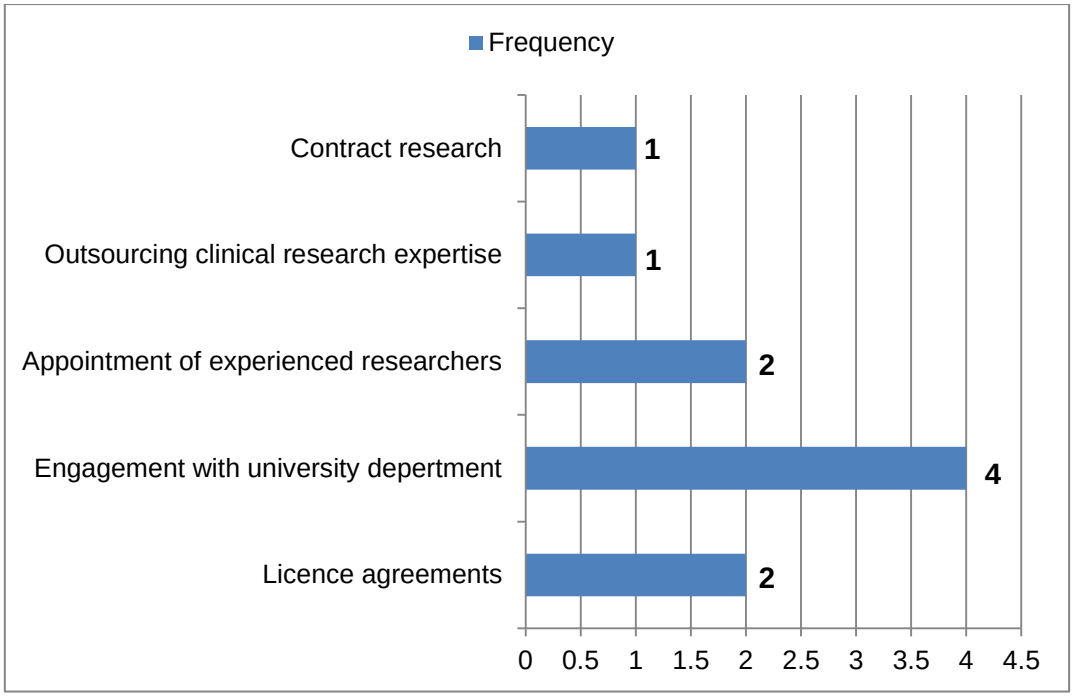

Figure 33: Types of knowledge flows, *(n = 10)*

4.12.8 Influence of knowledge flows

Box 4 indicates the influence of knowledge flows on pharmaceutical firms' innovation activities, according to the views of the expert commentators drawn from universities and national departments and government producing knowledge institutions.

Box 4: Influence of knowledge flows on pharmaceutical firms' innovation activities

- Create innovations in product technologies
- Adopt new technologies from universities and develop innovation
- Help pharmaceutical firms to focus on research in order to address their technology needs and deliver on new technologies that might create competitive advantage
- Enhance capacity within pharmaceutical firms to innovate
- Increase pharmaceutical firms' potential to compete on the market
- Further the research focus within pharmaceutical firms
- Develop technology platforms focusing on drug discovery projects
- Reduce costs for doing research within pharmaceutical firms

Universities are perceived cheaper by the pharmaceutical firms

- Assist the pharmaceutical firms to gain insight and understanding - so to do research differently.
- Make decisions on research projects that would lead to incremental innovation

4.12.9 Cost effectiveness

All participants agreed that cost effectiveness is important to pharmaceutical firms when acquiring technological knowledge from universities. This is indicated in Box 5.

Box 5: The importance of cost effectiveness of the university knowledge acquisition by the pharmaceutical firms

- Most pharmaceutical firms' technological capabilities enable them to make decisions on selection of appropriate universities to form linkages with
- The R&D budgets of pharmaceutical firms are small or limited-- about R2.5 million. As such, pharmaceutical firms are interested in collaborating with universities to advance their research budget.
- Knowledge acquisition supports pharmaceutical firm strategy
- Pharmaceutical companies have research strategies with identified research areas of focus. They utilise university linkages to identify highly experienced researchers whom they can employ in the future
- Knowledge flows save the pharmaceuticals time in research and innovation process

4.12.10 Reasons for pharmaceutical firms for choosing universities

The participants indicated that pharmaceutical firms have reasons why they are choosing universities as external specialist technological knowledge. Box 6 indicates the summary of the reasons in terms of the views of the participants.

Box 6: The reasons of pharmaceutical firms for choosing the universities

- Universities have partial full cost models which do not entail labour and overhead costs as compared to science councils – having full cost model for R&D
- Pharmaceutical firms have a history of relationships with universities which have been built over time and know what research is being performed at universities.
- Universities produce quality of research linked to students. Students can be employed by the pharmaceutical firms for research work.
- It is cheaper to collaborate with universities than science councils, for example.
- Working with universities gives pharmaceutical firms the credibility and enhances their reputation
- To take advantage of research funding opportunities at universities

This data were used in this study to get additional insights and achieve a higher degree of reliability of the primary data collected from the initial elite interviews with the pharmaceutical firms operating in South Africa. Triangulation was included to compensate for the small sample size of the pharmaceutical firms that were studied in this research project.

It was observed that there is a high level of correspondence between the views expressed by the pharmaceutical firms and those of the individuals drawn from the selected universities and government knowledge generation institutions and national departments, with minor variations in some instances. The general validation of the views of the pharmaceutical firms regarding the types of linkages with the universities, search processes and the selection criteria was observed. These can enhance our understanding of the nature of the management decision-making process within the pharmaceutical firms operating in South Africa.

5. CHAPTER 5: ANALYSIS OF FINDINGS

5.1 Introduction

This chapter presents an analysis of the key research findings of the study. The chapter is organised to address the two research questions: (a) What are the types of linkages between the pharmaceutical firms that participated in the study and universities? (b) How do the pharmaceutical firms that participated in the study make decisions which university to form linkages with?

The study uses data collection from the pharmaceutical firms operating in South Africa that participated in the study, and triangulation. The data collection from the pharmaceutical firms was obtained by interviewing senior executives and managers from the study cohort of local and international pharmaceutical firms operating in South Africa. Data was gathered from interviews with respondents who worked as senior scientific and technology researchers and senior technology transfer managers at South African universities. Furthermore, triangulation included interviews with expert commentators from the South African government departments and knowledge generation institutions owned by the South Africa government. These included senior consultants, technology commercialisation managers and directors. The data was analysed together with the information gathered from earlier interviews with the pharmaceutical firms that participated in the study.

The analysis of the findings obtained from the pharmaceutical firms and triangulation are integrated to create a coherent argument.

5.2 Types of linkages between firms and universities

Edquist (2001) asserts that the innovation systems approach is a framework to understand and identify innovation policy issues. One of the issues identified in innovation policy is interactions across and between firms and other actors within the innovation system such as universities. The scholars from the system of innovation

perspective all argue that firms across industrial sectors do not innovate in isolation but do this through interacting with other actors, such as universities, financial institutions, governments, industrial networks and other organisations such as non-governmental organisations, whose roles are the production, dissemination and diffusion of knowledge to create innovation outcomes (Freeman 1982; Edquist 1997, 2001; Fischer 2000; Ludvall 2004). The types of interactions are shaped by a variety of factors such as social, political and institutional laws (Edquist 2001). The literature mentions that firms form interactions with these agents in order to harness their learning and technological capability building in order to encourage innovation (Adams, Bessant and Phelps 2002 citing Tidd, Bessant and Pavit 1997).

Linkages between universities and firms are a relatively new phenomenon in the South African context especially from the perspective of firms. However, different types of linkages have been studied within the context of South Africa, focusing on the perspective of universities within technology-intensive industries. This was mainly to understand the view of universities in forming linkages with highly technology-intensive firms, with a view to making universities respond to addressing the economic and social needs of the country through policy measures (Kruss 2005a, 2005b).

According to Kruss (2005a, 2005b), linkages are defined as knowledge networks, partnerships and even collaborations between universities and firms that are of mutual benefit to both. In view of this definition, scientific and technological knowledge flows both ways and is diffused through different channels in order to promote learning (Morondi 2011, citing Das and Teng (2000). Ryall and Sampson (2003) state that from the perspective of firms, the main purpose of linkages is to enable access to and the acquisition of complementary assets, technology, sharing of research costs, mitigate risk of innovation and enter new markets, and a range of other benefits. Kruss (2005a) and Smith and Katz (2000) cite that linkages have multiple intentions and meanings and can be developed at various levels – such as individual, group and research departments, sectors and country and in complex environments, probably characterised by technological change, market dynamics and competition to name a few. Linkages have become innovation strategy by firms to overcome these complex environments (Castells and Cardoso 2005). According

to Kruss (2005a), the formation of linkages between universities and firms in technology intensive industry are influenced by forms of universities and their historical legacy, uneven research capacity, institutional capacity and financial base and shaped by financial and intellectual imperatives driving both firms and universities to form linkages. What is needed is the conscious decision at the governmental level, through sound policy options and programmes, to promote the desirability of linkages between universities and firms, in order to make universities and firms part of the system in contributing to the economic and social development of South Africa.

The South African government, through the Department of Trade and Industry and National Department of Science and Technology established the THRIP (Technology and Human Resources for Industry Programme) (refer THRIP website http://thrip.nrf.ac.za). According to the THRIP website (http://thrip.nrf.ac.za), the purpose of THRIP is to promote linkages between firms and universities across technology-intensive industries such as the pharmaceutical industry, through incentives and funding in order to address the shortage of technological knowledge and skills for firms and respond to general socio-economic challenges. Since the operationalisation of the THRIP Programme, different types of linkages have been formed between firms and universities, which have been studied and cited in empirical studies in specific technology sectors such as biotechnology in terms of their benefits and risks (Kruss 2005a, 2005b, 2012).

Kruss (2005a, 2005b) developed an analytical framework, which distinguishes typologies of linkages, to provide an understanding of the different types of linkages between firms and universities in high technology industries. The typologies are: donations and sponsorship, commercialisation; consultancy and contract, and incentive and collaboration. The framework is applied to provide an analysis of the types of linkages revealed in this study between firms and universities in the South African pharmaceutical industry. Kruss (2005a, 2005b) argues that these are shaped and defined by the motivations of firms and universities to form linkages, and strongly associated with specific benefits and risks for innovation (Kruss 2012).

‘Donation’ has been described as the oldest form of linkages in South Africa and from the perspective of firms, has been conceptualised as benefaction or philanthropy. It is closely related to a sponsorship type of a linkage. Through this type of a linkage, a firm provides funds to universities to execute a research project that would help firms to address technology issues, develop new products, enter new markets, and attain overall competitiveness. Donations and sponsorships for research help firms to develop competitive advantage in relation to competitors. Examples of linkages in this typology include postgraduate student research, conferences, and post graduate studentships.

Consultancies are the most dominant type of linkages in South Africa and motivated by universities’ financial need for R&D. In consultancies, a university researcher provides technology services in the form of advice to a firm. Furthermore, universities may provide a firm with training or mentorship on a specific technology. Contracts are closely related to consultancies and tailored to solving research problems of firms. Firms choose universities with the appropriate technological expertise, experience, capacity and research infrastructure and equipment to provide consultancy services, through contractual agreement, in order to deliver on research objectives within an agreed timeframe. The disadvantage of consultancies to universities is the restriction to pursue their research agenda in exchange for the protection of the financial interests of industry.

Collaboration is viewed as the most traditional form of linkage between firms and universities in South Africa. This type of linkage is motivated by the intellectual strategies of the university and proactive strategies of firms and more likely to be bi-directional. In this view, technological knowledge and other inputs flow two ways and there is a high potential for learning taking place between firms and universities. Examples of linkages include joint R&D projects, networks and science parks, as well as hiring post graduate students, conferences and publications.

Commercialization is the emerging form of linkage between firms and universities in South Africa, mainly driven by the economic strategies of universities and the proactive strategies of firms. These types of linkages usually take the form of spin-off companies or incubators and require personal interactions. Most firms in highly

technology- intensive industries prefer universities that display entrepreneurship in R&D activities and are able to protect and manage intellectual property appropriately. Such universities are characterised by the presence of Technology Transfer Offices.

The responses from the pharmaceutical firms as well as from individuals from universities and expert commentators who participated in this study are typical types of linkages that would be found in high technology-intensive industries including the pharmaceutical industry. The research findings also correlate with the findings obtained by Kruss (2012) for firms and universities in the biotechnology industry. The pharmaceutical and biotechnology industries are closely related in their nature. While this study supports the findings of Kruss (2005a, 2005b, 2012), it further suggests that knowledge flows to and from firms and knowledge producing institutions, and influences the firms' innovation activities by helping them to focus on research that would address technology issues and deliver products that would create competitive advantage. This study suggests that these types of linkages were created to benefit the pharmaceutical firms that participated in the study in providing the firms with intellectual abilities in technology development and innovation activities (Kruss 2012), as well as building learning capabilities.

Furthermore, the findings of this study corroborate the findings of Siyanbola and co-authors in their study of the type and intensity of linkages between firms and universities in the Nigerian pharmaceutical industry using a survey of 25 pharmaceutical firms operating in Nigeria (Siyanbola et al 2012). These authors found that consultancy, staff exchange and fellowship programmes and sponsored workshop participants are the most common types of linkages. Similar findings were also obtained by Parahons (2009) in the Brazilian pharmaceutical industry using a quantitative research methodology in the form of a survey.

5.3 Effectiveness of the decision-making process

Kofinas and Saur-Amaral (2008) describe the pharmaceutical industry as research intensive, and its competitiveness depends on continuous inventions and innovations. The ultimate embodiment of knowledge creation in the pharmaceutical

industry is the successful commercialization of new drug technologies which represent the key competitive factor for the industry.

The Business Monitor Report (2009) as well as the South African Department of Trade and Industry Report profiling the South African pharmaceutical industry (2011) stated that the South African pharmaceutical industry is faced with several challenges, which make it not respond effectively to addressing the health needs of the population. These challenges include a declining share of the South African pharmaceutical market as a percentage of the global market, unpredictable consequences of the price control of medicines and measures to contain the fast-rising cost of public healthcare, ever changing regulations for drug approvals and clinical research conduct, closing down of manufacturing plants for drug technologies resulting in loss of manufacturing capabilities and lowering costs of conducting research and development.

In view of these reports, what is needed in the South African industry, especially at the level of firm, is executive and senior management to consider decision making processes as part of innovation management in order to respond more effectively to industry challenges and tackle organizational complexity and multiple marketplace demands. Decision-making effectiveness ought to be regarded as a crucial complementary asset along with other capabilities enabling decisions to seek external specialist technological knowledge providers.

5.3.1 Searching

The search function is an important aspect of innovation management at the firm level (Tidd and Bessant 2009). Cited by Laursen and Salter (2004), Katila and Ahura (2002) and Mahdi (2003) firms search for new product ideas and solutions to existing technological problems. Based on this view, firms conduct search in order to identify, process and select knowledge (e.g. scientific and technological knowledge) from the environment that would trigger innovation process; and to create new knowledge (Purcell and McGrath 2013). This gave rise to the following question: How do pharmaceutical firms operating in South Africa that participated in this study search for technological knowledge and other inputs from universities?

