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INTERORGANISATIONAL KNOWLEDGE FLOWS BETWEEN AND INNOVATIVE PERFORMANCE OF SCIENCE PARK FIRMS: AN EXPLORATORY STUDY OF SOUTH AFRICAN NEW TECHNOLOGY-BASED FIRMS

by

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Declaration

I declare that the thesis, which I hereby submit for the degree Philosophiae Doctor (Technology Management) at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at another University.

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Kai-Ying Alice Chan

Summary

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by

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The establishment of science parks is an important way of connecting technological innovation and economic development and such initiatives have shown success in many developed countries (for example, the Silicon Valley in the USA). In this research, science parks are regarded as spatially bounded infrastructures for facilitating and promoting knowledge flows between knowledge-intensive small and medium-sized technology-based firms. Policy makers in emerging economies, such as South Africa, have placed the development of science parks on their national system of innovation agendas.

Research problem and main question

The fast growth of science parks around the world has inspired many researchers to investigate the function and performance of science parks (SPs). Interestingly, mixed findings are reported on science park performance in the literature: some researchers found that SPs have benefits for the firms located on site; whereas other researchers doubt the benefits that SPs are claimed to have. This thesis aims to explain these mixed findings and proposes a relational approach to study the general view of interorganisational knowledge flows. The main research question to be answered is:

How can the mixed findings of previous research studies regarding innovative performances of science park firms be explained?

To answer the above over-arching research question, four subquestions were formulated and addressed in the Chapters 2 to 5:

- Chapter 2 answers the theoretical subquestion: *Which theoretical explanations can be given for the mixed findings regarding the performance of science park firms?*
- Chapter 3 answers empirical subquestion 1: *Which knowledge exchange behaviours do science park firms show?*
- Chapter 4 answers empirical subquestion 2: *If science park firms behave differently with regard to knowledge exchange, do these differences matter for the firms' performance?*
- Chapter 5 answers empirical subquestion 3: *How can the mixed findings be explained from an empirical point of view?*

Methodology

The Gauteng region in South Africa was chosen because it has the most innovative activities in the country. Moreover, the first internationally recognised science park, namely The Innovation Hub, is located in this region. The unit of analysis is at the firm level. A sample of 52 new technology-based firms (NTBFs) was interviewed by means of structured questionnaires. Twenty-four of them were NTBFs situated in The Innovation Hub and 28 were independent NTBFs not located on a science park, but still in the Gauteng region. The collected data were analysed by applying multivariate analytical techniques.

Main findings

The theoretical explanation of the mixed findings was proposed in Chapter 2. It was argued that:

The positive relationship between intended knowledge flows and innovative performance of firms will be negatively moderated by higher levels of unintended knowledge flows. This moderating effect is stronger for on-park firms than for off-park firms, due to the close geographical distance.

Although this theoretical explanation was not empirically confirmed in Chapter 5, it was found that there is some evidence that, for this set of South African firms, science park location (a geographical dimension) matters when one looks at the multi-dimensional aspects of innovative performance. Moreover, three empirical studies further explore the theoretical framework developed in Chapter 2 to address three topics: *knowledge exchange behaviours* (Chapter 3), *knowledge transfer effectiveness* (Chapter 4) and *knowledge transfers and innovative performances* (Chapter 5).

The study presented in Chapter 2 found the existence of two groups of firms located in The Innovation Hub (denoted as on-park firms): one group of on-park firms only interact with firms located outside the park (off-park firms); and one

group of firms interact with both other on-park firms and off-park firms. In other words, not all on-park firms are involved in knowledge transfer activities between one another. Some of them may be situated on the park only for the sake of their reputation. Chapters 4 and 5 reported several factors that matter for knowledge transfer effectiveness and innovative performance. To enhance knowledge transfer effectiveness two factors are of importance, namely frequency of knowledge transfer and technological similarity. For a firm to improve on its new innovative sales, two configurations of knowledge flows should be encouraged: intended knowledge inflows via informal network ties; and unintended knowledge inflows via informal and/or social network ties.

Despite the fact that this research did not empirically confirm the theoretical explanation of the mixed findings found in science park literature, some issues raised in the recommendation section of this thesis could account for the mixed findings, namely differences in the scanning processes of new entrant firms, the nature of networking activities, services provided by SP management teams, academic-industry links and configurations of knowledge flows. The findings and recommendations of this study may help policy makers to further improve the design and functioning of science parks in emerging economies.

Keywords

Science parks, NTBFs, interorganisational knowledge flows, innovative outcomes, emerging economies, regional system of innovation, South Africa.

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Chapter 1

Introduction

1.1 Setting the stage

Building economic strength is given top priority in most developing countries as one of the ways of improving the wealth standards of their citizens. The integration of technology and innovation into the development process plays an important role in creating a sustainable economy and has proven to be a success in many developed countries. Developing countries, in trying to catch up with the developed countries who have gained from their *knowledge-driven* economies by establishing regional or national systems of innovation, have started establishing their own systems of innovation. The establishment of science parks (SPs) is one of the important ways of connecting technological innovation and economic development, which are often integrated with the innovation systems of developed countries, especially in the West. SPs can be regarded as spatially bound infrastructures for facilitating and promoting knowledge flows between knowledge-intensive small and medium-sized technology-based firms. In other words, SPs provide these firms with a supportive environment in order to conduct innovative knowledge-based activities and thus improve their performance. Despite several successful stories about SPs and the benefits that SPs bring to their firms located on site (Felsenstein, 1994; Lindelöf and Löfsten, 2004), some researchers doubt the benefits that SPs claim to have (Westhead, 1997; Malairaja and Zawdie, 2008) to their on-site firms. From previous studies, a picture of mixed findings in terms of science park firm performances emerges. This thesis aims to explain the mixed findings regarding science park firm performances found in the SP literature (more details are reported in Chapter 5). In order to explain these mixed findings, this thesis proposes to study the general view of and the problems of interorganisational knowledge flows which are important aspects of a system of innovation.

In the next section, the concept of national system of innovation (NSI), which forms one of the backbones of this study, is discussed. The science park concept is rooted in the NSI literature. After the discussion of the NSI concept, the concept of SP is elaborated in terms of its definitions and its relation to a regional system of innovation in Section 1.3. Because the data used in this study was collected from firms located in Gauteng, South Africa (SA), a country with an emerging economy, the history and the state of the affairs of NSI implementations, as well as the technology and innovation situation in the SA economy and the Gauteng region in particular, are discussed in Section 1.4. With all the relevant concepts and the South African innovation background study in place, Section 1.5 will develop the main research question of this study and propose a relational approach with a resource-based view (RBV) as its theoretical basis. More details of the RBV and the theoretical relevance of this research are discussed in Section 1.6. The main research question is broken down into several subquestions in Section 1.7. This section will also discuss how each of the following chapters in the thesis relate to each subquestion. In this way, the coherence of this thesis will become clear. In the last section of this chapter, a discussion about the research contribution will be presented to show how this thesis is (together with the theoretical relevance as discussed in Section 1.6) practically and scientifically relevant.

1.2 National system of innovation and knowledge-driven economy

Governments often have used the National System of Innovation (NSI) framework to promote innovations and economic development (Lundvall, 2010). The NSI approach can be traced as far back as 1841, when Friedrich List proposed the concept of "national system of production" where he pointed out the need for a national infrastructure (to transport people and commodities) and institutions (including educational institutions) to promote "mental capital", which, in turn, boosts economic development. Later the concept of NSI was firstly published by Freeman in 1987, when he defined NSI as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies" (Freeman, 1987: 1). Subsequently, in 1992, Lundvall published

a book that was, according to Freeman (1995), "highly original and thought-provoking", entitled *National systems of innovation: towards a theory of innovation and interactive learning*. It is proposed in this book that an NSI should consist of elements and relationships that interact in the production, diffusion and use of new, and economically useful, knowledge (Lundvall, 1992: 2). The term *elements* can be regarded as "a set of institutions whose interactions determine the innovative performance of national firms" (Nelson, 1993: 4). On the other hand, *relationships*, as in "relationships between institutions", may be seen as "carriers of knowledge, and interaction as processes where new knowledge is produced and learnt" (Johnson et al., 2003: 5). As opposed to Freeman and Lundvall's broad understanding of NSIs, Mowery and Oxley (1995) narrowed these relationships to only the relationships "between R&D-efforts in firms, S&T-organisations, including universities, and public policy" (Muchie et al., 2003). These relationships closely resemble the Triple Helix concept where the changing relationships between universities, government and business are the focus. The Triple Helix concept is relevant to this study as it is strongly associated with the science park concept (which will be elaborated further in Section 1.3).

According to Godin's literature review, the concept of knowledge economy re-emerged in Lundvall's book on NSI (Godin, 2006: 18), where Lundvall proposes that "the most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning" (Lundvall, 1992: 1). He further elaborates on the process of learning and states that "the most important forms of learning may fundamentally be regarded as *interactive learning*" (Lundvall, 1992: 9). Interactive learning is a process where "the interaction with external actors determines a firm's access to a diversity of resources; and the learning enables firms to transform these resources into innovations" (Meeus et al., 2001: 146). In the innovation system, knowledge has tacit elements that are embodied in the minds of people, routines of firms and interactions between people and organisations (Dosi, 1999). For an economy to be knowledge-driven, it is vital that individuals and organisations should take part in an active and interactive learning during the different stages of the innovation processes (Johnson, Edquist and Lundvall, 2003).

Science parks are often used as government initiatives to indirectly facilitate interactive learning and to promote regional systems of innovation (RSI). As a subset of NSIs, RSIs are another geographical demarcation in the system of innovation approach. There are three possible reasons for regional or special boundaries in knowledge production and exchange: (a) "a minimum level of localised learning spill-overs (between organisations), which is often associated with the importance of transfer of tacit knowledge between (individual and) organisations"; (b) "localised mobility of skilled workers as carriers of knowledge, i.e. that the local labour market is important"; and (c) "a minimum proportion of the collaborations between organisations leading to innovations should be with partners within the region"…"i.e. the extent to which learning processes between organisations are interactive within regions" (Edquist, 2001: 14). RSI can be defined as a geographical system "in which firms and other organisations are systematically engaged in *interactive learning* through an institutional milieu characterised by embeddedness" (Cooke, 1998).

More details of the concept of science parks and their inhabitants, namely new technology-based firms, will be provided in the next section.

1.3 Science parks and new technology-based firms

As mentioned earlier, science parks (SPs) are often used by policy makers as initiatives to indirectly facilitate interactive learning and stimulate information and knowledge exchange between regional actors, and, in the long run, regional innovations and economic progress. A region is one of the entities providing firms with the requisite support for innovation because close geographical proximity, as shown in literature, facilitates the exchange of knowledge and interactive learning (Arundel, 2001; Boschma and Kloosterman, 2005; Baptista and Mendonça, 2009). In order to understand the role of SPs in a regional system of innovation, one first needs to know what SPs are all about.

Many definitions of a science park can be found in the literature. In 1986, the United Kingdom Science Park Association (UKSPA) defined a science park as a property-based initiative that:

(i) has formal operational links with a university or other higher educational or research institution;

(ii) is designed to encourage the formation and growth of knowledge-based businesses and other organisations normally resident on site; and

(iii) has a management function that is actively engaged in the transfer of technology and business skills to the organisations on site.

The Association of University-related Research Parks (AURRP) states in its Worldwide Research & Science Park Directory (1998) that the research and science park concept generally includes three components:

• A real estate development.
• An organisational programme of activities for technology transfer.
• A partnership between academic institutions, government and the private sector.

Westhead et al. (2000) define a science park as an area that allows an agglomeration of technological activities, leading to positive externality benefits to individual firms located in the park.

The website of the International Association of Science Parks (IASP) defines a SP as:

> "*A Science Park is an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities'*" (IASP website)

Based on the above definitions, one can see that some important general characteristics of SPs are that knowledge flows between technology-based firms that are spatially bounded, that there are industry-academic links, and that small technology-based firms are formed and supported. Drawing from the common characteristics shown in various definitions, science parks are viewed in this research as physical infrastructures (often initiated by governments) where small or medium innovation- or technology-based firms (see a next section for details) are situated within a spatial boundary. A SP is not another kind "office park", because there is a management team on site that supports the new technology-based firms (NTBFs) by encouraging innovative activities and a flow of knowledge between them.