The study suggests that these firms perform the search for technological knowledge and other inputs from universities through patent searches using their own patent search engines; consulting or making regular contacts with researchers at universities in meeting settings to find out the kind of research universities are doing, for instance, whether the research is relevant to the firm, is aligned to the company's strategy, is cost effective and can be applied to developing technologies that can be commercialised; regular attendance at local conferences hosted by universities to find out developments in the research environment, create networks and identify potential research partners; consulting technology transfer offices located at universities to find out what technologies are available; using their own knowledge management systems such as a database of the list of universities and review reports of past collaborations with universities; conducting feasibility studies and market analyses to search for any signals in the environment.

Furthermore, all the participants drawn from the universities and national governments and government-owned institutions of knowledge generation agree that the pharmaceutical firms operating in South Africa search for technological knowledge and other inputs by using a "word of mouth" strategy. This referred to sharing of important and useful information among the firms which could be applied in the innovation process activities as all participants agree that firms attend academic conferences to search for technological knowledge. The views of the respondents from universities and national government departments and government-owned knowledge generation institutions indicated that the pharmaceutical firms use academic publications to find out developments with research, and to identify researchers and affiliated institutions; calls for proposals to identify research that is aligned to the firm strategy that the firm can fund; and student recruitment to attract and employ research with talent.

The study provides an insight that the pharmaceutical companies make use of people with specialist competencies to undertake the process of search and scan functions. These are boundary agents whose role is to go out to interact with universities to identify opportunities for technological development and innovation for firms and to communicate such information to the firm (Salas 2009 citing Allen 1977), with possible consideration for the acquisition of technological knowledge and

other inputs. This viewpoint was confirmed by the respondents, who indicated that the pharmaceutical firms' use of people with specialist competencies becomes evident since these people had been exposed in the research environment through previous post graduate studies.

The study suggests that the search process employed by the pharmaceutical firms is organised and adds value to what firms wish to create, which is improved and or new technologies and even production and manufacturing processes. While this was supported by the respondents from universities and expert commentators drawn from the national government departments and knowledge producing institutions, the findings further suggest that search helps the pharmaceutical firms to keep abreast of the nature of the research being performed at universities and also how to apply technological knowledge and other inputs to improve decision-making effectiveness. According to Laursen and Salter (2004), the search strategies employed by firms in technology intensive industries such as pharmaceuticals, coupled with investment in R&D, pre-empt the ability to draw external technological knowledge from universities. This is crucial for management decision making in shaping the propensity of firms to seek technological knowledge and other inputs from universities. This suggests that the pharmaceutical firms would have developed internal capabilities also known as complementary assets over time coupled with a strong research component to enable firms to use external technological knowledge and other inputs from universities effectively (Marcelle 2011).

Given the nature of the South African pharmaceutical industry, which is technology-intensive and requires external knowledge for competitive advantage, there are particular projects and types of knowledge required by firms from universities in order to increase their competitive advantage. For this reason, the firms within the pharmaceutical industry have in general been resilient and competitive in producing drug technologies to improve the quality of health of the South African society and even on the African continent (through export).

The study suggests that the participating firms operating in the South African industry required university knowledge packaged in a commercial framework during the search process. While this viewpoint is supported by individuals and expert

commentators from universities and national government departments and knowledge producing institutions, the findings further suggest that the university projects that have progressed downstream in the value chain are considered during search process, and decision making processes. According to the Research Report on South African Manufacturing of Pharmaceuticals compiled by Mahomedy (2010), the university research that has progressed downstream in the value chain stimulates pharmaceutical technology development and innovation to develop drug technologies to address pressing disease areas facing South Africa and the African continent such as HIV and AIDS, TB and malaria and other infectious diseases. Furthermore, university knowledge related to R&D and knowledge in technology development and process manufacturing helps pharmaceutical firms to solve problems in production or manufacturing processes, as well as to make improvements on old or completely new technologies as these will increase changes of technology or product commercialisation.

5.3.2 The factors in the search process

According to the literature, there are a variety of factors which could influence a firm's search process for technological knowledge and other inputs from universities. The factors may include firm size and R&D budget (Laursen and Salter 2003). These factors could shape how management makes decisions on the type of attributes they are looking for in a potential external partner for the establishment of linkages. The results indicate that among the factors found in this study, the resources available at universities for research and clinical research, such as experienced researchers in R&D and clinical research, research equipment and research laboratories, the reputation of the university in the research frontier for doing and producing quality research including commitment to deliver, are the most significant factors in searching for knowledge from universities. The empirical literature on studies of industry-university linkages, which focus on the determinants and motivation for collaboration in the case of the firms, suggest that reputation and quality of university research are responsible for the formation of linkages between firms and universities across sectors and contribute to the success of the collaboration (Mora-Valentin, Montoro-Sanchez and Guerras-Martin 2009). Other factors found by the present study include university research complementarity to the firms and alignment to the

company strategy; university research with commercial potential and intellectual confidentiality by universities as well as cost implications for knowledge acquisition and the public good provided by the universities. Strikingly, pharmaceutical firms are not looking for cost-effective knowledge acquisition from the universities for their production and manufacturing processes. This implies that cost is not a decisive factor for pharmaceutical firms when deciding on whom to collaborate with.

In summary, pharmaceutical firms operating in South Africa are involved in a search process for external knowledge at universities and are able to recognise signals in the marketplace. This implies that firms have a degree of knowledge and capabilities related to R&D and technological development built over time, which enable them to recognise the knowledge they need for innovation.

5.3.3 Selection of universities

5.3.3.1 Factors influencing the selection process

According to Lundvall (2004), the key agents are firms and public research organisations, also known as “science councils” in South Africa, and universities whose role is to create and disseminate knowledge to firms to create innovations. Based on this view, firms across technology-intensive industries are therefore exposed to a variety of possibilities and options from which they can access and acquire external technological knowledge for innovation outcomes and competitive advantage, as firms are faced by ever increasing competitive pressures (Hung and Tang 2008). Based on the work of these authors, firms need to develop strategies that would allow then to gain new technologies from external sources in order to initiate their own innovation processes leading to improved production processes.

However, Tidd and Bessant (2009) make a case that the challenge facing the management of firms is how to choose among a variety of options for external technological knowledge and other inputs. Tidd and Bessant (2009) further argue that in order for firms to choose among external technological knowledge, they need to develop criteria which articulate how innovation can help them survive and grow in

competitive technological markets and develop competitive advantage in relation to competitors.

Rothaermel (2001) conducted a quantitative study of how pharmaceutical firms select alliances from the population of biotechnology start-up companies in their quest to seek technological knowledge to commercialise their products. The findings of Rothaemel (2001) study suggested that the pharmaceutical firms select the new biotechnology start-ups based on new technologies and stages of development, economic of scale (cost effectiveness), public ownership and geographic location of start-ups in relation to the firms. Rothaemel (2001) argues that these selection attributes make the biotechnology start-up companies more attractive to form alliances as opposed to other knowledge providers.

Although the study of Rothaemel (2001) focused on firm to firm linkages, the findings of the present study suggested that the factors that influenced the decisions of the participating pharmaceutical firms operating in South Africa to select universities are more likely when there is an intention to develop technologies to the point of commercialisation. The universities which have good reputations, perform quality research relevant to the firms' technology development and commercialisation needs, and those based in close proximity relative to firms are likely to be preferred for collaboration by the participating pharmaceutical firms. The findings of this study are in agreement to studies conducted on motivations or the propensity of firms in technology-intensive industries where the quality of research, geographic location and reputation increased the likelihood of firms to form collaborations with universities.

5.3.3.2 Characteristics of universities

Universities are important agents in creating knowledge which is an important source of innovation at the firm level. According to Sbuwufu, Ludwick and Beland (2012), universities, especially in developing countries, are being positioned by national governments as strategic assets in innovation and economic competitiveness, and as problem-solvers for socio-economic problems affecting their countries. However, these authors argue that in order for countries to fully capitalise on the value of

universities in addressing their socioeconomic issues, governments and institutions need to actively pursue policies and strategies that would create conditions for the development of university linkages with industries.

The mandate of universities explicitly requires that they undertake upstream R&D, produce human resources and contribute to addressing socioeconomic challenges. In the South African context, many universities are now setting up Technology Transfer Offices, establish technology platforms and in some cases establishing incubation centres as a way of making themselves attractive to firms for the formation of linkages on R&D, and technology development. For this reason, universities in South Africa have over many years been gradually building institutional capacity through the production of experiences and skilled human resources and research infrastructure, to gain overall competitiveness.

This study suggests that universities with trained and experienced research personnel and technical expertise are the main considerations of the participating pharmaceutical firms for selecting universities for the formation of linkages. This finding is, however, contradictory to the findings of Giuliani and Arza (2008) in the wine industry in Chile using a qualitative research methodology on managers of the firms. The authors argued that the quality of the research related to experienced researchers who conduct the research at university departments does not influence the firm's decisions to select universities based on this characteristic. It is therefore very important to take context into account in order to understand the relationship between the quality of research and the firm's selection process with the likelihood of the formation of linkages from the perspective of firms.

In this study, firms further indicated that they would select universities whose researchers have good reputations linked to international exposure and standing among their local and international peers. Dollinger et al (1997) argue that the reputation, which is information about the partners that is publicly known by the rest of the agents taking part in a given sector or activity (Mora-Valentin, Montoro-Sanchez and Guerras-Martin 2004), may expose the characteristics of universities concerning management, the quality of their products or financial status to the potential firms that wish to form linkages. This study suggests that the firms would

select universities for forming collaborations, which conduct quality research and that is relevant, and have experienced researchers who are highly respected in their area of research which is relevant to the firm's core business and strategy.

Accessibility in this case, can be framed in terms of the geographical proximity of the location of the university. It is referred to as the distance between a firm and university and often measured in kilometres. Thus, accessibility can be explained in terms of the value of direct and interpersonal contacts, primarily to acquire tacit knowledge and access to new research. Arundel and Geuna (2003) argue that geographical proximity has an effect on firms' ability to access tacit knowledge for innovation. The authors make a case that the public research organisations, including the universities' knowledge flow, can make a substantial contribution to firm innovation. In other words, geographic proximity favours knowledge flows from knowledge producers to the innovators such as firms. The present research suggests that the pharmaceutical firms that participated in the study would select universities that have closer proximity in order to facilitate knowledge flows and access to knowledge. It can be assumed that the accessibility of university knowledge is important to a firm's desire to produce new products at least for the manufacturing pharmaceutical firms interviewed. Empirical research supports this finding and suggests that the closer the university is to the firm in a developing country context, the more the knowledge is accessible to the firm and can encourage cooperation between academic and firm R&D staff (Garcia et al 2014).

5.3.4 Firms' management hierarchy of decision-making

Senior executives and managers were asked to indicate where decisions regarding knowledge collaboration with universities are undertaken. Knowledge collaboration in this case, refers to R&D and clinical research. The latter encompasses access to patients' medical history and recruitment of patients to participate in clinical research.

This study found that the majority of the decisions are undertaken at the behest of the board, senior executive (including CEO) and senior manager's levels. It is observed that most decisions are taken by the senior executive including the CEO and managers. However, few pharmaceutical firms had indicated that the decisions

are taken by the board members of the company. This finding is not surprising since board members mainly pay attention to decision-making that involves and influences organisational direction, administration and structure (Naghibi and Baban 2011) rather than the operational aspects of the firm. It is also notable in this study that most of the decisions regarding knowledge collaboration with universities are taken by senior managers who are involved in the operational aspects of the knowledge collaboration with the universities. Schmidt and Buell (2014) mention that senior managers (including senior operation mangers) in business environments that require introduction of new product technologies into the market are required to make the decisions that would ensure long term sustainability and performance.

Senior managers are responsible for the implementation of strategic decisions that are taken at CEO level and ensure that the appropriate university is identified and contracts are signed and collaboration is established. In other words, they are the ones who interact with and engage the universities in meetings, in order to identify the university knowledge relevance to drive the firm strategy for R&D processes. Senior managers are accountable to the CEO and are very careful in the choice of university research partners. This finding of the present research is in alignment with the view of Arasa and K'Obonye (2012) citing Hofer and Schendel (1978) that operational decisions involve an evolution of environmental changes in relation to a changing company's internal structures and production processes as well as efficiencies, and managers should be able to integrate such changes with organisational strategy and structure in order to achieve innovation and performance.

This research found that decisions on identifying universities on R&D partnership with universities are not taken with the involvement of the investment committee. This is rather surprising since taking decisions could be a complex process and inherently risky and may have a negative impact on the future of the organisation (Al-Tarawneh 2012). Hence, the involvement of committees to provide recommendations on the appropriate decisions would be expected. However, there were pharmaceutical firms that indicated the involvement of their investment committee. These were the international companies operating in South Africa and whose main offices are based in developed countries. The results obtained from this

study revealed that the parent pharmaceutical firms based in developed countries approve the decisions regarding knowledge collaboration made by their firms operating in South Africa. This indicates that there is a threshold for decisions that get made by the pharmaceutical firm operating in South Africa. Although the parent pharmaceutical firm approves the decisions made by firms operating in South Africa, they are not involved in the implementation of the decisions or operationalization of knowledge collaboration.

5.3.5 Decision-making processes

This research discusses the nature of the management decision-making processes used by the pharmaceutical firms, as they form linkages with specialist providers of technological knowledge and other inputs such as universities. According to the Industrial Policy Action Plan (IPAP) of South Africa (2014), the pharmaceutical industry is among the industrial industries to contribute to economic growth and job creation in South Africa (IPAP 2014). Furthermore, the pharmaceutical industry is a strategic sector within the country's innovation strategy and universities are also recipients of public support for R&D.

In South Africa, firms in the pharmaceutical industry have the option to seek specialist technological inputs from other firms, publicly funded research councils and from universities. According to IPAP (2014), the pharmaceutical industry has been experiencing a number of challenges and constraints to realise growth and development including loss of manufacturing capabilities. Nonetheless, pharmaceutical firms have strong linkages with public research institutions including universities and seek out these relationships in order to have access to scientific knowledge, know-how, and research equipment in order to build their own capabilities for technology development and attain a competitive advantage relative to their competitors (Al-Bader et al 2009, Kruss 2012). These studies report that the firms experience a number of challenges when collaborating with the universities, including lack of commercial knowledge, prolonged intellectual property negotiations and unrealistic expectations in terms of royalties generated from the commercial exploitation of their research.

The decision making processes have been described as iterative and incrementally facilitated by relevant and even irrelevant factors over time (Teal 2011). They are part of the firm's innovation strategy which enables firms to build deep stock of complementary assets over time including financial, physical, natural, intellectual, human, and social capital (Marcelle 2011), as well as to enhance a firm's innovation management effectively. According to Marcelle (2011), decision making processes at firm level are referred to as implementation steps that seek to search for resources and apply these in ways that add value and generate advantage over competitors (Marcelle 2011). The resources are linked to the nature of the production and consumption process in the industry in which the firm operates and also to factors such as the lifecycle of the technologies in use, and socio-economic conditions in which the firm is embedded.