In many SP studies, SPs are related to cluster theory and regarded as clusters. As Chan and Lau mention in their SP study, "high tech firms of similar characteristics and within the value chain would be attracted to cluster together in the science park and therefore, gradually emerge as a strong allied group complementary to each other" (Chan and Lau, 2005: 1217). However, SPs are not just ordinary clusters, they have a special characteristic, namely that they are adjacent to universities to promote higher education institute (HEI) and industry linkages and to foster knowledge transfer. This industry-academic link is important for transforming scientific knowledge into innovations and thus improving the economic growth in the region.

Moreover, as indicated in Doloreux's study about regional systems of innovation (RSI), the interactions, which can be regarded as flows of knowledge between learning firms in a cluster, "constitute the most important process driving the evolution and reinforcement of an RSI" (Doloreux, 2002: 247). In other words, the knowledge flows between NTBFs in an SP environment or from an SP to its region (knowledge spillovers) form an important element of RSIs. In the next paragraph, more particulars of NTBFs are provided.

New technology-based firms (NTBFs) situated on an SP possess certain characteristics that one needs to investigate to understand their contributions to the process of innovation. NTBFs can be seen as small high-technology firms

(Oakey 1994). Since the early 1970s, governments in advanced economies have recognised these small firms as key economic role-players in generating employment, introducing technological innovations and diffusing new technological knowledge (OECD, 1982; Johnson, 2007). Johnson points out that the small firms have close links with entrepreneurial activities. The term *entrepreneur* refers to the founder or owner of a small firm who is seen as a risk-taker and innovator (Hebert & Link, 2006; Johnson, 2007). This behaviour could possibly account for the radical innovations (which involve high levels of uncertainty) that are observed in small firms (OECD, 1982; Kirby, 2003). Like most small firms, NTBFs have the liability of being new and encounter two main problems: a lack of a large variety of different resources and a lack of external legitimacy (Singh, Tucker and House, 1986). Because the firms are young and new in the market, they have limited external linkages with key players or partners in the market and are thus less recognised. Small technology-based firms, especially those involved in high-tech developments, need *knowledge* resources, which are fundamental to technological innovations. Establishing linkages with partners can be regarded as a strategy to access sufficient knowledge for innovative activities. With the aim to facilitate knowledge circulation, the establishment of science parks provides NTBFs with opportunities to establish such linkages, due to their close geographical proximity with each other, and especially with adjacent universities where the fundamental knowledge resides.

1.4 The research context: South Africa and the Gauteng region

1.4.1 NSI in South Africa

South Africa is regarded as the most economically and technologically developed country on the African continent. However, it is a fact that a dramatic decrease in research and development (R&D) intensity since 1991 can be noticed (Mani, 2003). It was towards the end of apartheid in 1993 that an IDRC report entitled “Towards Science and Technology Policy for a Democratic South Africa” was commissioned by the soon-to-be new government, the African National Congress (ANC), which came into power in 1994. This report led to a Green Paper on

Science and Technology in 1996 and later a White Paper on Science and Technology, entitled "Preparing for the 21st Century", which constitutes the official science and technology policy of the country. In this document, "knowledge is valued as an important component of national development" and the NSI, as a framework in the national policy on science and technology, is described as a "means through which the country will seek to create, acquire, diffuse and put into practice new technology that will help the country and its people to achieve their individual and collective goals" (DACST, 1996). At that time, South Africa was the first developing country that used the NSI as a framework for promoting innovation in the nation, or as Lorentzen says, "an explicit anchor of its innovative endeavours" (Lorentzen, 2009: 33). However, criticisms were also noticed at the same time. In Kaplan's review study, he stated that the objectives outlined in the NSI policy could not be easily put forward into plans of action (Kaplan, 1999). Moreover, Lorentzen pointed out that the focus of the NSI was "on the policies and initiatives of the government and not on the private sector or any other constituents" (Lorentzen, 2009: 35).

Although a number of new South African government initiatives post-1994 had set a foundation for NSI, the Spatial Development Initiatives (SDI) programme, led by the Department of Trade and Industry (DTI), undoubtedly captured the most public attention because of its explicit spatial focus (Bloch, 2000) and its aim to fast-track private sector investment and stimulate the growth of SMMEs (Crush and Rogerson, 2001). The SDI was devised by the national government and has been implemented since 1996 as a short-term investment strategy aimed at unlocking economic potential in selected areas or zones of South Africa, inter alia, by developing the necessary infrastructure, implementing marketing and investment strategies, reducing bureaucratic red tape, and encouraging skills training and resource building (Rogerson, 1998; Crush and Rogerson, 2001). To support the SDI programme, the Gauteng Provincial Government established an initial R1.7 billion fund for ten mega-projects, named Blue-IQ projects, with the aim to build a platform for business of the future. Gauteng, as the region with the most innovative activities in South Africa (Lorentzen, 2008), will be discussed in the next section to show that it is an appropriate region in South Africa for any innovative policies to take place.

1.4.2 Gauteng and The Innovation Hub

In the 1970s, high-technology developments began in Midrand [1] and the Johannesburg-Pretoria (the two major cities in Gauteng) high-technology belt, which was identified in Hodge's study in 1997, started emerging. In Rogerson's study, the spatial distribution of high-technology industry in South Africa is illustrated by a figure revealing "an intense agglomeration of activity in the Gauteng province" (Rogerson, 1998). A recent study by Lorentzen shows that a regional innovation system possibly exists in Gauteng where it "seems to exploit diversified knowledge industries" (Lorentzen, 2008). The presence of such a system means that the necessary conditions to establish a science park have been met.

The Innovation Hub (TIH) was one of the Blue-IQ projects initiated by the Gauteng Provincial Government to invest in regional economic infrastructure development to create a truly smart province. TIH is South Africa's first internationally accredited science park and a full member of the International Association of Science Parks (IASP). It is regarded as "the catalyst that will spur the development of a new wave of knowledge-intensive, hi-tech industries in South Africa" (Foster, 2003: 13). It was officially opened at its new site in Pretoria in April 2005 as a high-tech cluster for knowledge-intensive companies. Anchor tenant company, SAPPI, moved into its building in January 2005. The Innovation Hub is located in Gauteng, between the Council for Scientific and Industrial Research (CSIR) and the Hatfield campus of the University of Pretoria. The 60 ha site, which is placed around 30 km from the OR Tambo International Airport, offers state-of-the-art ICT technology. Its focus sectors are advanced engineering (value-added materials and manufacturing and defence technology spin-offs), biotechnology and ICT. These focus areas are aligned with the recommendations of the previous technology foresight project conducted by the SA government. The Innovation Hub focuses on clustering high-tech businesses to foster innovation and drive the development of

[1] Midrand lies in between two urban cities, Johannesburg and Pretoria, in Gauteng. Midrand was considered to have a "'disproportionately large share of South Africa's private and public demand, as well as factor inputs for high-technology sectors" (Hodge, 1998: 851). Moreover, the dynamic information technology and high technology manufacturing activities have brought Midrand vibrant economic growth (Rogerson 1998). Now, Midrand is no longer a separate entity, but is incorporated into Greater Johannesburg.

new intellectual property, which will add significant value to Gauteng as the country's "smart" province and to South Africa as a competitive economy in the high-tech sector.

1.5 Research goal and main research question

Despite the rapid growth in the number of science parks, researchers have often asked the question: Do science parks really perform as promised? With this question in mind, researchers in the past have done comparative studies (between on- and off-park firms) at firm level and analysed firm characteristics and their innovative performances as the main foci. This research reviews the SP literature and reports that there are mixed findings in the studies regarding the performances of science park firms (details in Chapter 4 of the thesis). The question that forms the main research question in this study is further raised:

How can the mixed findings found in previous research studies regarding the innovative performance of science park firms be explained?

With this main research question in mind, the research goal is to find alternative theoretical and empirical ways to examine technology-based firms and their innovative outcomes. Discussions about the concepts of NSI, RSI, knowledge-based economy and science parks all focus on *knowledge* and *relationships* between elements, institutions and firms. This guided the research to adopt a theoretical perspective emphasising a relational approach to answer the research question. The relational approach here is regarded as the interorganisational relations that exist in *knowledge* networks of social relations. Both relational (characteristics of relationships) and structural (characteristics of the relational structure) aspects of these networks will provide insights into how firms exchange knowledge with one another and which effects will emerge. As Gulati mentions, relational aspects of a network "stress the role of direct cohesive ties as a mechanism for gaining fine-grained information", typically with actors who are "strongly tied to each other and likely to develop a shared understanding of the utility of certain behaviour as a result

of discussing opinions in strong, socializing relations" (Gulati, 1998: 296). On the other hand, the structural aspects of a network allow one to observe the degree (for example, the number of relationships with others) to which an actor does have access to resources. Resources in this study refer to *knowledge,* which is a very important resource for any innovative firm. In the literature, the resource-based view (RBV) is often been used to explain the differences between firms' performances, which causes this theoretical perspective to be important when studying the performance differences of science park firms. Lavie (2006) has *extended* the RBV by including the "relational approach" in his *extended* version of the RBV. This research project will take the extended RBV as its theoretical backbone, which will be elaborated further in the next section.

1.6 Theoretical background: the resource-based view of the firm

Until the 1980s, the resources of a firm were regarded as the tangible (for example, machinery and personnel) and intangible (for example, knowledge and brand names) assets a firm possesses (Caves, 1980). The resource-based view (RBV) model is often used to explain the differences in performances between firms: "performance differentials are viewed as derived from rent differentials, attributable to resources having intrinsically different levels of efficiency […] in the sense that they enable the firms […] to deliver greater benefits to their customers for a given cost (or can deliver the same benefit levels for a lower cost)" (Peteraf and Barney, 2003: 311). In this statement, *rents* refer to earnings in excess of breakeven if their existence does not induce new competition (Peteraf, 1993). Resources in RBV are regarded to be heterogeneous (unique) and imperfectly mobile (nontradable), and firms often design *resource-position barriers* such as patents (Wernerfelt, 1984). These characteristics enable firms to protect their internal resources to some extent against imitation by competitors (Reed and DeFillippi, 1990; Lavie, 2006). The fundamental principle in RBV is that if a firm has the ownership and control of its *internal resources*, it has a competitive advantage (Lavie, 2006). In most of the RBV studies, there is a strong association between a firm's internal resource and its performance. For example, in

Bharadwaj's empirical study, there is a positive and significant relationship between firms' IT capabilities as their internal resources, and their performances (Bharadwaj, 2000).

The conventional RBV introduced above does not take into account the "superior resources of alliance partners" when a focal firm is involved in inter-firm interactions. These resources are referred to as *network* or *external resources*, which are also of importance in this study, as the focus is on the impacts of relationships and knowledge flows between organisations located in science parks.

In Lavie's study (2006), a theoretical framework is developed with the aim of extending the RBV by taking into account the *inter-firm relationships* aspects. As opposed to the conventional RBV, where resources are imperfectly mobile, Lavie points out that resources can be directly shared between independent actors and that the benefits associated with these resources can be indirectly transferred between firms. In his so-called extended RBV model, where a firm shares resources with its partner, it can gain additional two types of rents (besides its own internal rent from its internal resources): *appropriated relational rent* from the shared resources and *inbound spillover rent* from both the shared and the non-shared resources. Appropriate relational rent is a common benefit from the idiosyncratic resources which are created by combining the respective resources of the partner firms or developed during the life of their alliance. These idiosyncratic resources are "more valuable, rare, and difficult to imitate than they have been before they were combined" (Dyer and Singh, 1998: 667). Idiosyncratic resources can both be tangible, for example, a joint manufacturing facility, or intangible, such as a more efficient process when two partners work together (Hunt, 2000). Inbound spillover rent is the "unintended gains" (in the condition when one acts "opportunistically") due to both the shared and non-shared resources of the alliance partners. Later in the thesis, this is identified as the "unintended knowledge flows" between organisations. These two resources are the "superior resources" (and additional resources) when a firm is involved in an alliance with its partners. RBV believes that the more (unique) resources a firm possesses, the more successfully it will perform.

If one wishes to apply Lavie's model in a SP context (where firms are geographically concentrated in a limited space), the geographical dimension is missing in the model. The theoretical relevance of this study is to add *geographical dimension* to Lavie's model, "extension of the RBV". Geographical proximity is required as an additional dimension because the establishment of science parks around the world is built on the assumption of the importance of geographical boundaries where they play a role in the relationship between SP firms and knowledge transfer among firms. For example, close geographical distance between two partnering firms may enhance the *appropriated relational rent* from the shared resources that these firms control. This may be due to the fact that when two R&D researchers are located next door to each other, they are able to spend more time (due to lower travelling cost) on face-to-face interaction where tacit knowledge can be gained via interactive learning and as a result bring benefits for both companies' innovative activities. In Chapter 2, in particular, the relationship between innovation and geography is discussed in more depth.