This study deduced that the nature of the decision making processes within the participating pharmaceutical firms is one of the strategic imperatives for sourcing external technological knowledge and other inputs from universities for technology development in manufacturing and production processes and even clinical research. The study therefore suggests that decision making processes on knowledge collaboration with universities within the pharmaceutical firms are informed by information and data collection from decision making influences such as search and selection processes, as well as consultation processes. The information and data collection is done during search and selection processes about universities' scientific expertise and capabilities and patient population and reviewing universities' past performance and the participating firms use this information to inform their decisions on forming linkages with the universities on research and technology development. The respondents from the participating firms mentioned that the decision making process is iterative, which means the information goes through a process of analysis to assess its alignment with the firm strategy. According to Accenture (2008), the decision making processes that have been informed by empirical data and factual information by the life science-based industries including pharmaceutical industry are used to compare organisational effectiveness and culture with the market norms.

Ideally, firms in technology-extensive industries such as pharmaceutical firms usually adopt tools and frameworks to help senior managers and executives to assess the

decision making effectiveness in order to achieve high performance and competitive advantage in relation to their competitors (Accenture 2008). However, this study shows that the decision making process of the participating pharmaceutical firms were iterative but not based on the adoption of tools to assess the comprehensive nature of the decisions as participating pharmaceutical firms were forming linkages with universities on R&D and technology development. These findings are contrary to the processes followed by the North American pharmaceuticals in evaluating decision making processes to improve its decision making processes in order to respond more effectively to competitive pressures and tackle organizational complexity and multiple marketplace demands. Accenture (2008) makes a case that the decision making processes and frameworks of the North America pharmaceutical firms were comprehensive, encompassing strong leadership involvement of the firm in providing understanding of the organisational complexities and culture; the use of decision making effectiveness diagnostic tools such as culture value analysis to review the firm's organisational culture and benchmarking with good practices, decision making mapping to quantify the cost of making decisions, labour risk, value and time, and organisation network analysis to understand how decisions really get made. Based on this view, it is deduced that the participating pharmaceutical firms' decision making processes were not holistic and comprehensive in order to provide understanding of the decision making processes as they form linkages with the universities. Furthermore, the decision making processes were improved and became effective as these firms were able to identify external opportunities, develop methodologies and tools for making further assessments and set metrics to quantify the attainment of business objectives.

This study suggests that the decision making processes are critical and should be holistic and comprehensive involving other business dimensions such as firms' leadership and culture. There is therefore an oversight of these important dimensions, tools and processes of decision making processes by the participating pharmaceutical firms. The firms could enhance their decision making processes by developing a holistic and comprehensive decision-making approach in addition to search and selection processes to overcome the challenges of the South African pharmaceutical industry and respond to market and industry dynamics.

5.4 Types of university specialised knowledge inputs and learning

The interviews in this study revealed that the most frequently mentioned type of specialist knowledge input by pharmaceutical firms was scientific knowledge related to R&D and technical knowledge in technology development and process manufacturing, followed by clinical research knowledge related to access to patients' information and recruitment of patients into clinical research and regulatory environment. These findings are not surprising since the South African pharmaceutical industry is comprised of firms in the manufacturing area of new or drug technologies that are no longer patented or that are not patented. The pharmaceutical industry is technology-intensive and requires technological knowledge and other inputs (e.g. from universities, biotechnology companies, suppliers or even competitors) in order to adapt in ever changing environments where markets and technology are unpredictable and changing (Santos 2003). Scientific knowledge related to R&D and knowledge in technology development and process manufacturing help pharmaceutical firms to solve problems in production or manufacturing processes, as well as to make improvements on old or completely new technologies as these will increase changes of technology or product commercialisation.

These specialised technological knowledge inputs are distributed within the boundaries of the R&D, production or manufacturing activities. External technological knowledge facilitates the firm learning process in order to be aware of technological developments as well as the unmet needs in an environment they are operating in. It also allows for securing of protection of intellectual property, mainly through patents, to build and sustain competitive advantage relative to their competitors.

The South African pharmaceutical industry is also competitive in conducting clinical research due to the population diversity of South Africa, high burden of diseases and universities that are connected to hospitals and provide courses in clinical research. Pharmaceutical firms involved in clinical research that were interviewed expressed the need for knowledge requirement in clinical research from universities. Clinical research knowledge requirement by pharmaceutical companies in this case, is the

knowledge relating to how firms can increase effectiveness of clinical research by accessing patients' records and recruiting quality patients into clinical research (through universities). The main reasons for pharmaceutical firms requiring this specialised knowledge inputs into their clinical research is to better understand how new drug product technology works on patients before registration and introduction into the market, to fulfill unmet medical needs and drug modalities.

Pharmaceutical firms have also expressed the need to develop their own internal expertise in designing protocols for clinical research programmes that would lead to enhancing decision-making and assist patient's safety, and improved identification of clinical research sites and investigators. The learning process from clinical research knowledge inputs through interaction with the universities take place through meetings and training programmes, to assist in building the firm's relevant internal skills and competencies.

The pharmaceutical industry operates within a changing regulatory environment due to government policies. The most regulated activities in the pharmaceutical industry include clinical research, drug registration, marketing and distribution. But the majority of pharmaceutical firms do not have the capacity and expertise on how to respond to the ever changing regulatory environment. To address this issue, the pharmaceutical firms interviewed noted that knowledge in the regulatory environment is important. This is due to the following reasons: to better understand the regulatory environment as universities have capacity and experience and offer academic courses in this area; achieve submissions on schedule; reduce clinical/non-clinical error; increase efficiency in clinical research operations; improve the quality of reports based on clinical research; implement improved regulatory timelines, leading to reduced MCC questioning; and increased agility to respond to changing regulatory requirements

5.4.1 Capturing of specialist knowledge

'Capture' is one of the dimensions of innovation management at the firm level, which refers to how firms derive value from external specialist knowledge – be it for commercial success, market share, cost reduction or social innovation in the

changing environment (Tidd and Bessant 2009). There are many ways in which firms capture external specialist knowledge. For instance, in this research, it has been found that the majority of the pharmaceutical firms operating in South Africa have repeatedly mentioned documentation systems as a way of capturing knowledge in physical hard copies. This capturing process of external knowledge probably creates opportunities for learning and development of innovations within firms which in turn would result in building capabilities that the firm desires. The main intention of physical hard copies for firms is to learn from completed projects. Abrol, Prajapati and Singh (2013) argue that learning in the case of pharmaceutical firms operating in developing countries can be in terms of technological lessons learned, for example, the acquisition of new processing or product features which add to the organisation's technological competencies. However, Abrol, Prajapati and Singh (2013) point out that learning can also be around the capabilities and routines needed for effective product innovation management.

Another way in which the pharmaceutical firms that participated in this study capture the specialist external knowledge is through knowledge management systems, such as electronic programmes and databases. Knowledge management is thought to be an effective way for firms to manage knowledge in order to improve performance and productivity through innovation (Rašul, Vukšić and Štemberger 2012). It can be deduced that pharmaceutical firms in this study capture specialist knowledge through these types of knowledge management systems in order to grow the knowledge pool of the firm and thus retain critical technical knowledge required for R&D, technology and innovation activities. Pharmaceutical firms in the present study are also using technology transfer agreements and project management systems as tangible assets of technological knowledge for economic gains (Teece 1998).

5.4.2 Codification of the learning process from knowledge inputs

The majority of the pharmaceutical firms codified their learning experiences from the universities through electronic document systems, followed by physical hard copies. Electronic document systems contain a database of past research papers produced by universities. Firms thus search through the database to look for research publications of interest. The physical hard copies, on the other hand, may include

contracts of previous collaboration with universities; recording and reviewing minutes of meetings; score cards; documents and study outcome reports; and business plans and strategic plans. Capacity building programmes in the form of mentoring and training are also ways by which pharmaceutical firms learn from universities. These allow exchange of knowledge and the development of new ideas for new projects. Networks are also used by firms with universities to develop learning processes.

It appears that firms belonging to very knowledge-intensive sectors such as the pharmaceutical industry, and that produce products whose quality is strictly dependent on the ability to acquire knowledge and to accumulate proprietary know-how learned through its use, tend to rely on external knowledge for new product development (Balconi 2002).

5.5 Pharmaceutical firms linkages with universities

5.5.1 Collaboration between firms and universities

According to Rhee and Kim (2010), public research organisations are established around the world to become involved in R&D as well as science and technology activities, primarily to meet national needs in research and technology areas in which firms cannot invest because of high costs and risks. Rhee and Kim (2010) make a claim that the role of public research organisations is to occupy a strategic position in national innovation systems as central network agents in national knowledge-generating activities, and to advance the state of knowledge and to disseminate a broad spectrum of public information in mostly science and technology areas, technologies developed by PROs are transferred to the sector for commercial exploitation. Rhee and Kim (2008) further claim that public research organisations contribute to building national science and technology by developing new technologies, nurturing and training talents, sharing knowledge, and consulting to set up technology policies. Around the world, public research organisations function within the specific context of a national social, cultural, political, financial and economic system, frequently carrying with them the legacies of colonial, post-colonial and other forms of governance.

In South Africa, public research organisations, also known as science councils, were established to play a catalytic role in establishing the strong and diverse science, engineering and technology to support social and economic development. The mandate of science councils in South Africa is to harness research, science and technology to support social and economic development through the allocation of government money in the form of Parliamentary Grant to carry out their mandate.

This study's respondents noted that it is often cheaper for the pharmaceutical firms to collaborate with universities. For instance, Walwyn (2008) argues that the cost for a research project is cheaper in the university sector. The budget allocated for the pharmaceutical firms' knowledge collaboration with universities is not more than two and a half million Rands (>R2.5M), suggesting a reason why firms in the pharmaceutical industry collaborate with universities. The literature suggests that pharmaceutical firms collaborate with universities on R&D to overcome low budget for R&D; and to avoid the risky business of performing R&D.

Rhee and Kim (2010) argue that there is often a clash of cultures between public research organisations including universities, commercial organisations and firms on the approach to research. Rhee and Kim (2010) state that universities place emphasis on exploratory or basic research to provide understanding of specific aspects of the R&D in order to develop potential technological solutions for industry, while government funding agencies simply want implementable solutions that work and yield commercial benefits. Firms are strongly focused on commercial research that would enable them to return investments to their shareholders on time and within budget.

5.6 Summary of the results

According to the literature, the pharmaceutical firms operating in South Africa have strong links with public research institutions including universities and use these to access specialist knowledge to build their own capabilities for technology development and innovation process. This viewpoint was a strong motivation to undertake this study in order to provide information on how the pharmaceutical firms operating in South Africa make decisions to form linkages with universities on

technological knowledge and other inputs. This viewpoint has been unexplored in the literature.

Using the research findings obtained in the study, it is argued that the cost model factor is not the primary motivator for the pharmaceutical firms participated to form linkages with universities. This study therefore contests the notion that firms across technology intensive industries such as pharmaceutical firms establish linkages with universities because of the partial cost model that universities employ in providing research services and thus making it less expensive to provide research services compared to science councils (Walwyn 2008).

The study argues that the pharmaceutical firms desire to form linkages with universities that conduct quality research, have experienced researchers and students to provide production and manufacturing solutions, and have a good track record and reputation related to research outputs such as students, publications and patents. The study also suggests that these factors are impact on firms' decision making processes through search and selection processes.

The study further makes a profound argument with respect to the international pharmaceutical firms operating in South Africa that are involved in clinical research. These firms form linkages with universities that are connected to hospital facilities where universities have access to patient information and records which are used in designing clinical research protocols. In addition, the ability of universities in recruiting patients with relevant disease profile to participate in clinical research increases firms desirability to form linkages with universities. Furthermore, universities with these kinds of characteristics as determined through selection process and criteria could assist firms to overcome the regulatory issues imposed by the South African government, through the MCC, on these firms wishing to conduct clinical research, as universities have a clear understanding of the regulatory requirements for clinical research in South Africa. Also, infrastructure linked to the research is crucial to firms to enable them to achieve innovation objectives and attain competitiveness.

In conclusion, this study makes a contribution to the existing literature on university and industry linkages on the part of firms operating in the South African pharmaceutical industry, by providing an understanding of how they make decisions to form linkages with universities on research and technology development. Hence, the data from this study states that the decision making process is comprised of search, selection and development of selection criteria, as well as evaluation processes.

6. CHAPTER 6: CONCLUSIONS

6.1 Introduction

This research is a preliminary study into exploring the perspectives of the private pharmaceutical firms operating in South Africa which participated in the study regarding the management decision making processes for forming linkages with universities on research and technology development. This chapter describes conclusions related to the research, providing recommendations for senior executives and managers of pharmaceutical firms, as well as recommendations for further research.

Consequently, the conclusions have been drawn on the types of linkages between the pharmaceutical firms which participated in this study and universities, the firms' decision making framework for the formation of linkages with universities and preference of these firms to form linkages with the universities.

6.2 Types of linkages between firms and universities

According to Plewa and co-authors, the term "linkages between firm and universities" refers to bi-directionality between firms and universities (Plewa et al 2013). Plewa and Quester (2007) cited by Plewa et al (2013) argue that linkages between firms and universities are created over time, in order to diffuse ideas, skills and people into the firms innovation processes. The intention for the establishment of linkages is therefore to create mutual value between a firm and a university. There are different forms of linkages which have been studied extensively in literature both from the perspective of the firm and the university.

This study revealed the types of linkages between the pharmaceutical firms and universities, using empirical data. The study found that R&D contracts, sponsored R&D, student post graduate research projects, internships, post graduate studentships, university consultancy and conferences as types of linkages. The predominant types, according to the pharmaceutical firms, are contract research and

sponsored R&D. These were frequently mentioned during elite interviews with the senior executives and management of the pharmaceutical firms.

These types of linkages are very much interrelated, meaning that the universities, as specialist providers of knowledge, act more as service providers to conduct scientific research on behalf of the pharmaceutical firms than a research partner. In this case, the pharmaceutical firms pay the research at full cost and as such all the intellectual property produced by the universities through scientific research belongs to the firms.

The data obtained from the triangulation stage of this research also revealed that private pharmaceutical firms are engaging universities through these types of linkages. The university commercial scientific research was revealed as another type of linkage, confirming that the private pharmaceutical firms prefer university research packaged in a commercial framework. Both findings obtained from elite interviews in this study and from the triangulation stage correlate with the findings obtained in the Kruss (2012) study. The latter was based on the South African life science industry, which includes the pharmaceutical industry, where it is reported that the majority of the private firms are using university collaboration to develop new technologies; and to improve R&D expertise and capabilities through linkages.

Furthermore, the findings in this study on the types of linkages corroborate with the findings of Siyanbola and co-authors in their study of the type and intensity of linkages between firms and universities in the Nigerian pharmaceutical industry using a survey of 25 pharmaceutical firms operating in Nigeria (Siyanbola et al 2012). These authors found that consultancy, staff exchange and fellowship programmes and sponsored workshop participants as the most common types of linkages. Similar findings were also obtained by Parahons (2009) in the Brazilian pharmaceutical industry using a quantitative research methodology in the form of a survey.

It can therefore be deduced that firms in the pharmaceutical industry would experience similar types of linkages with universities. Hence, it was not surprising to the researcher of this study to find out these types of linkages due to the nature of

the South African pharmaceutical firms as a knowledge and technology-intensive industry.