1.7 Research subquestions and layout of the thesis

The focus of this thesis is on explaining the mixed findings found in the science park literature by following a relational approach to investigate inter-firm knowledge networks. With the relational approach in mind, the main research question is broken down into several subquestions. The chapters that follow are targeted to answer these subquestions. Chapter 2 is a theoretical study that positions the whole research by giving a theoretical overview of the factors that influence firms' innovative outcomes, using a knowledge flow perspective. The main argument developed is that the mixed findings may be due to the combined effects of intended and unintended knowledge flows. Therefore, this chapter answers the theoretical subquestion:

Which theoretical explanation can be given for the mixed findings regarding the performance of science park firms?

Using the theoretical framework developed in Chapter 2, chapters 3 to 5 empirically examine some models and answer three empirical subquestions. Chapter 3 is a descriptive and empirical study that aims to answer the empirical question:

Which knowledge exchange behaviours do science park firms show?

In order to answer this question, Chapter 3 investigates how science park firms behave with respect to each of the factors identified in the theoretical framework in Chapter 2. Therefore, this part of the study focuses on a diagnosis of knowledge flows between a specific group of firms, namely firms located in a science park (The Innovation Hub in South Africa). The results of this chapter show that firms behave differently with regard to knowledge exchange. Taking the results found in Chapter 3 into account, the next empirical subquestion is raised:

If science park firms behave differently with regard to knowledge exchange, do these differences matter for firm performance?

The above question is answered empirically in Chapter 4 by taking a sample of firms located in the South African Gauteng region and it is investigated to what extent certain behaviours affect certain innovation outcomes of firms. This chapter focuses on the *usefulness of knowledge received* as the variable to be explained. The findings in this chapter show that there are different factors that impact on this dependent variable:

- Organisational similarity is negatively related to usefulness of knowledge received.
- Technological similarity is positively related to usefulness of knowledge received.
- Frequency of knowledge transfer is positively related to usefulness of knowledge received.

Chapter 4 shows that differences in firm behaviours when they exchange knowledge do matter for firms' outcomes or performances. This finding inspired the following empirical subquestion:

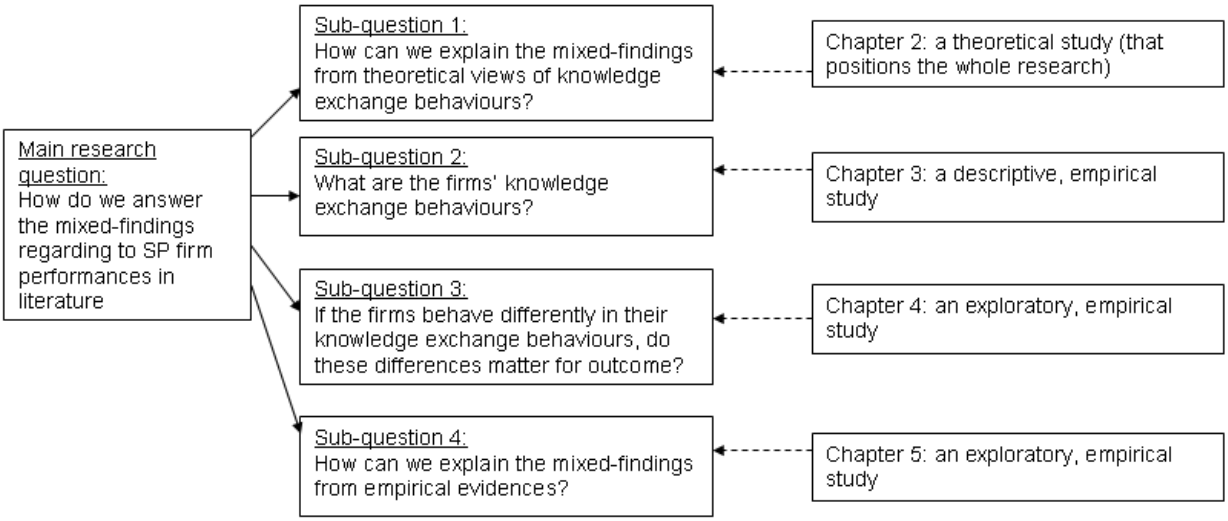
How can the mixed findings be explained from an empirical point of view?

Chapter 5 is an empirical study that takes the same sample of firms again and tries to explain the mixed findings. The findings of this study show that various types of knowledge inflows impact differently on various innovative outcomes:

- Intended knowledge inflows via formal interorganisational relationships have a positive impact on firms' relative innovations.
- Intended knowledge inflows via informal interorganisational relationships have a positive impact on firms' new innovations.
- Intended knowledge inflows via social network relationships have a negative impact on firms' new innovations.
- Unintended knowledge inflows (when a firm is involved in informal and/or social networks) have a positive impact on firms' new innovations.

Figure 1 shows the coherence of this study with the main research question as the guiding principle. In addition, Appendix 1 shows the variables identified in Chapter 2 and how these variables will be empirically examined in chapters 3 to 5 (which are published or submitted journal papers). This appendix will help to guide the readers to the overview of the research while reading each chapter.

Figure 1: Coherence of the study: research questions and related chapters



The last chapter, Chapter 6, is a concluding chapter that will summarise the findings in chapters 2 to 5 and propose an answer to the main research question. The implications of the findings, the limitations of this study, and recommendations for future research will be addressed in this concluding chapter.

1.8 Research contributions

At the end of each individual chapter, there is a description of how that specific chapter contributes to the research. However, the overall practical relevance of this study is that it enables South African policy makers to better understand the implication of science parks in its NSI. Recommendations for policy makers are discussed at the end of the empirical studies (chapters 3 to 5) so that they can assist the design or support initiatives regarding science park establishments. As for the scientific relevance, this research explores the SP performances in the literature and finds mixed findings with regard to SP firm performances (details in Chapter 5). The main contribution of this study is to explain these mixed findings

theoretically and empirically. Moreover, this study increases insight in the performance of SP firms in the emerging economy of South Africa.