The pharmaceutical firms, which participated in this study, use linkages with the universities as a mechanism to access university knowledge which can be applied in technology development and innovation activities. Furthermore, the type of knowledge flows linked to linkages that take place between universities and firms in the South African pharmaceutical industry, as indicated by the individuals drawn from the selected universities and government-owned institutions and national departments, are as follows: license agreements; engagement with university departments; appointment of experienced researchers; outsourcing clinical research expertise; and contract research. Based on these knowledge flows, this study may conclude that pharmaceutical firms and universities have formal linkages since they involve contractual agreements to access knowledge from universities. This is except with engagement with university departments, which take place on an ad hoc basis, for instance, a pharmaceutical firm may approach the individual researcher in the university department whenever the need arises for scientific knowledge.

6.3 The decision making framework

The qualitative research methodology in the form of elite interviews resulted in the emergence of the framework used by the pharmaceutical firms that participated in the study when making decisions to link with the universities. The key dimensions of the decision-making framework, which influence the type of linkages as well as knowledge flows, are as follows:

6.3.1 Search process

Search functions are an important component of the management of innovation at the firm level. However, there is insufficient evidence regarding how pharmaceutical firms operating in South Africa operationalise this aspect of innovation management and how they choose between alternative sources of specialised knowledge. The fact that search is important in identifying, processing and selecting information from the environment (Tidd and Bessant 2009), gave rise to the following question— How

do pharmaceutical firms operating in South Africa perform the process of searching for knowledge at universities?

This study collected evidence interviewing executives and senior managers from pharmaceutical firms that perform the process of search through patent searches using their own patent search engines; consulting or making regular contacts to engage universities in meeting settings to find out the kind of research universities are doing, and its relevant to their firm, is aligned to the alignment with their company's strategy, cost effectiveness and able to be applied to developing technologies that can be commercialised; making regular attendances of local conferences hosted by universities to find out developments in the research environment and to create networks and identify potential research partners; consulting technology transfer offices located at universities to find out what technologies are available; using from their own knowledge management systems such as a database of the list of universities and review reports of past collaborations with universities; conducting feasibility studies and market analyses to search for any signals in the environment.

In addition to these search and scan functions, this study also found that a "word of mouth" strategy was also used, probably because of the relatively small size of the South African pharmaceutical sector where people know each other. Additionally, academic publications are consulted to find out developments with research and identify researchers and affiliated institutions; calls for proposals to identify research that is aligned to the firm strategy that the firm can fund; and student recruitment to attract and employ research with talent.

The majority of the pharmaceutical companies interviewed indicated that they make use of people with specialist competences and experiences to undertake the process of search and scan functions. This viewpoint was confirmed by the reflections on universities' and government-owned institutions and departments on search process by private pharmaceutical firms operating in South Africa. These individuals with specialist competencies have been exposed to the research environment either through previous post graduate studies and jobs are selected to identify

opportunities for innovation and business development such as knowledge, people with expertise and market signals.

In the view of the respondents, the search process by the pharmaceutical firms is organised as follows:

- Pharmaceutical firms' consideration to make time to attend local academic conferences gives them the opportunity to identify potential researchers whose research is aligned to the company's strategy. This is followed by follow-up meetings and further discussions.
- Most pharmaceutical firms have in-house research programmes to advance their innovation, and it becomes easier for firms to engage universities that fit their innovation profile and company strategy
- Pharmaceutical firms have governance structures comprising of scientific research board and advisors, who provide advice on research strategy and implementation. This capability helps firms to successfully identify universities as research partners for the innovation process and develop desired technologies with market potential.

Pharmaceutical firms are involved in a search process with the specific intention of identifying where to find scientific knowledge and how to apply it in the innovation process to improve decision-making effectiveness. This suggests that pharmaceutical firms have accumulated internal capabilities with a strong research component, and these capabilities enable firms to draw from external knowledge sources for innovation. Thus, internal research capabilities together with external knowledge play an important role in the innovation process.

This study further explored the factors that shape the search process by pharmaceutical firms operating in South Africa for scientific knowledge and other inputs at universities. The pharmaceutical firms believe that these factors would play a significant role in informing their decisions in identifying the universities in research fields which are relevant for their own R&D and innovation activities.

The results indicate that among the factors found in this study, the resources available at universities for research and clinical research, such as experienced researchers in R&D and clinical research, research equipment and research laboratories; the reputation of the university in the research frontier for doing and producing quality research including commitment to deliver are the most significant factors in searching for knowledge from universities. The empirical literature on studies of industry-university linkages which focus on the determinants and motivation for collaboration in the case of the firms, suggest that reputation and quality of university research are responsible for the formation of linkages between firms and universities across sectors and contribute to the success of the collaboration (Mora-Valentin, Montoro-Sanchez and Guerras-Martin 2004). Other factors identified by the present study include university research complementarity to the firms and alignment to the company strategy; university research with commercial potential and intellectual confidentiality by universities as well as cost implications for knowledge acquisition and the public good provided by the universities. Strikingly, pharmaceutical firms are not looking for cost-effective knowledge acquisition from the universities for their production and manufacturing processes. This implies that cost is not a decisive factor on whom to collaborate with. The pharmaceutical firms are involved in a search process for external knowledge at universities and were able to recognise signals in the marketplace. This implies that firms have a degree of knowledge and capabilities related to R&D and technological development built over time, which enable them to recognise the knowledge they need for innovation.

6.3.2 Selection process

Given the importance of university technological knowledge and other inputs and collaboration with firms in the pharmaceutical industry, this research explored factors that influence the pharmaceutical firms' selection process of universities rather than other knowledge providers and how such factors influence the firm's strategic decisions. It is interesting to note that the highest scores (both frequency and relative frequency) are expertise, experience and scientific knowledge; followed by reputation; and relevance and alignment of the university knowledge to firm's business strategy. The individuals drawn from the selected universities and

government-owned institutions and government add to these factors by mentioning that the cost model, stage of technology development, historical relations, area of research focus and research excellence tied up to quality of research as important factors considered by pharmaceutical firms in the selection process for choosing universities among other technological knowledge providers.

These results indicate that the factors that the private pharmaceutical firms consider are science-based, confirming that the pharmaceutical industry is driven by scientific knowledge and dynamic technological development to attain competitiveness. Firms which lack the necessary knowledge and abilities will seek to cooperate with universities so as to gain access to the know-how and internalise their abilities and competence, thereby creating new competencies that are valid for the firm (Bayona, Garcia-Marco and Huerta 2001).

Other factors found in this research include research infrastructure; and availability of technology transfer offices at universities; and the distance of a university to a firm's location is equally important. These findings can be deduced as important factors facilitating the formation of linkages between pharmaceutical firms and universities.

Strikingly, cost implication to acquire university knowledge for technological inputs is regarded by pharmaceutical firms as least important in their selection process. This is in contrast to the R&D cooperation between firms and universities characterised by high transaction costs for knowledge acquisition requiring the presence of absorptive capacity and high spillovers to other market actors (Veugelersa and Cassiman 2005). These factors influenced the firm's selection process with a given technology or in other words how the firm innovation process affects the firm's view on collaboration with universities.

6.3.3 Characteristics of the universities

Several studies have explored the characteristics of private firms that promote the formation of linkages with universities (Arundel and Geuna 2004; Cohen, Nelson and Walsh 2002; Fontana et al 2003). University characteristics play a fundamental role in firm management decision-making processes and vary from one university to the

other and affect the propensity of firms to form linkages with universities (Giuliani and Arza 2009). This research found that there are different university characteristics that facilitate the pharmaceutical firm's selection process. The characteristics of the universities that pharmaceutical firms operating in South Africa are looking for at universities when forming linkages are:

- Trained and experienced personnel and technical expertise
- International exposure and standing
- University research relevance to the firm
- Good track record and reputation
- Accessibility

These university characteristics may suggest that firms may successfully achieve their R&D objectives in projects with universities. This study also found that the pharmaceutical firms also look for the following characteristics in universities in order to establish linkages:

- **research expertise** to support firm innovation activities in areas of competitive advantage to the firms and building competencies in core technological areas
- **historical relationships** with the institution based on a track record on delivering on research projects on time within time framework agreed upon in the contract
- **cost model** related to doing the research on behalf of the company. If the university has a full cost model, which includes not only the direct project cost but includes costs for use of research space and infrastructure, cost of salaries and other indirect costs, such as administration and management fees for projects, it is unlikely that the firm will choose such a university with a full cost model.
- **research focus** aligned to the company's strategy and implementation
- **compliance** with drug development standards to receive market approval

6.3.4 Selection criteria

The main criteria used by pharmaceutical firms for selecting the universities among other knowledge providers is summarised as follows in relative ranking:

- Expertise and experienced researchers
- Reputation of the university department against international benchmarks
- Relevance and alignment of the university research to the firm's strategy
- Quality of the research in terms of research publications output and research excellence tied up to students with necessary talent, and stage of technology development in the innovation value chain
- Research facilities and availability of technology transfer offices within a university
- Cost model

The findings of the study show that the pharmaceutical firms have a diversity of technological knowledge providers to choose from, depending on their research, technology development and innovation needs.

6.3.5 Evaluation of the decision-making processes

This research indicates that the pharmaceutical firms have few decision- making processes and rules. Fewer decision processes probably help pharmaceutical firms face the challenge of quickly improving its product technologies and innovation activities in the midst of organizational, competitive and marketplace transformation including the regulatory environment.

6.4 Interaction of the pharmaceutical firms with universities

The study revealed that the pharmaceutical firms which participated in the study show preference to forming linkages with the universities, as 57% of the respondents from the participating pharmaceutical firms indicated they collaborated with the universities on science and technology projects as opposed to 43% of the

respondents who indicated collaborating with the science councils. These findings were supported by the views of the individuals and expert commentators drawn from universities and national government departments and knowledge producing institutions of government.

The respondents noted that it is often cheaper for the pharmaceutical firms to collaborate with universities, as Walwyn (2008) argues that the cost for a research project is cheaper in the university sector. The literature suggests that pharmaceutical firms collaborate with universities on R&D to overcome low budget for R&D; and to avoid the risky business of performing R&D.

Kim and Rhee (2010) make a claim that there is often a three-way clash of cultures between academic institutions, government funding entities for technological innovation and private firms in terms of their approach to R&D. The universities are simply interested in providing an understanding of the research phenomenon and producing research publications and students which could be used by firms as sources of innovation. Companies are interested on research which has a commercial potential in order to fulfill their mandate to shareholders – which is generating profit on time and within budget.

6.5 Recommendations

This section presents the recommendations based on the research findings, which have implications for both firms' senior executive and senior managers and government innovation policy makers.

6.5.1 Firm management

Senior executive and senior managers should investigate a number of issues relating to formation of linkages between firms and universities. It is generally accepted that firms in high technology-intensive industries such as pharmaceutical are using linkages with public research organisations including universities to share the resources such as research costs. Only a few of the pharmaceutical firms operating in South Africa that participated in this research do not consider a cost

factor in their search and selection processes. It is recommended that senior executive and senior managers consider co-funding with public research organisations which could be achieved through linkages. They should use co-funding to supplement their internal research budget.

Because decision-making is the most critical success factor for firms and improving decision-making processes and effectiveness are key to reducing risk and enhancing performance to maximise profits. The empirical data of this research highlights that pharmaceutical firms go through a series of processes to enhance decision-making practices. Some decision-making is done on an ad hoc basis, for example, firms would approach universities when the need arises. As such, these processes appear not to be organised and effective. The inputs and outputs are, therefore, often not defined. It is recommended that senior executive and senior managers implement decision-making practices, which may include:

- paying particular attention to the risks of the external collaboration and examined financial model for the establishment of linkages with universities, sensitivity analysis, and the relationship of those risks to the risks of other projects in the firm’s portfolio. Learning from past comparable situations may also be beneficial;
- ensuring that different firm business units such as strategy, marketing and finance participate in discussions about any decision and are included on the basis of skills and experience; that decision criteria is transparent, and decisions are discussed in relation to the organisation’s other strategic decisions; and
- putting the firm’s goals ahead of business unit goals, and encouraging efforts to build consensus across business units.

6.5.2 Government innovation policy makers

The basic premise of this research is that the legal, economic, and policy environments that comprise the system of innovation determine the rate and type of

university knowledge and thereby influence the rate of technological change within firms.

Therefore, it is suggested that, in order for the South African Government to be successful at promoting linkages between firms and universities, it should be doing more to understand innovation processes within private pharmaceutical firms and how these firms make decisions to form linkages with universities. The South African government should engage firms in the pharmaceutical industry on search and selection practices, which could be used to inform decision-making. Furthermore, policies are needed that stimulate South African universities to continue engaging with firms and to adopt a method of systematic and formal consultation with industry in the development of structured Master and PhD programmes that address industry's requirements.

6.6 Suggestion for possible future work

This research is a preliminary study into understanding how firms in the South African pharmaceutical industry make decisions to link with public research organisations including universities on research and technology development, considering search and selection processes. As a preliminary study, it may form part of a future longitudinal study that investigates change within the South African context.

The future study may include a larger sample of private pharmaceutical firms, in order to increase the number of firms in the study. This would aid in better understanding the innovation processes and complexities and improving decision-making effectiveness. Additionally, such a study might help to differentiate between private pharmaceutical firms in developed and developing countries, as well as the multinational pharmaceutical firms operating in South Africa and local firms, in order to better understand the nature of the competition faced by local firms from the presence and activities of different international firms.

7. REFERENCES

Abrol, D., Prajapati, P and and Singh, N. (2013) Innovation patterns, limits to learning and the pathway of neoliberal globalisation: evidence from Indian pharmaceutical multinationals, *International Journal of Technological Learning, Innovation and Development*, Vol. 6, pp. 102 – 134.

Academy of Science of South Africa (2009) Revitilising clinical research in South: a study on clinical research and related training in South Africa, Consensus Report, Pretoria, South Africa, pp. 1-30, last accessed 12 April 2013, from http://www.bhfglobal.com/files/bhf/Mayosi_S1.pdf.

Accenture (2008) Decision making effectiveness programme proves the right choice for high performance at North American Pharmaceutical company, A consulting report, pp. 1-4, last accessed 4 August 2013, from http://www.accenture.com/sitecollectiondocuments/pdf/napharma_strategy_finaldec08.pdf.

Adams, R. Bessant, J. and Phelps, R. (2002) Innovation management measurement: a review, R&D Management Volume 32, pp. 409–417, last accessed 6 May 2013, from http://onlinelibrary.wiley.com/doi/10.1111/1467-9310.00272/pdf.

Al-Bader, S., Frew, S.E., Essajee, I., Liu, V.U. and Daar, A.S. (2009) Small but tenacious: South Africa's health biotech sector, *Nature America*, Volume 27, pp. 427-436.

Al-Bader, S., Frew, S.E., Essajee, I., Liu, V.U., Daar, A.S. and Singer, P.A. (2009) Paper No, 5, Small but tenacious: South Africa's health biotech sector, *Nature Biotechnology*, Volume 27, pp. 427-436, last accessed 21 February 2013, from http://www.nature.com/nbt/journal/v27/n5/pdf/nbt0509-427.pdf.

Al-Tarawneh, H.L. (2012) The main factors beyond decision-making, Journal of Management Research, Volume 4, pp. 1-23.

Escribanoa, A., Fosfuri, A. and Tribó, J.A. (2009) Managing external knowledge flows: The moderating role of absorptive capacity, *Research Policy*, Volume 38, pp. 96–105.

Ankrah, S.N., Burgess, T.F., Grimshaw, P. and Shaw, N.E. (2013) Asking both university and industry actors about their engagement in knowledge transfer: What single-group studies of motives omit, *Technovation* Volume 33, pp. 50–65.

Araujo, V., Garcia, R., Mascarini, S. and Santos, E.G. (2011) The role of geographical proximity to foster University-industry linkages, Paper presented to the 9th Globelics International Conference "Creativity, Innovation and Economic Development". Buenos Aires, Argentina, pp. 1-23, last accessed 19 April 2013, from http://www.ungs.edu.ar/globelics/wp-content/uploads/2011/12/ID-357-Araujo-Garcia-Mascarini-Santos-Universities-as-Knowledge-Producers-for-EconomicDevelopm.pdf.

Arranz, N and Arroyabe, J.C.F. (2008) The choice of partners in R&D cooperation: An empirical analysis of Spanish firms, *Technovation*, Volume 28, pp. 88-100.

Arundel, A. and Geuna, A. (2004) Proximity and the use of public science by innovative European firms, *Economics of Innovation and New Technology*, Volume 13, pp. 559-580, last accessed 29 April 2013, from http://www.tandfonline.com/doi/pdf/10.1080/1043859092000234311.

Arza, V. and López, A. (2008) Characteristics of university-industry linkages in the Argentinean Industrial Sector, pp. 1-17, In Globelics Conference, Mexico.

Arza, V. and López, A. (2011) Firm's linkages with public research organisations in Argentina: drivers, perceptions and behaviours, *Technovation*, Volume 31, pp. 384-400.

Arza, V. and López, A. (2011) Firms' linkages with public research organizations in Argentina: drivers, perceptions and behaviors from a firm's perspective, National Council for Science and Technology Research (CONICET) Centre of Studies for the

Transformation (CENIT), pp. 1-26,, last accessed 21 June 2013, from www.merit.unu.edu/MEIDE/papers/2011/1295530619_VA.pdf.

Atalay, M., Anafarta and Sarvan, F. (2013). The relationship between innovation and forms performance: an empirical evidence from Tukish automotive supplier industry, *2nd International Conference on Leadership: Technology and Innovation Management, Procedia – Social and Behavioural Sciences*, Volume 75, pp. 226-235.

Balconi, M. (2002) Tacitness, codification of technological knowledge and the organisation of industry, *Research Policy* Volume 31, pp. 357–379.

Bayona, C., Garc´ıa-Marco, T. and Huerta, E. (2001) Firms' motivations for cooperative R&D: an empirical analysis of Spanish firms, *Research Policy*, Volume 30, pp. 1289-1307.

Bayona, C., Garcia-Marco, T. and Huerta, E. (2001) Firms' motivations for cooperative R&D: An empirical analysis of Spanish firms, *Research Policy*, Volume 30, pp. 1289-1307.

Bayona, C., Garcıa-Marco, T. and Huerta, E. (2001) Firms' motivations for cooperative R&D: an empirical analysis of Spanish firms, *Research Policy*, Volume 30, pp. 1289–1307.

Beise, M. and Stahl, H. (1999). Public research and industrial innovations in Germany, *Research Policy*, Volume 28, pp. 397–422.

Bekkers, R. and Bodas-Freitas, I. (2008) Analysing knowledge transfer channels between universities and industry: to what degree do sectors also matter? *Research Policy*, Volume 37, pp. 1837–1853.

Bell, M. (2009) Innovation capabilities and directions of development, innovation, sustainability, development: new manifesto, STEPS Working Paper 33, Brighton: STEPS Centre, University of Sussex, UK, pp. 1-69, last accessed 01 February 2013, from http://www.sciencedirect.com/science/article/pii/S1359644608003656.

Bioeconomy Strategy (2014) The initiative of the Department of Science and Technology, Department of Science and Technology, pp. 1-44, Pretoria, South Africa.

Brostrom, A. (2008) “Firms’ Rationales for Interaction with Research Universities,” CESIS Working Paper Series, No 115 last accessed 13 September 2013, from http://www.diva-portal.org/smash/get/diva2:487617/FULLTEXT01.pdf.

Brostrom, A. (2010) Firms’ rationales for interaction with research universities and the principles for public co-funding, *Journal of Technology Transfer*, Volume 4, pp. 1-17.

Broström, A. (2010) Working with distant researchers—distance and content in university–industry interaction, *Research Policy*, Volume 39, pp. 1311–1320.

Business Monitor International (2009) South African Pharmaceuticals and Healthcare: Report, Q1 including 5-year industry forecast, No. 1748, Business Monitor International, Mermaid House, Puddle Dock, London.

Carcary, M. (2009) The research audit trial – enhancing trustworthiness in qualitative inquiry, *Journal of Business Research Methods*, Volume 7, pp. 11 – 24.

Castells, M and Cardoso, G. (2005) The Network Society: from knowledge to Policy, Castells, M and Cardoso, G (Editors), pp. 1-460, Johns Hopkins Center for Transatlantic Relations, Washington, DC, USA, last accessed 25 June 2013, from http://www.umass.edu/digitalcenter/research/pdfs/JF_NetworkSociety.pdf.

Cockburn, I. and Henderson, R. (2000) Publicly funded science and the productivity of the pharmaceutical industry, In Conference NBER on Science and Public Policy, pp. 1-35, last accessed 16 June 2013, from https://www.acs.org/content/dam/acsorg/policy/acsonthehill/briefings/nihfunding/cockburn-chapter.pdf

Cohen, W., Nelson, R. and Walsh, J. (2002) Links and impacts: the influence of public research on industrial R&D Management, *Science*, Volume 48 (Issue 1), pp. 1–23.

Cohen, W.M. and Levinthal, D.A. (1990) Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly*, Volume 35, pp. 128-152.
Cooper, D.R. and Schindler, P.S. (2011) Business research methods, 11th Edition, The McGraw-Hill Companies, Inc, 1221 Avenue of the America, New York, last accessed 12 July 2013, from http://sutlib2.sut.ac.th/sut_contents/H139963.pdf.

D'Este, P. and Patel, P. (2007) University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry?, *Research Policy*, Volume 36, pp. 1295-1313.

Das, T. K. and Teng, B. (2000) A resource-based theory of strategic alliances, *Journal of Management*, Volume 26, pp. 31–61, last accessed 18 August 2013, from http://aux.zicklin.baruch.cuny.edu/tkdas/publications/dasteng_jom00_resourcebasedtheory_31-61.pdf.

De Fuentes, C. and Dutrénit, G. (2012) Best channels of academia–industry interaction for long-term benefit, *Research Policy*, Volume 41, pp. 666-1682.

DeCarolis, D. M. and Deeds, D. L. (1999) The impact of stocks and flows of organizational knowledge on firm performance: An empirical investigation of the biotechnology industry, *Strategic Management Journal*, Volume 20, pp. 953–968.

Denscombe, M. (2008) The Good Research guide for small-scale special research projects, 3rd Edition, Open University Press, New York, pp. 1-319, last accessed 23 June 2013, fromhttp://iwansuharyanto.files.wordpress.com/2013/04/martyn_denscombe_the_good_research_guidebookfi-org.pdf.

Department of Trade and Industry (2011) The South African pharmaceutical sector profile for the consideration of designation of pharmaceutical products in terms of

PPPFA, pp. 1-44, The Industrial Development Division of the Department of Trade and Industry, The South African Department of Trade and Industry, Pretoria, South Africa.

Dollinger, M. and Golden, P. (1992) Interorganizational and Collective Strategies in small firms: environmental effects and performance, *Journal of Management*, Volume 18, pp. 695–715.

Dutrénit, G., De Fuentes, C. and Torres, A. (2010) Channels of interaction between public research organisations and industry and their benefits: evidence from Mexico, *Science and Public Policy*, Volume 37, pages 513–526.

Edquist, C. (2001) The systems of innovation approach and innovation policy: an account of the state of the art, In Conference DRUID Conference: National Systems of Innovation, Institutions and Public Policies, Aalborg, pp 1-24, last accessed 23 March 2013, from http://www.druid.dk/uploads/tx_picturedb/ds2001-178.

Eoma, B-Y. and Lee, K. (2010) Determinants of industry–academy linkages and their impact on firm performance: the case of Korea as a latecomer in knowledge industrialization, *Research Policy*, Volume 39, pp. 625–639.

Erden, Z., Klang, D., Sydler, R. and Von Krogh, G (2014) Knowledge flows and firm performance, *Journal of Business Research*, Volume 67, pp. 2777 – 2785.

Etzkowitz, H. and Leydesdorff, L. (2000) The dynamics of innovation: from national systems and ‘‘Mode 2’’ to a triple helix of university–industry–government relations, *Research Policy*, Volume 29, pp. 109–123.

Eun, J.-H., Lee, K., and Wu, G. explaining the university-run enterprises in China: a theoretical framework for university-industry relationship in developing countries and its application to China, *Research Policy*, Volume 35, pp. 1329-46.

Fontana, R., Geuna, A. and Matt, M. (2006) Factors affecting university-industry R&D projects, *Research policy*, Volume 35, pp. 309–323.

Freeman, C. (1995) The National System of Innovation in historical perspective, *Cambridge Journal of Economics, Volume* 19, pp. 5-24, last accessed 27 March 2013, from http://www.globelicsacademy.org/2011_pdf/Freeman%20NSI%20historial%20perspective.pdf.

Fu, X and Li, J. (2009) The dual role of universities in industrial innovation in emerging economies: a comparative study of China and the UK, TMD Working Paper Series No. 45, Department of International Development, University of Oxford, UK, pp. 1-40, last accessed 20 June 2013, from http://www3.qeh.ox.ac.uk/pdf/ptmd/SLPTMD-WP-045.pdf.

Furman, J.L. and Megan J. M. (2007) Academic science and the birth of industrial research laboratories in the U.S. pharmaceutical industry, *Journal of Economic Behavior and Organization*, Volume 63, pp. 756-776.

Garcia, R., Araujo, V.C., Mascarini, S., Santos, E.G. and Costa, A. (2014) University-Industry linkages in Engineering and Agrarian Science in Brazil the influence the quality of academic research, the absorptive capacity of firms and the territorial factors, In Conference III Geography of Innovation 2014, Utrecht, pp. 1-14, last accessed 28 August 2014, from http://elio6.eurolio.eu/indico/getFile.py/access?contribId=179&sessionId=91&resId=0&materialId=paper&confId=3.

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

Giuliani, E. and Arza, V. (2009) What drives the formation of "valuable" university-industry linkages? An under-explored question in a hot policy debate, SPRU Electronic Paper Series No. 170, SPRU Science and Technology Policy Research, UK, pp. 1-35, last accessed 13 March 2013, from https://www.sussex.ac.uk/webteam/gateway/file.php?name=sewp170&site=25.

Gunasekara, C. 2006 Reframing the role of universities in the development of regional innovation systems, *Journal of Technology Transfer*, Volume 31, pp. 101–113.

Hamdan, H., Yusof, F., Omar, D., Abdullah, F., Nasrudin, N. and Abullah, I.C (2011) University Industrial Linkages: Relationship towards economic growth and development in Malaysia, International Journal of Social, Management, Economics and Business Engineering, Volume 5, pp. 205 – 212.

Hess, A. M. and Rothaermel, F. T. (2011) When are assets complementary? Star scientists, strategic alliances, and innovation in the pharmaceutical industry, *Strategic Management Journal*, Vol. 32, p. 895-909.

Hobday, M. (2005) Firm-level innovation models: perspectives on research in developed and developing countries, *Technology Analysis and Strategic Management*, Volume 17, pp. 121-146.

Industrial Policy Action Plan (2014) Economic Sectors and Employment Sectors: Plastics, Pharmaceutical, Chemicals and Cosmetics, pp. 97- 100, The Department of Science and Technology, Pretoria, South Africa, http://www.thedti.gov.za/news2013/ipap_2013-2016.pdf.

Innovation, Higher Education and Research for Development (2012) Promoting Higher Education – Industry Partnerships and Collaborations: Report to the Research and Innovation Strategy Group Higher Education South Africa, pp1-46, last accessed 8 March 2013 http://www.hesa.org.za/sites/hesa.org.za/files/2012_HESA_Promoting%20Higher%20Education_Industry%20Partnerships.pdf.

Intarakumnerd, P and Schiller, D. (2009) University-Industry Linkages in Thailand: Successes, failures, and lessons learned for other developing countries, *Seoul Journal of Economics*, Volume 22, pp. 551-589.

Kafouros, M.I. and Buckley, P.J. (2008) Under what conditions do firms benefit from the research efforts of other organizations? *Research Policy*, Volume 37, pp 225 – 239.

Karakas, M. and Yildiz, E. (2012) Institutional determinants of multinational corporations entry mode choice in Turkey, Afyon Kocatepe Üniversitesi, İİBF Dergisi, pp. 295-306, last accessed 23 September 2013, from http://www.iibfdergi.aku.edu.tr/pdf/14_2/18.pdf.

Katila, R and Ahuja, G. (2002) Something old, Something New: a longitudinal study of search behaviour and new product introduction, *Academy of Management Journal*, Vol. 45, pp. 1183-1194, last accessed 21 September 2013, from http://web.stanford.edu/~rkatila/new/pdf/KatilaSomethingold.pdf.

Kim, Y-C and Rhee, M (2010) The contingent effect of social networks on organizational commitment: a comparison of instrumental and expressive ties in a multinational high-technology company, *Sociological Perspectives*, Volume 53, pp. 479-502.

Kingsley, G., Bozeman, B. and Coker, K. (1996) Technology transfer and absorption: Kofinas, A and Saur-Amaral, I. (2008) 25 years of knowledge creation processes in pharmaceutical contemporary trends, Comportamento Organizacionale Gestao, Volume 14, pp. 257-280, last accessed 23 April 2013, from http://www.scielo.gpeari.mctes.pt/pdf/cog/v14n2/v14n2a09.pdf.

Kruss, G. (2005a) Harnessing innovation potential? - Institutional approaches to industry-higher education research partnership in South Africa, *Industry and Higher Education*, Volume 19, pp. 131-142.

Kruss, G. (2005b) Creating knowledge networks: higher education, industry and innovation in South Africa, In Conference Globelics Africa *2005,* Tshwane University of Technology, Pretoria, pp. 1-20, last accessed 21 April 2013, from http://www.globelics2005africa.org.za/papers/p0024/Globelics2005_Kruss.pdf

Kruss, G. (2012) Channels of interaction in health biotechnology networks in South Africa: who benefits and how?, *International Journal of Technological Learning*, Innovation and Development, Volume 5, pp. 204-220.

Kruss, G., Adeoti, J. and Nabudere, D. (2009) Universities and knowledge-based development in sub-Saharan Africa: Comparing university-firm interaction in Nigeria, Uganda and South Africa, In Proceedings of the innovation for development: frontiers of research, policy and practice symposium, University of Witwatersrand, South Africa, pp 1-17.

Kwanghui Lim (2004) The relationship between research and innovation in the semiconductor and pharmaceutical industries (1981–1997), *Research Policy*, Volume 33, pp. 287-321.