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Chapter 2

Explaining mixed results on science parks' performance: bright and dark sides of the effects of interorganisational knowledge transfer relationships[2]

In the recent past, several researchers have explored the added values of science parks. On the basis of empirical research, some questioned the assumed benefits of the science park model, whereas others reported positive outcomes. As a result, mixed findings regarding the benefits of science parks for firms can be observed. These mixed empirical findings ask for a theoretical explanation. This study argues that different levels and types of knowledge exchange behaviour of science park firms could be one of the theoretical explanations for these mixed findings. The literature on networks mainly stresses the benefits of networking in general, and networking between firms located on science parks in particular. This study proposes that networks can have both positive (knowledge sharing) and negative effects (opportunistic behavior and knowledge spillovers) for firms located on science parks. When the latter occurs, location on a science park might produce negative effects. A conceptual model is developed that summarises the theoretical arguments.

2.1 Introduction

The majority of the currently existing science parks in the world were created during the 1990s and about 18% of the existing science parks were launched in the first two years of the new century. This rapid growth of science parks attracted the interest of many researchers to undertake studies of science parks (for example, Bigliardi et al, 2006; Goldstein and Luger, 1990 & 1991; Löfsten and

[2] This chapter has been published in a slightly different format as Chan, K.Y., Oerlemans, L.A.G. and Pretorius, M.W., 2009. Explaining mixed results on science park performance: bright and dark sides of the effects of interorganisational knowledge transfer relationships. *South African Journal of Industrial Engineering*, 20(2), 53-67.

Lindelöf, 2003; Westhead and Batstone, 1999). In the recent past, several researchers explored the added values of science parks (for example, Löfsten and Lindelöf, 2003; Ferguson and Olofsson, 2004; Fukugawa, 2006) by exploring the characteristics and performance of firms located on and outside science parks. These researchers showed that science parks provide an important resource network for on-park new technology-based firms (NTBFs) and that on-park NTBFs are likely to establish knowledge linkages.

However, other researchers questioned the assumed benefits of the science park model (for example, Chan and Lau, 2005; Quintas and Massey, 1992; Westhead, 1997) and found in their studies that firms do not gain any benefits from networking and clustering or from the linkages between academic research and industrial activity. How can these different empirical findings be explained from a theoretical point of view? This study tries to answer this main research question and proposes that knowledge flows in networks can have both positive and negative effects for firms located on them. It distinguishes knowledge flows between organisations as "intended" and "unintended". The effects of both types of knowledge flows are combined with geographical and technological proximity. From the literature, two contrasting views can be derived of the effects of this specific combination. Alcacer and Zhao found that firms try to prevent the risk of unintended knowledge outflow by locating themselves further away from their competitors with similar technological backgrounds and in similar industries (Alcacer and Zhao, 2007). This implies that by clustering firms together (as on a science park) the probability of unintended knowledge flow is higher and thus the firms with leading technologies will, if possible, move further away from their competitors to prevent their technology being spillovered to them. On the other hand, the main purpose of science park location is to aggregate firms in related industries and supporting organisations (that is, to create high geographical proximity) so that they are able to collaborate in research, thereby facilitating intended knowledge exchanges. These contrasting views create a gap in the literature and lead to the main hypothesis of this study: “The positive relationship between intended knowledge flows and innovative performance of firms will be negatively moderated by higher levels of unintended knowledge flows. This moderating effect is stronger for on-park firms than for off-park firms”. To formulate

an answer to the main research question, the following research subquestions are formulated:

1. What are the effects of intended interorganisational knowledge transfer on the innovative performance of firms located on and off science parks?
2. What is the effect of unintended interorganisational knowledge flow (knowledge spillover) on the innovative performance of firms located on and off science parks?

The aim of this study is to theoretically reconcile the mixed results found in empirical research on science park performance. Moreover, it proposes a research model with which the propositions developed in this study can be tested empirically. The remainder of this study is structured as follows. Section two gives a brief background of the development of science parks around the world and their characteristics that form the focus of this study. Section three unfolds the literature of networks and knowledge flows with respect to innovations. Several propositions are formed to build the theoretical model of this study. The final section will conclude this study.

2.2 Science parks: history of development, definition and characteristics

2.2.1 History of development of science parks

Science parks are not a new phenomenon. The first science-based park, Standford Industrial Park (later resulting in the development of Silicon Valley), was established in 1951 in the USA. In 1972, Cambridge Science Park was established in the UK. The majority of the currently existing science and technology parks in the world were created during the 1990s and 18% of the existing science parks have been launched in the first two years of the new century (IASP website). The Association of University Research Parks (AURP) reports that there are 123 university-based science parks in the United States (Link & Link, 2003). The UK Science Park Association (UKSPA) reported that there were 32 science parks in

the UK in 1989 and 46 in 1999. In Asia, there are more than 200 science parks, with Japan topping the list with 111 initiatives. Currently, there are over 400 science parks in the world and the number continues to grow rapidly due to regionally targeted initiatives introduced by governments and other organisations to provide an appropriate physical infrastructure for a successful local economy and social environment (Löfsten and Lindelöf, 2002).

2.2.2 Definitions of science parks

As early as 1986, the UKSPA defined a science park as a property-based initiative that:

(i) has formal operational links with a university or other higher educational or research institution;
(ii) is designed to encourage the formation and growth of knowledge-based businesses and other organisations normally resident on site; and
(iii) has a management function that is actively engaged in the transfer of technology and business skills to the organisations on site.

Later, another science park association, the Association of University Related Research Parks (AURRP), stated in its Worldwide Research & Science Park Directory in 1998:

"The definition of a research or science park differs almost as widely as the individual parks themselves. However, the research and science park concept generally includes three components:

(i) A real estate development.
(ii) An organisational program of activities for technology transfer.
(iii) A partnership between academic institutions, government and the private sector."

A more recent visit to the website of the International Association of Science Parks (IASP) reveals that its official definition of a science park is as follows:

> *"A Science Park is an organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities."* (IASP website)

Even though there are several definitions and an absence of a generally accepted definition for the term *science park*, these definitions outline the important aspects of a science park such as links with universities, a management function in a science park, a knowledge-sharing environment to encourage innovations and the creation of spin-off companies. In this study, science parks are defined using the IASP's definition, as it includes most of the aspects of a science park.