Laestadius, S. (2004) Innovation management in the knowledge economy: series on technology management, Ben Dankbaar (Editor); Imperial College Press, London, pages, pp. 593-594 (including index), London.

Laursen, K. and Salter, A (2004) Searching high and low: what types of firms use universities as a source of innovation?, *Research Policy*, Volume 33, pp. 1201–1215.

Leten B. Landoni P. Van Looy B. (2014) Science or graduates: How do firms benefit from the proximity of universities?, Research Policy, Volume 43, pp. 1398-1412.
Letena, B., Landonic, P. and Van Looy, L.B. (2014) Science or graduates: How do firms benefit from the proximity of universities?, *Research Policy*, Volume 43, pp. 1398-1412.

Leydesdorff, L and Meyer, M. (2006) Triple helix indicators of knowledge-based innovation systems Introduction to the special issue, *Research Policy*, Volume 35, pp. 1441–1449.

Lööf, H. and A. Broström **(2008)**, “Does Knowledge Diffusion between University and Industry Increase Innovativeness?” *Journal of Technology Transfer*, Volume 33, pp. 73-90.

Luiza, A. and Bucharth, A (2008) What Drives the formation of technological cooperation between university and industry in less-developed innovation systems? evidence from Brazil, Centre for Organisational Renewal and Evolution, Aarhus School of Business, University of Aarhus, pp. 1-28, last accessed 18 April 2013, from http://www.uniempre.org.br/userfiles/files/What%20Drives%20the%20Formation%20of%20Technological.pdf.

Lundvall (2004) National innovation systems – analytical concept and development tool, Paper to be presented at the DRUID Tenth Anniversary Summer Conference 2005 on Dynamics of industry and innovation: organisations, networks and systems, Copenhangen, pp. 1-43, Denmark, last accessed 23 April 2014, from http://www.druid.dk/conferences/Summer2005/Papers/Lundvall.pdf.

Lundvall, B. (2003). Why the new economy is a learning economy, DRUID Working Papers No. 04-01, DRUID, pp. Copenhagen Business School, Department of Industrial Economics and Strategy/Aalborg University, Department of Business Studies, Copenhagen, pp.1-13, last access 26 June 2013, from http://www.francoangeli.it/riviste/Scheda_Rivista.aspx?IDArticolo=20479&Tipo=ArticoloPDF.

Lundvall, B. (2004) Knowledge management in the learning economy, DRUID Working Paper No. 06-6, pp. 1-24, Danish Research Unit for Industrial Dynamics, Danmark, last accessed 12 June 2013, from http://www3.druid.dk/wp/20060006.pdf.

Lundvall, E-A. (2007) National Innovation Systems—analytical concept and development tool, industry and innovation, Volume 14, pp. 95-119, last accessed 11 July 2013, from http://infojustice.org/download/gcongress/dii/lundvall%20article.pdf.

Mahdi, S. (2003) Search strategy in product innovation process: theory and evidence from the evolution of agrochemical discovery process Industrial and Corporate Change, In Conference Druid-Nelson and Winter Conference in Aalborg, Denmark, pp. 1-33, last accessed 24 June 2013, from https://www.researchgate.net/publication/5212433_Search_strategy_in_product_inn

ovation_process_theory_and_evidence_from_the_evolution_of_agrochemical_lead_discovery_process.

Mahomedy, Y (2010) Manufacture of pharmaceuticals, Research report, pp. 1-64, WHO Owns Who, Essential Business Information, Randburg and Port Elizabeth, South Africa, last accessed 16 September 2013, from www.whoownswho.co.za.

Maloney, C and Myburgh, A. (2007) The growth and potential of the pharmaceutical sector in South Africa, last accessed 18 June 2013, from genesis-analystics.com/search_results_projects.asp.

Maloney, C. and Myburgh, A. (2007) The Growth Potential of the Pharmaceuticals Sector in South Africa: Background Working Paper, Genesis Analytics (Pty) Ltd, Johannesburg, South Africa.

Manfred M. F. (2000) Innovation, Knowledge Creation and Systems of Innovation, In Conference 40th European Congress of the Regional Science Association, Barcelona, Spain, last accessed 23 February 2013, from www.researchgate.net/...INNOVATION...SYSTEMS...INNOVATION.

Mansfield, E.D. (1998) The proliferation of preferential trading arrangements, *Journal of conflict resolution*, Volume 42, pp. 523-543.

Marcelle, G. (2004) Technological Learning – A Strategic imperative for firms in the developing world, pp. 1-21, Edward Elgar Pub, UK.

Marcelle, G. (2011) The inter-sessional panel of the United Nations commission on science and technology for development, United Nations on Trade and Development Report, Wits Business School, University of Witwatersrand, Johannesburg, South Africa, pp. 1-24, last accessed 18 August 2013, from http://unctad.org/sections/un_cstd/docs/cstd2011d24_Marcelle_EN.pdf.

Medicine Control Council (2011) Licences issued in terms of section 22C of the medicine and related substance Act, 1965: manufacturers, importers, exporters and

wholesaler and distributor, Licensing Report: Licence to Manufacture, Import or Export, Act as a Wholesaler or Distributor, No. 20.08, South African Medicine Control Council, Department of Health, Pretoria, South Africa, website: www.mcc.gov.za.

Meyer-Krahmer, F. and Schmoch, U. (1998) Science-based technologies university–industry interactions in four fields, *Research Policy*, Volume 27, pp. 835–852.

Micheal D. R and Sampson, R.C. (2006) Do prior alliances influence alliance contract structure?, Working Paper No. 11.05, Intellectual Property Research Institute of Australia, The University of Melbourne, Australia, last accessed 21 April 2013, from http://www.ipria.org/publications/wp/2005/ipriawp11.2005.pdf.

Mol, M.J. and Birkinshaw, J. (2009) The sources of management innovation: when firms introduce new management practices, *Journal of Business Research*, Volume 62, pp. 1269-1280.

Monjon, S. and Waelbroeck, P. (2003) Assessing spillovers from universities to firms: evidence from French firm-level data, *International Journal of Industrial Organization*, Volume 21, pp. 1255–1270.

Morandi, V. (2013) The management of industry–university joint research projects: how do partners coordinate and control R&D activities? *Journal of Technology Transfer*, Volume 38, pp. 69-92.

Mora-Valentin, E.M., Montoro-Sanchez, A. and Guerras-Martin, L.A. (2004) Determining factors in the success of R&D cooperative agreements between firms and research organizations, *Research Policy*, Volume 33, pp. 17–40.

Moroz, D. (2005). Production of Scientific Knowledge and Radical Uncertainty: The Limits of the Normative Approach in Innovation Economics, *European Journal of Law and Economics*, Volume 20, pp. 305–322.

Mowery, D. C. and Sampat, B.N. (2002) Universities in National Innovation Systems, In Globelics, pp. 1-38 last accessed 21 September 2013, from www.globalicsacademy.net/pdf/davidmowery_1.pdf.

Mowery, D.C., Oxley, J.E. and Silverman, B.S. (1996) Strategic Alliances and Interfirm Knowledge Transfer, *Strategic Management Journal*, Volume 17, pp 77-91.
Muskat, M., Blackman, D. and Muskat, B. (2012) Mixed methods: combining expert interviews, cross-impact analysis and scenario development, *Journal of Business Research Methods*, Volume 10, pp. 9 – 21.

Naghibi, M.A. and Baban, H. (2011) Strategic change management: the challenges faced by organizations, In Conference *2011 International Conference on Economics and Finance Research, IPEDR, Singapore*, pp. 542-544, last accessed, from http://www.ipedr.com/vol4/108-F00035.pdf.

OECD (2010) The OECD Innovation Strategy: getting a head on tomorrow, Organisation for Economic Cooperation and Development, Switzerland, pp. 1-226, last accessed 23 March 2013, from http://www.oecd.org/sti/theoecdinnovationstrategygettingaheadstartontomorrow.htm.

OECD (1997) Government venture capital for technology based firms (unclassified – OECD/GD(97)201), Organisation for Economic Co-operation and Development, Paris, pp 1-34, last accessed 13 June 2013, from http://www.oecd.org/sti/inno/2093654.pdf.

Østergaard, C.R. (2009) Knowledge flows through social networks in a cluster: Comparing university and industry links, *Structural Change and Economic Dynamics*, Volume 20, pp. 196–210.

Paranhos, J. and Hasenclever, L. (2009) Economic and management of innovation, technology and organizational change, In Conference DRUID-DIME Academy Winder PhD Conference, Hotel Comwell Rebild Bakker, Aalgorg, Denmark, pp. 1-20, last accessed 10 August 2013, from http://www2.druid.dk/conferences/viewpaper.php?id=4225&cf=33.

Patel, S., Tang, D.P.H. and Elliot, G. (2005) Research methods for organisational studies, *Strategic Planning and Quality Assurance in Higher Education*, Volume 34, pp. 64-76.

Pavitt, K. (2003) The process of innovation, Working Paper No. 89, SPRU: Science and Technology Policy Research, The Freeman Centre, University of Sussex, Brighton, England, pp. 1-48, last accessed 16 March 2013 https://www.sussex.ac.uk/webteam/gateway/file.php?name=sewp89&site=25.

Pek-Hooi Soha, P-H and Roberts, E.B. (2003) Networks of innovators: a longitudinal perspective, *Research Policy,* Volume 32, pp. 1569-1588

Perkmann, M. and Walsh, K. (2009) The two faces of collaboration: impacts of university–industry relations on public research, *Industrial and Corporate Change*, Volume 18, pp. 1033–1065.

Pertuze, J.A., Calder, E.S., Greitzer, E.M. and Lucas, W.A. (2010) Best practices for industry-university collaboration, *MITSloan Management Review*, Volume 51, pp. 82 91, last accessed 21 June 2013, from http://osp.mit.edu/sites/osp/files/u8/bestpractices.pdf.

Plewa, C., Korff, N., Johnson, C., Macpherson, G., Baaken, T. and Rampersad G.C. (2013) The evolution of university–industry linkages - A framework, *Journal of Engineering and Technology Management*, Volume 30, pp. 21-44.

Purcell, R and McGrath, F. (Year) The Search for External Knowledge The *Electronic Journal of Knowledge Management*, Volume 11, pp158-167.

Purwaningruma, F., Eversb, H-D. and Yaniasih (2012) Knowledge flow in the academia- industry collaboration or supply chain linkage? Case study of the automotive industries in the Jababeka Cluster, In Conference 10th Triple Helix Conference, *Procedia - Social and Behavioral Sciences*, Volume 52, pp. 62–71.

Ramos-Vielba, I., Ferna´ndez-Esquinas, M. and Espinosa-de-los-Monteros, E. (2009) Measuring university–industry collaboration in a regional innovation system, *Scientometrics*, Volume 84, pp. 649–667.

Rasiah, R. and Govindaraju, C. (2009) University-industry R&D collaboration in the automotive, biotechnology and electronics firms in Malaysia, *Seoul Journal of Economics*, Volume 22, pp. 529-550.

Rašul, J., Vukšić, V.B. and Štemberger, M.I. (2012) The impact of knowledge management on organisational performance, *Economic and Business Review*, Volume 14, pp. 147-168.

Robert Arasa and Peter K'Obonyo (2012) The Relationship between Strategic Planning and Firm Performance, *International Journal of Humanities and Social Science, Vol. 2, pp. 201-213.*

Solow, R.M. (1957) Technical Change and the Aggregate Production Function, *The Review of Economics and Statistics*, Volume 39, pp. 312-320.

Romer, P.M. (1990) Endogenous technological change, *Journal of Political Economy*, Volume 98, pp. 71–101, last accessed 14 May 2013, from http://pages.stern.nyu.edu/~promer/Endogenous.pdf.

Rothaermel, F.T. (2001) Complementary assets, strategic alliances, and the incumbent's advantage: an empirical study of industry and firm effects in the biopharmaceutical industry, *Research Policy,* Volume 30, pp. 1235–1251.

Saeed, P., Tommaso, C. and Saurabh, A (2006) economic growth, innovation systems and institutional change, In Conference: Globelics India Innovation Systems for Competitiveness and Shared Prosperity in Developing Countries, Kerala, India, pp. last accessed 23 September 2013, from https://smartech.gatech.edu/jspui/bitstream/1853/35242/1/Tomasso%20ciarli.pdf.

Salas, J.A.P. (2009) Best practices for industry-university research collaborations, Master these in Science in Technology and Policy, Massachusetts Institute of Technology, last accessed 15 April 2013, from http://dspace.mit.edu/bitstream/handle/1721.1/52756/501820032.pdf?sequence=1.

Santos, F.M. (2003) The coevolution of firms and their knowledge environment: Insights from the pharmaceutical industry, *Technological Forecasting and Social Change*, Volume 70, pp. 687–715.

Santos, F.M. (2003) The coevolution of firms and their knowledge environment: Insights from the pharmaceutical industry, *Technological Forecasting and Social Change*, Volume 70, pp. 687–715.

Schartinger, D., Rammera, C., Fischer, M.M. and Fröhlich, J. (2002) Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants, *Research Policy*, Volume 31, pp. 303-328.

Schartinger, D., Schibany, A. and Gassler, H. (2000) Interactive relations between university and industry: empirical evidence for Austria, *Journal of Technology Transfer*, Volume 26, pp. 255–268.

Schmidt, W. and Buell, R.W. (2014) Decision making under information asymmetry: experimental evidence on belief refinements, Working Paper 15-001, Harvard Business School, USA, pp. 1-44, last accessed 28 July 2013, from http://www.hbs.edu/faculty/Publication%20Files/15-001_5954aa68-170b-4c0d-9b9d-67ff6e630319.pdf.

Sebuwufu, J., Ludwick, T. and Béland, M. (2012) Strengthening University-Industry Linkages in Africa: A Study of Institutional Capacities and Gaps: A Study on Institutional Capacities and Gaps, pp. 1-61, Association of African Universities (AAU), Accra-North Ghana, Last accessed 18 October 2013, from http://www.aucc.ca/wp-content/uploads/2011/07/aau-case-study-university-industry linkages-africa.pdf.

Siyanbola, W.O., Oladipo, O.G., Oyewale, A.A., Famurewa, A.J. and Ogundari, I.O. (2012) Academia-industry interactions in Nigeria pharmaceutical innovation systems, *Prodedia – Social and Behavioral Sciences*, Volume 52, pp. 279-289.

Smith, D and Katz, J.S. (2000) Collaborative approaches to research: HEFCE Fundamental Review of Research Policy and Funding, Final Report, pp1-117, Higher Education Policy Unit, University of Leeds and the Science Policy Research Unit (SPRU) University of Sussex, UK, last accessed 18 February 2013, from http://www.sussex.ac.uk/Users/sylvank/pubs/collc.pdf.

Sofka, W. and Grimpe, C. (2008) Managing Search Strategies for Open Innovation – the role of environmental munificence as well as internal and external R&D, Discussion Paper No. 08-075, Centre for European Economic Research, Germany, last accessed 21 July 2013, from https://ub-madoc.bib.uni mannheim.de/2113/1/dp08075.pdf.

Stuart, T.E. and Podolny, J.M. (1996) Local search and the evolution of technological capabilities, *Strategic Management Journal*, Volume 17, pp. 21-38, last accessed 8 September 2013, from http://onlinelibrary.wiley.com/doi/10.1002/smj.4250171004/pdf.

Teal, E J. (2011) Strategic decision under uncertainty from foundations of creativity, Psychology and Management Research: an examination and synthesis, Journal of Business Administration Online Volume 10, pp. 1-21.

Teece, D.J. (1998) Capturing value from knowledge assets: The new economy, markets for know-how and intangible assets, *California Management Review,* Volume 40, pp. 55-79.

Tidd, J. and Bessant, J. (2009) Managing innovation: integrating technological, market and organisational change, 4th Edition, Wiley, J. and Sons Ltd, West Sussex, England.

Tralau-Stewart, C.J., Wyatt, C.A., Kleyn, D.E. and Ayad, A. (2009) Drug discovery: new models for industry-academic partnership, *Drug Discovery Today*, Volume 14, pp. 95-101.

Triulzi, G., Scholz, R and Pyka, A (2011) R&D and knowledge dynamics in university-industry relationships in biotech and pharmaceuticals: an agent-based model, Discussion Paper No. 33, Universität Hohenheim, Forschungszentrum, Stuttgart, last accessed 21 June 2013, from https://fzid.uni-hohenheim.de/fileadmin/einrichtungen/fzid/CC_Competence_Center/fzid_dp_2011_33_pyka.pdf.

Van Maanen, J (1979) Reclaiming qualitative methods for organizational research, *Administrative Science Quarterly*, Volume 24, pp. 520-526.

Vega-Jurado, J., Guti´errez-Gracia, A., Fern´andez-de-Lucio, I. and Manjarr´es-Henr´ıquez, L. (2008) The effect of external and internal factors on firms' product innovation *Research Policy*, Volume 37, pp. 616-632.

Veugelersa, R. and Cassiman, T.B. (2005) R&D cooperation between firms and universities: some empirical evidence from Belgian manufacturing, *International Journal of Industrial Organization*, Volume 23, pp. 355– 379.

Viljoen, T. (2014) US pharmaceutical giant Pfizer and North-West university join forces: In Science and Technology Newsletter July/August Issue, pp. 3, National Department of Science and Technology, Pretoria, South Africa.

Walwyn, D.R. (2008) A comparison of the cost of research in South Africa's public research and higher education institution, *South African Journal of Science*, Volume 104, pp. 431 – 435.

Wang, A. (2009) Government's role as public venture capitalist in high technology small and medium sized enterprises, Published Masters Thesis in *Entrepreneurship, Department of Management and Entrepreneurship*, Tshwane University of Technology, Pretoria.

Wolff, J. and Pett, T. (2006) Small firm performance: modelling the role of product and process improvements. *Journal of Small Business Management*, Volume 44, pp. 268-284, last accessed 12 August 2013, from http://onlinelibrary.wiley.com/doi/10.1111/j.1540-627X.2006.00167.x/pdf.

Zawislak, P.A. and Dalmarco, G. (2011) The Silent Run: New Issues and Outcomes for University-Industry Relations in Brazil, *Journal of Technology Management and Innovation*, Volume 6, pp. 66-81.

8. APPENDICES

Appendix A: Interview protocol directed at the participated pharmaceutical firms operating in South Africa

Background

The purpose of these questions is to explore the perspectives of pharmaceutical firms regarding forming collaborations for research and development (R&D), with universities as opposed to science councils and other knowledge providers. In particular, I am interested to understand the selection and decision-making processes that lead to firms choosing particular university with whom to collaborate.

The questionnaire is directed at R&D Managers, Commercialisation Managers, IP Managers, Senior Technology Acquisition Managers, Project Managers and Strategic Collaborations Managers within pharmaceutical firms.

The questionnaire has been structured into two separate parts and will take approximately sixty minutes.

Thank you

Sechaba Bareetseng
Tel.: 012 841 2574contact information
Cell: 082 332 8367
Email: sbareetseng@csir.co.za

PART 1

The first part of the interview covers the general profile of respondent firms in terms of company age and the broad nature of knowledge collaboration with universities.

Date: ……....
Company Name: ……
Location of the Company: ……..
Interviewee Name: ……
Interviewee's Portfolio: ……

What is the nature of your business?

Please select from the following-

☐ *Manufacturing*
☐ *Export*
☐ *Import*
☐ *Clinical research*
☐ *Quality control*
☐ *Packaging*

Has your company collaborated with a university?

☐ *Yes*
☐ *No*

If yes, how many R&D collaboration agreements do you have?

What is the nature of your company's collaboration with universities:

☐ *R&D contracts*
☐ *Sponsored R&D*
☐ *Student postgraduate research projects*
☐ *Internships*
☐ *Postgraduate Studentships*
☐ *University consultancy*
☐ *University commercial scientific research*
☐ *Conferences*

For how many years has your company been collaborating with universities?

Does your firm use university collaboration for technological development and innovation?

☐ *Yes*

☐ *No*

On how many R&D projects have you collaborated with universities?
To what extent has your company derived value from the collaboration?
How many patents has your company produced due to collaboration?
If you have not already done so, does your firm intends to enter into research collaboration with universities in the near future?
Does your firm intend to enter into R&D collaboration with universities?
Does your firm engage in R&D in-house?

☐ *Continuously*

☐ *Occasionally*

☐ *Never*

PART 2

The second part of the interview seeks your perceptions and descriptions of firm activities.

Searching for universities for collaboration and innovation management

1. How do you scan the environment to keep abreast of research being performed in different universities?
2. Does the process of searching and scanning for knowledge add value to value creation? If yes, why?
3. Do you use staff with specialist competencies to undertake this search and scan roles and functions?
4. What factors does your company consider when performing a search for knowledge?
5. How does your firm decide which R&D projects of technologies to explore?
6. What types of projects are considered by your firm? Do you choose to acquire pure science knowledge inputs from universities or do you prefer to have these packaged in a commercial framework?
7. Are you looking for cost-effective manufacturing services from universities?
8. Where do the decisions on knowledge collaboration get made in your firm? How do these decisions get made? Is there an investment committee or other body involved in the approval process?
9. In the case of international firms operating in South Africa, does the approval making process involve head office or regional office? Are there thresholds for decisions and approvals that are made in South Africa?
10. Beyond, the approval stage, does the head office or regional office get involved in the operational aspect of knowledge collaboration with universities?

Selection criteria for choosing among knowledge providers

1. What factors influence your selection of universities rather than other knowledge providers and how do these influence your decision?
2. What characteristics of the universities facilitate your selection?
3. Has your company collaborated with a science council before?

Yes 

No 

4. If yes, what was the experience?
5. If no, why has your company not collaborated with a science council?
6. How did your firm manage improving knowledge collaboration over time with universities and science councils?
7. How would you compare the value derived from collaboration with universities as opposed to science councils?

8. Types of knowledge and learning from the university knowledge
9. What types of specialised knowledge inputs do you most seek when collaborating? And why?
10. How do you capture that knowledge?
11. How do you codify the learning from knowledge inputs and the search process?

Value

1. Why is your firm dedicating resources to knowledge collaboration?
2. How has university knowledge affected
3. research activity within your firm; or
4. innovation activity and/or technological innovation

Appendix B: Sample frame of the pharmaceutical firms operating in South Africa from which the sample size of the participating pharmaceutical firms emerged which excludes pharmaceutical firms involved in retail and distribution

Name of a pharmaceutical firm	Nature of a business						
	Manufacturing	Export	Import	Clinical research	Quality control	Packaging	Regions
Sub-population 1							
1. Alliance Pharma: Faraday Street	X	X		X	X	X	GP
2. Be-Tabs Pharmaceuticals (Pty) Ltd	X	X	X				GP
3. Divpharm Manufacturing & Packaging – Agvet Site	X						GP
4. Schering-Plough (Pty) Ltd (Site 1)	X	X	X				GP
5. Aventis Pharma (Pty) Ltd	X	X	X				GP
6. Mirren (Pty) Ltd	X	X					GP
7. Johnson & Johnson Medical (Pty) Ltd	X	X	X				GP
8. Roche Products (Pty) Ltd	X	X	X				GP
9. Columbia Pharmaceuticals (Pty) Ltd	X	X					GP
10. Hersol Manufacturing Laboratories	X	X					GP
11. Isotec Nutrition (Pty) Ltd – Johannesburg	X						GP
12. Pharmaceutical Contractors (Pty) Ltd	X						GP
13. Pharmaceutical Contractors (Pty) Ltd	X						GP
14. Specpharm Holdings (Pty) Ltd	X	X	X				GP
15. Adcock Ingram Healthcare (Pty) Ltd – Clayville	X	X	X				GP
16. Adcock Ingram Critical Care (Pty) Ltd	X	X	X				GP
17. Dismed Criticare (Pty) Ltd	X	X	X				GP
18. Adcock Ingram Healthcare (Pty) Ltd – Wadeville	X						GP
19. Inspectorate M & L (Pty) Ltd	X			X			GP
20. Alliance Pharma (Pty) Ltd – Wadeville	X						GP
21. Syntacoll (Pty) Ltd	X		X				GP
22. Pharma-Q trading as Cosi Pharmaceuticals	X			X			GP
23. Pharma Natura (Pty) Ltd	X	X	X				GP
24. MSD (Pty) Ltd	X	X	X	X		X	GP
25. Technikon Laboratories (Pty) Ltd – Anvil Road	X						GP
26. Natural Medicinal Services (Tvl) (Pty) Ltd	X	X					GP
27. Contractum (Pty) Ltd	X	X	X				GP
28. Adcock Ingram Limited – Research & Development	X						GP
29. Portfolio Laboratories (Pty) Ltd	X						GP
30. African Oxygen Ltd – Highveld Process Operations Plant	X						GP

31. African Oxygen Ltd – Pretoria West Process Operation Plant	X						GP
32. African Oxygen Ltd – Gases Operation Centre (Germiston)	X	X					GP
33. Air Products SA (Pty) Ltd – Vanderbijlpark	X						GP
34. Air Products S.A. (Pty) Ltd – Kempton Park	X						GP
35. Cyclotope (Pty) Ltd	X						GP
36. Altis Biologics (Pty) Ltd	X						GP
37. Air Liquide (Pty) Ltd – Alrode	X						GP
38. Air Liquide (Pty) – Cape Town	X						GP
39. Dezzo Trading 392 (Pty) Ltd trading as Indo Pharma	X	X					GP
40. Sandoz South Africa (Pty) Ltd	X	X	X				GP
41. SABS TCS				X			GP
42. Khululekani Laboratories Services CC				X			GP
43. Analyticon (Pty) Ltd				X			GP
44. Institute for Pharmaceutical Services				X			GP
45. Consulting Chemical Laboratories (Pty) Ltd				X			GP
46. Stainer Laboratories Services (Pty) Ltd				X			GP
47. Consulting Microbiological Laboratories				X			GP
48. Sedek Agrikem CC				X			GP
49. Laboratory & Biological Services				X			GP
50. Labhouse (Pty) Ltd				X			GP
51. Bioindustrial Services CC				X			GP
52. C.V Analytical Consultant (Pty) Ltd				X			GP
53. Pet Labs Pharmaceuticals (Pty) Ltd			X	X		X	GP
54. AstraZeneca Pharmaceuticals (Pty) Ltd			X				GP
55. Biogaran South Africa (Pty) Ltd		X	X				GP
56. B Braun Medical (Pty) Ltd		X	X				GP
57. Altana Madaus (Pty) Ltd		X	X				GP
58. Abbott Laboratories S.A. (Pty) Ltd		X	X	X	X		GP
59. Instavet Import & Export (Pty) Ltd		X	X				GP
60. Intervet South Africa (Pty) Ltd		X	X				GP
61. Biotech Laboratories (Pty) Ltd		X	X				GP
62. Novartis South Africa (Pty) Ltd – Spartan		X	X				GP
63. Biovac SA (Pty) Ltd		X	X				GP
64. Boots Healthcare South Africa (Pty) Ltd		X	X				GP
65. Soflens (Pty) Ltd		X	X				GP

66. GE Healthcare (Pty) Ltd		X	X				GP
67. UCB (SA) (Pty) Ltd		X	X				GP
68. Servier Laboratories South Africa (Pty) Ltd		X	X				GP
69. Ikhambi Health (Pty) Ltd						X	GP
70. Solvay Pharma (Pty) Ltd		X	X				GP
71. Egis Pharmaceuticals South Africa (Pty) Ltd		X	X				GP
72. Pharmacare Limited – Woodmead		X	X				GP
73. Akromed Products (Pty) Ltd		X	X				GP
74. Triomed (Pty) Ltd		X	X				GP
75. Ingelheim Pharmaceuticals (Pty) Ltd – Ferndale		X	X				GP
76. Wyeth South Africa (Pty) Ltd		X	X				GP
77. Xixia Pharmaceuticals (Pty) Ltd		X	X				GP
78. Fresenius Kabi South Africa (Pty) Ltd – JHB		X	X				GP
79. Arrow Pharma S.A. (Pty) Ltd		X	X				GP
80. Eli Lilly (S.A.) (Pty) Ltd		X	X				GP
81. 3M Pharmaceuticals South Africa (Pty) Ltd		X	X				GP
82. H. Lundbeck (Pty) Ltd		X	X				GP
83. Merck (Pty) Ltd		X	X				GP
84. Caps Pharmaceuticals (Pty) Ltd		X	X				GP
85. Allergan Pharmaceuticals (Pty) Ltd		X	X				GP
86. Merck Generics RSA (Pty) Ltd		X	X				GP
87. Donmed Pharmaceuticals (Pty) Ltd		X	X				GP
88. Genop Healthcare (Pty) ltd		X	X				GP
89. Safeline Pharmaceuticals (Pty) Ltd		X	X				GP
90. Bristol-Myers Squibb (Pty)		X	X				GP
91. Teva Pharmaceuticals (Pty) Ltd		X	X				GP
92. Schering (Pty) Ltd		X	X				GP
93. Ferring (Pty) Ltd		X	X				GP
94. Virbac RSA (Pty) Ltd		X	X				GP
95. Ranbaxy (SA) (Pty) Ltd		X	X				GP
96. SCP Pharmaceuticals (Pty) Ltd		X	X				GP
97. Specpharm (Pty) Ltd		X	X				GP
98. Bayer (Pty) Ltd – Isando		X	X				GP
99. Pharmafrica (Pty) Ltd		X	X				GP
100. Pharmachemie (Pty) Ltd		X	X				GP
101. Tyco healthcare (Pty) Ltd		X	X				GP
102. Sanofi-Synthelabo (Pty) Ltd		X	X				GP