2.2.3 Characteristics of science parks

The subject of science parks has generated a vast amount of literature and various aspects of science parks' characteristics have been researched. These characteristics include:

2.2.3.1 Clustering

High-tech firms with similar characteristics (sharing a common market for their end products, using a similar technology or labour force skills, requiring similar natural resources, etc.) and/or within the same value chain (linked by buyer-seller relationships) would be attracted to cluster together as a strong allied group to

complement each other (Chan and Lau, 2005). This phenomenon can be seen on science parks, which are supposed to be a geographically concentrated cluster of independent firms that are technology-related and knowledge-based and supported by other organisations. Through this clustering, firms have a degree of geographical proximity, which facilitates knowledge flows. Studies have shown that maximum flow of information and ideas exists among geographically proximate firms (Gordon and McCann, 2000) because this type of proximity supports the learning process through networking and thus positively influences the innovative outputs of firms (Romijn and Albu, 2002).

2.2.3.2 Academic-industry link

The transformation of scientific knowledge into technological innovation lies within the core of science parks (Quintas and Massey, 1992; Phillimore, 1999), thus a host academic institution (mainly HEIs) is often formally associated with a park. This academic-industry link can take many forms (Quintas and Massey, 1992; Monck et al., 1988):

- The transfer of people, including founder-members of firms, key personnel and staff, to employment in firms.
- The transfer of knowledge through collaborations with researchers and students of HEIs.
- Contract development, design, analysis, testing, evaluation, etc.
- Access to university facilities.
- The establishment of "academic spin-off firms", formed by academic staff taking research out of the laboratory and into the science park, starting their own commercial enterprises.

The presence of HEIs often improves the prestige or image of science parks and is often a major factor in a firm's choice to locate in a science park (Monck et al., 1988; Westhead and Batstone, 1998). The contribution by HEIs has set the science park apart from other property initiatives and also helps to raise rental values.

2.2.3.3 Management function

From the UKSPA's definition of a science park it follows that it has a management function that is actively engaged in facilitating the transfer of technology and business skills to the organisations on site. Johannisson (1994) further explains a science park's management function as a formal administrative structure to manage the property on the park and/or to manage the delivery of auxiliary activities and professional services required by firms located on science parks, with a focus on channelling information and resources to the on-park firms (Westhead and Batstone, 1999) by providing internal networking services between on-park firms and HEIs and external networking services with customers, collaborators and potential investors (Von Zedtwitz and Grimaldi, 2006). A managed science park is considered to have a general full-time manager or management company on site whose principal task is to manage the park. As a concluding statement, Westhead and Batstone point out that science parks generally need to strengthen their managerial functions with an emphasis on developing an effective way of linking tenant firms to the facilities and resources provided by a local HEI (Westhead and Batstone, 1999).

2.2.3.4 Knowledge flows

Firms located on science parks are bound in space and therefore more geographical proximate than rival firms located elsewhere. This spatial agglomeration promotes the transmission of knowledge, due to lower costs of communication in a dense environment. Researchers have distinguished two categories of knowledge transmission: intended and unintended knowledge flows (Fallah and Ibrahim, 2004; Oerlemans and Meeus, 2005). If knowledge is exchanged with the intended people or organisations, it is "knowledge transfer", while any knowledge that is exchanged unwillingly and outside the intended boundary is "knowledge spillover". When firms form networks (formal as via collaboration or informal as via social networking) on science parks, knowledge

exchange occurs via these direct connections (Cross and Cummings, 2004; Mowery et al., 1996). Economists have been studying "knowledge spillovers", as firms investing in research and development end up facilitating other firms' innovations by revealing their knowledge unintentionally (Arrow, 1962; Nelson, 1959). A firm can access unintended knowledge in various ways, such as knowledge from reverse engineering on rivals' innovative products or knowledge from patent information.

These science park characteristics enable the construction of the theoretical framework that is presented in the following section.

2.3 Theoretical framework and conceptual model

2.3.1 Knowledge transfer networks

In the literature, there is a common emphasis on the importance of interorganisational networks and networking for innovation through the external acquisition of knowledge and information (Cowan and Jonard, 2004; Kingsley and Malecki, 2004; Pittaway et al., 2004). Many aspects of networks have been studied, but for the purpose of this study, the emphasis is on pursuing networking for profiting from intended knowledge flows. Two levels of analysis can be seen in network studies: whole networks and egocentric networks. At the whole network level, the entire set of present and absent linkages between firms needs to be examined. For this study, it is assumed that the boundary of the network of science park firms is difficult to determine because on-park firms can also have many links with firms off-park and the network structure of this latter group of firms is hard to determine. Therefore, the so-called egocentric network level is chosen for this study because this approach considers only the direct linkages ("alters") of a given (science park) firm ("ego"), and, operationally, this usually relies entirely on ego's self-reports about its network. To build the argument, three concepts are used: degree centrality, tie characteristics (trust, proximities and knowledge

quality) and diversity of actors, and relate these to knowledge transfer and innovation.

2.3.1.1 Number of interorganisational knowledge transfer relationships and innovation

During the 1990s, innovation became faster and increasingly involved interorganisational networking (Rothwell, 1992). Through networking, firms are able to access knowledge externally from other actors and develop their own innovations. When firms interact formally (by explicit agreement) or informally (on a social basis), knowledge sharing often occurs and the resultant knowledge is available to partners. Evidence from the literature illustrates that "those firms which do not co-operate and which do not formally or informally exchange knowledge, limit their knowledge base over the long term and ultimately reduce their ability to enter into exchange relationships" (Pittaway et al., 2004). Network position, such as centrality, is an important aspect of the network structure because it determines the degree to which an actor has access to resources throughout the network. Centrality as a type of network position indicates the involvement of an actor in the network; the more a firm is involved in its network, the more it can compare information across multiple information sources and discover new information. More central firms are less likely to miss any vital information and are able to combine information in novel ways to generate innovations (Van de Ven, 1986). Various studies have shown that centrality is highly associated with innovation and enhances firm performance (Bell, 2005; Powell et al., 1999; Zaheer and Bell, 2005). This leads to the first proposition.

Proposition 1: The more direct ties a firm maintains, the higher the firm's innovative performance.