103. Merial South Africa (Pty) Ltd		X	X				GP
104. Sekpharma (Pty) Ltd		X	X				GP
105. Novo Nordisk (Pty) Ltd (Paulshof Site)		X	X				GP
106. Cipla Medpro (Pty) Ltd		X	X				GP
107. Alcon Laboratories (SA) (Pty) Ltd		X	X				GP
108. Omnimed (Pty) Ltd		X	X				GP
109. Key Oncologics (Pty) Ltd		X	X				GP
110. Stiefel Laboratories (SA) (Pty) Ltd		X	X				GP
111. Immuno-Vet Services CC		X	X				GP
112. Innovata Pharmaceuticals		X	X				GP
113. Pharmascript Pharmaceuticals Ltd		X	X				GP
114. Moses Marketing Venture CC		X	X				GP
115. Thusanong Healthcare (Pty) Ltd		X	X				GP
116. Golden Neo-Life Diamite (Pty) Ltd		X	X				GP
117. Tema Medical (Pty) Ltd		X	X				GP
118. Medwich Pharma (Pty) Ltd		X	X				GP
119. Schering-Plough (Pty) Ltd (Site II)		X	X				GP
120. Mediscience (Pty) Ltd		X	X				GP
121. Aurobindo Pharma		X	X				GP
122. CompuPharm (Pty) Ltd			X				GP
123. Bioforce SA (Pty) Ltd			X				GP
124. Apex Pharmaceuticals (Pty) Ltd			X				GP
125. Camox Pharmaceuticals (Pty) Ltd			X				GP
126. Serono South Africa (Pty) Ltd			X				GP
127. The Dental Warehouse (Pty) Ltd			X				GP
128. Medi Challenge (Pty) Ltd			X				GP
129. Opus Pharmaceuticals (Pty) Ltd			X				GP
130. MC Pharma (Pty) Ltd			X				GP
131. Dr Reddy's Laboratories (Pty) Ltd			X				GP
132. National Druggist (Pty) Ltd			X				GP
133. P.V. Berry			X				GP
134. Medicine Developers International CC			X				GP
135. Austell Laboratories (Pty) Ltd			X				GP
136. Pharmaco Distribution (Pty) Ltd			X				GP
137. Procter & Gamble South Africa (Pty) Ltd			X				GP
138. Norgine (Pty) Ltd			X				GP
139. Norbrook Laboratories S.A. (Pty) Ltd			X				GP

140. Tshepo Pharmaceuticals (Pty) Ltd			X				GP
141. Galderma Laboratories S.A. (Pty) Ltd			X				GP
142. Axim Pharmaceuticals (Pty) Ltd			X				GP
143. Pharmachem Pharmaceuticals (Pty) Ltd			X				GP
144. Revision SA (Pty) Ltd			X				GP
145. Heel South Africa (Pty) Ltd			X				GP
146. Strides S.A. Pharmaceuticals (Pty) Ltd			X				GP
147. Biopure South Africa (Pty) Ltd			X				GP
148. Trinity Pharma (Pty) Ltd			X				GP
149. Qestmed (Pty) Ltd		X					GP
150. Reckitt Beckinser Pharmaceuticals (Pty) Ltd		X					GP
151. African Medicines (Pty) Ltd		X					GP
152. Equity Pharmaceutical (Pty) Ltd		X					GP
153. Alclin (Pty) Ltd		X					GP
Sub-population 2							
154. The Biovac Institute		X				X	WC
155. Anmaraté (Pty) Ltd		X	X				WC
156. Cipla Life Sciences		X	X	X			WC
157. Generix International SA (Pty) Ltd		X	X				WC
158. Group Laboratories South Africa (Pty) Ltd		X	X				WC
159. Astellas Pharma (Pty) Ltd		X	X				WC
160. Medpro Pharmaceutica (Pty) Ltd		X	X				WC
161. Pharma Dynamics (Pty)		X	X				WC
162. Orthomedics Pharmaceuticals (Pty) Ltd – CT (M)		X	X				WC
163. Bouwer Bartlett (Pty) Ltd		X	X				WC
164. M. Katovsky CC			X				WC
165. MeyerZall Laboratories (Pty) Ltd			X				WC
166. Pfizer Global Manufacturing, A Division Of Pfizer Laboratories (Pty) Ltd	X	X	X				WC
167. Pharmaceutical Enterprises (Pty) Ltd	X	X	X				WC
168. Barrs Pharmaceuticals (Pty) Ltd	X	X	X				WC
169. Vitalfarm (Pty) Ltd	X	X	X				WC
170. African Oxygen Ltd – Kuilsriver Process Operation Plant	X						WC
171. African Oxygen Ltd – George	X	X					WC
172. African Oxygen Ltd – Mosselbay	X	X					WC
173. iThemba LABS	X			X			WC

174. Herbal-Homeopathic (Pty) Ltd	X	X	X				WC
175. GlaxoSmithKline South Africa (Pty) Ltd		X	X				WC
176. Cipla Life Sciences		X	X	X			WC
177. Parceval Pharmaceuticals	X						WC
Sub-population 3							
178. Acorn Pharmaceuticals (Pty) Ltd	X			X	X		KZN
179. Bayer (Pty) Ltd Animal Health Division – Pietermaritzburg	X	X	X				KZN
180. Impilo Drugs (1966) (Pty) Ltd	X						KZN
181. National Bioproducts Institute	X	X	X				KZN
182. Allied Drug Company (Pty)	X	X	X				KZN
183. African Oxygen Ltd – Pietermaritzburg Process Operation Plant	X						KZN
184. African Oxygen Ltd – Maydon Wharf, Durban	X	X					KZN
185. GM Pharmaceuticals (Pty) Ltd	X	X					KZN
186. African Oxygen Ltd – NCP CO_2 Process Operations Plant – Umgeni	X	X					KZN
187. African Oxygen Ltd – Newcastle	X	X					KZN
188. Molecular Diagnostic Services (Pty) Ltd				X			KZN
189. Pharmacia South Africa (Pty) Ltd		X		X			KZN
190. Smith & Nephew Pharmaceuticals (Pty) Ltd		X		X			KZN
191. Hexal Pharma SA (Pty) Ltd		X	X				KZN
192. Resmed Healthcare		X	X				KZN
193. Gulf Drug Company (Pty) Ltd		X	X				KZN
194. Xeragen Laboratories (Pty) Ltd t/a Firstpharm Pharmaceuticals		X	X				KZN
195. Pfizer Laboratories (Pty) Ltd		X	X				KZN
196. Biochemical & Scientific Consultants CC				X			
Sub-population 4							
197. Bodene (Pty) Limited trading as Intramed	X	X	X				EC
198. Beta Pharmaceuticals CC		X	X				EC
199. African Oxygen Ltd – Port Elizabeth	X						EC
200. African Oxygen Ltd – East London	X	X					EC
201. Zedchem (Pty) Ltd	X	X					EC
202. Aspen Pharmacare East London (Pty) Ltd	X						EC
203. Mentholatum-SA			X				EC
204. Merck Pharmaceuticals Manufacturing (Pty) Ltd	X		X				EC

205. Pharmedica Laboratories (Pty) Ltd	X	X					EC
206. Pharmacare Limited	X	X	X				EC
207. Divpharm Manufacturing & Packaging – Longdale	X	X					EC
208. GR Pharmaceuticals (1967) (Pty) Ltd	X	X					EC
209. Ferlot Manufacturing and Packaging (Pty) Ltd	X						EC
Sub-population 5							
210. Centre for Quality Assurance of medicines				X			NW
211. Research Institute for Industrial Pharmacy				X			NW
212. Zydus Healthcare (Pty) Ltd			X				NW
213. Unichem SA (Pty) Ltd			X				NW
214. LeBasi Pharmaceuticals (Pty) Ltd			X				NW
Sub-population 6							
215. Micro Healthcare (Pty) Ltd	X	X	X				FS
216. African Oxygen Ltd – Bloemfontein	X	X					FS
217. South African National Control Laboratory for Biological Products				X			FS
Sub-population 7							
218. African Oxygen Ltd – Nelspruit	X						MP
Sub-population 8							
219. African Oxygen Ltd – Kimberley	X	X					NC

Appendix D

INTERVIEW PROTOCOL FOR EXPERT COMMENTATORS DRAWN FROM UNIVERSITIES

Background

The purpose of this research is to explore perspectives of private pharmaceutical firms operating in South Africa as they form linkages with specialized providers of technological knowledge and other inputs, such as universities.

The purpose of these interview questions is to explore the views and opinions of individuals, drawn from selected South African universities, regarding knowledge partnerships between universities and pharmaceutical companies. Consequently, the aim of the research is to investigate how and why pharmaceutical companies select and form linkages with universities as opposed to other sources of knowledge inputs, such as science councils. This stage of the research is a triangulation process that provides opinions that will be compared with those derived from earlier interviews with executives and managers from pharmaceutical companies.

The questions are directed at principal or chief researchers, laboratory managers, and senior researchers, clinical research investigators at university research departments and technology transfer offices at universities.

The interview, using these questions as a guide, should take approximately 30 - 45 minutes.

Thank you
Sechaba Bareetseng
Tel.: 012 841 2574
Cell: 082 332 8367
Email: sbareetseng@csir.co.za
These interview questions explore the perspectives of the universities regarding knowledge partnerships between universities and pharmaceutical companies in South Africa.

Search processes of pharmaceutical companies

1. In your opinion, how do pharmaceutical companies operating in South Africa perform the knowledge search function?

    - How is it organised?
    - Is it effective?
    - What are the typical sources of knowledge?

2. Do you have any sense of why pharmaceutical companies might select universities as opposed to other types of research performers such as science councils?

3. In your opinion, how do pharmaceutical companies go about finding out about the research that is being performed at universities or which technologies are available at different universities?

Selection criteria for choosing among knowledge providers

1. In your opinion, what criteria are used by pharmaceutical companies to select universities as compared to other knowledge providers, such as science councils?

2. What characteristics of universities facilitate being selected by pharmaceutical companies?

Types of linkages between pharmaceutical companies and knowledge providers

1. In your experience, which of these types of linkages do pharmaceutical companies seek from universities? For example, do pharmaceutical companies link with universities on-

    ■ *R&D contracts*
    ■ *Sponsored R&D*
    ■ *Student postgraduate research projects*
    ■ *Internships*
    ■ *Postgraduate Studentships*
    ■ *University consultancy*
    ■ *University commercial scientific research*
    ■ *Conferences*

2. What types of scientific knowledge outputs are most required by pharmaceutical companies? For instance, do pharmaceutical companies prefer knowledge in the form of basic research or packaged in commercial framework?

3. What types of knowledge flows take place between universities and pharmaceutical companies?

4. How do these knowledge flows influence the firms' innovation activities?

5. How important is the issue of cost-effective production of knowledge for pharmaceutical companies? How does this affect the likelihood of linkage with universities, as opposed to other knowledge production agencies, such as science councils?

Value

1. How has university scientific knowledge contributed to the value of pharmaceutical companies, for instance in terms of:

   (i) R&D and technology development activities; or
   (ii) innovation activity

N.B: The same interview questions were directed at expert commentators drawn from government departments and government knowledge generation institutions.

Appendix E: The general profile of the pharmaceutical firms that participated in the present study

Questions	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6	Company 7
What is the nature of your business	Manufacturing & Clinical research	Clinical research	Manufacturing & packaging	R&D	Manufacturing	Clinical research	Clinical research
Has your company collaborated with a university?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If yes, how many R&D collaboration agreements do you have?	4	22	1	3	10	65	20
What is the nature of your company's collaboration with universities	Internships & Postgraduate Student ships	Sponsored R&D	Student postgraduate research projects & University consultancy	R&D contracts	R&D contracts & Internships	R&D contracts	R&D Contracts Sponsored R&D & University consultancy
For how many years has your company been collaborating with universities?	10 years	15 years	10 years	12 years	10 years	20 years	20 years
Does your firm use university collaboration for technological development and innovation?	Yes	No	Yes	Yes	Yes	No	Yes
On how many R&D projects have you collaborated with universities?	5	22	4	6	20	40	No answer
To what extent has your company derived value from the collaboration?	High	High	Varies	High	High	High	High
How many patents has your company produced due to collaboration?	1	None	0	1	5	0	0
If you have not already done so, does your firm intends to enter into research collaboration with universities in the near future?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does your firm intend to enter into R&D collaboration with universities?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Does your firm engage in R&D in-house?	Continuously	Occasionally	Continuously	Continuously	Occasionally	Never	Continuously

Questions	Company 8	Company 9	Company 10	Company 11 (a)	Company 12 (b)	Company 13	Company 14
What is the nature of your business	Export Clinical research Quality control	Manufacturing	Clinical Research	Manufacturing	Manufacturing Export Import	Import Clinical Research Quality Control	Manufacturing Export (R&D)
Has your company collaborated with a university?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
If yes, how many R&D collaboration agreements do you have?	40	0	5	1	None	15	3
What is the nature of your company's collaboration with universities	R&D contracts Sponsored R&D Conferences	Postgraduate Studentships University consultancy	R&D contracts Sponsored R&D	R&D contracts, Internships, Postgraduate studentships, University consultancy	University consultancy	Sponsored R&D	R&D contracts Internships
For how many years has your company been collaborating with universities?	75 years	30 years	12 years	40 years	5 years	20 years	12 years
Does your firm use university collaboration for technological development and innovation?	Yes	No	No	No	No	No	Yes
On how many R&D projects have you collaborated with universities?	>100	Not sure	7	>10	None	30	Many
To what extent has your company derived value from the collaboration?	Crucial – helps with patient recruitment	Mainly intellectual value through collaboration	Gained expertise in the design of clinical trial protocols; access to patient population	Enable to bring new products to market; enhance skill base	Solving of production process through technical expertise	Success on clinical research; ability to deliver on patients for clinical research	Gained expertise and knowledge on registration to conduct clinical trials
How many patents has your company produced due to collaboration?	0	0	0	0	0	0	0
If you have not already done so, does your firm intends to enter into research collaboration with universities in the near future?	Yes	No	Yes	Yes	No	No	Yes
Does your firm intend to enter into R&D collaboration with universities?	Yes	No	Yes	Yes	Yes	No	Yes
Does your firm engage in R&D in-house?	Continuously	Continuously	Continuously	Occasionally	Never	Continuously	Continuously

Please note: 11 (a) and 12 (b) represent the same pharmaceutical firms

Questions	Company 15	Company 16	Company 17	Company 18	Company 19	Company 20
What is the nature of your business	Manufacturing	Export	Manufacturing Clinical research	Manufacturing Export Import Quality control Packaging	Manufacturing Import Clinical research	Import Distribution Research
Has your company collaborated with a university?	Yes	Yes	Yes	Yes	No	Yes
If yes, how many R&D collaboration agreements do you have?	No response	0	Many	1	No response	2
What is the nature of your company's collaboration with universities	Conferences	Postgraduate studentships	R&D contracts Sponsored R&D	Student postgraduate research projects, Postgraduate Studentships, University commercial scientific research, Conferences	No	Sponsored R&D, University commercial scientific research (Business support)
For how many years has your company been collaborating with universities?	7 years	30 years	17 years	5 years	N/A	5
Does your firm use university collaboration for technological development and innovation?	Yes	Yes	Yes	Yes	No	Yes
On how many R&D projects have you collaborated with universities?	N/A	Many	25 projects	1	No	5
To what extent has your company derived value from the collaboration?	N/A	Immense and immeasurable value	Helped to register drugs in South Africa	Were able to commercialise their research and filed patents	No response	No really
How many patents has your company produced due to collaboration?	N/A	0	0	15	0	0
If you have not already done so, does your firm intends to enter into research collaboration with universities in the near future?	No response	N/A	N/A	Yes	Yes	Unlikely
Does your firm intend to enter into R&D collaboration with universities?	N/A	Yes	N/A	Yes	Yes	No
Does your firm engage in R&D in-house?	Never	Occasionally	Continuously	Never	Continuously	Occasionally