While most researchers pay attention to network structures (for example, Ahuja, 2000; Chang, 2003; Cheuk, 2007; Sparrowe et al., 2001), some researchers argued that the characteristics of ties within networks cannot be neglected, as they also influence the performance of actors (for example, Cross and Cummings,

2004; Granovetter, 1983; Newell and Swan, 2000). Ties are connections between nodes. In this case, the nodes are organisations and the connection is the interactions between them that make knowledge transfer possible. As mentioned earlier, some researchers have focused more on the dynamics of ties/relations than on their structural configuration. Various aspects of ties dynamics can be considered, such as purpose, direction, content and strength (Lin, 2002). This study focuses on knowledge as the tie content and therefore the purpose of a tie is aimed at knowledge sharing for innovations. The other two dynamics of ties, strength (associated with trust and proximity) and contents (quality of knowledge flowing in the tie), need to be explored as well to fully understand the characteristics of a tie.

2.3.1.2 Trust, interorganisational knowledge transfer and innovation

The willingness of organisations to exchange knowledge and information is often associated with tie strength (Cross and Sproull, 2004; Hansen, 1999) and studies have identified trust between partners in interorganisational relationships as an important relational asset (Storper, 1997) that promotes the willing exchange of knowledge. Trust can be defined as "the judgment one makes on the basis of one's past interactions with others that they will seek to act in ways that favour one's interests, rather than harm them" (Lorenz, 1999). From this definition it can be concluded that having trust can minimise the risks that stem from exposure to opportunistic behaviour by partners. Through past interactions, organisational members are more involved emotionally with each other and eventually trust is built between them. This form of trust is often called the "intentions" form of trust (Lazaric and Lorenz, 1998) because it refers to the belief that partners intend to uphold the commitments they make. Another form of trust is "competence-based trust", which refers to the belief the partners have in their capabilities to meet joint commitments. In this study, trust refers to the belief that a partner is capable (competence form of trust) of providing the knowledge a firm needs for innovations as well as the belief that a partner is willing to share such knowledge for the mutual benefit of all parties (intentions for trust). Therefore, the higher these trust levels, the more willing actors are to exchange knowledge and information. As a

result of this exchange, actors can increase their innovative performance. Based on the above discussions, the following hypothesis is developed:

Proposition 2: The higher the level of trust a firm has with its actors, the better the firm's innovative performance.

2.3.1.3 Proximities, interorganisational knowledge transfer and innovation

Gertler states that "recent work on innovation and technology implementation suggests the importance of closeness between collaborating parties for the successful development and adoption of new technologies" (Gertler, 1995). In the literature this closeness between organisational actors is also known as the "proximity" concept, which refers to "being close to something measured on a certain dimension"" (Knoben and Oerlemans, 2008). Scholars distinguish various dimensions of proximity and most of the time their definitions overlap. Following Knoben and Oerlemans' literature review, this study uses three dimensions of proximity and relates these with knowledge transfer and innovation.

In the study of innovation and knowledge transfer, there is an emphasis on the importance of geographical proximity for the transfer of (tacit) knowledge. The concept is often defined as geographical distance expressed as a specified radius of each firm (Orlando, 2000) or travel times/perception of this distance (Boschma, 2005). A short distance between two actors facilitates knowledge sharing and the transfer of tacit knowledge, in particular. Tacit knowledge transfer is enhanced through face-to-face contact and therefore the spatial dimension is essential.

Proposition 3(a): The greater the geographical proximity of innovative firms in relation to their partners, the higher the innovative performance will be.

The concept of proximity goes beyond geographical distance. Researchers, for example, Freel (2003), Boschma (2005), and Knoben and Oerlemans (2006), maintain that the concept of proximity is not only a spatial phenomenon. Geographical proximity is often combined with some level of cognitive proximity for

interactive learning to take place. Cognitive or technological proximity can be understood in terms of a shared knowledge base in order for two networking firms to communicate, understand, absorb and process new information (Boschma, 2005). Two firms may be located next to each other, but if their knowledge bases are too distant, so that people cannot understand each other, geographical proximity does not matter for effective knowledge transfer. This suggests that cognitive proximity may be a condition that makes geographical proximity less important. In addition, geographical proximity is influenced by the nature of innovation. Innovations that need very special or scarce knowledge may force firms to collaborate with international partners because such knowledge cannot be found locally (Arndt and Sternberg, 2000). In this case, where two firms are located in two different countries, other dimensions of proximity play a more important role than geographical proximity.

Technological proximity refers to the similarities between actors' technological knowledge, in other words, how similar the knowledge bases are between them. The transfer of unrelated knowledge can cause difficulties in the assimilation and application of the knowledge (Cassiman et al., 2005) because the firm that receives the knowledge is not capable of identifying, assimilating and exploiting knowledge coming from external sources (relative absorptive capacity, as defined by Lane and Lubatkin, 1998). On the other hand, the novelty of sources triggers new ideas and creativity (Cohendet and Llernea, 1997). Nooteboom et al. (2007) state that the interaction between people with different knowledge bases allow them to stretch their knowledge. Moreover, when two firms have identical knowledge bases, they may face the risk of lock-in, where their view of technology may be obscured and is less open to the outside world (Boschma, 2005). With this notion, Proposition 3(b) now reads as follows:

Proposition 3(b): There is an inverted U-shaped relationship between technological proximity and firm innovative performances.

The third dimension of proximity refers to "organisational proximity". In Knoben and Oerlemans' paper (based on Rallet and Torre, 1999), organisational proximity is defined as *"the set of routines – explicit or implicit – which allows coordination*

without having to define beforehand how to do so. The set of routines incorporates organisational structure, organisational culture, performance measurements systems, language and so on". Collaborating firms that have low organisational proximity have different sets of routines and thus, instead of creating innovations together, they create problems due to these non-overlapping routines. As a worst-case scenario, an unsuccessful collaboration leads to no innovative outputs. Based on the discussion above, geographical, technological, and organisational proximity between firms enhances the ease with which firms collaborate in general, and exchange knowledge in particular. Consequently, firms can increase their innovation outcomes and consequently the next proposition is formulated.

Proposition 3(c): The greater the organisational proximity of innovative firms in relation to their partners, the higher the innovative performance will be.

2.3.1.4 Qualities of knowledge exchanged and innovation

Soo and Devinney's paper found a positive relationship between knowledge quality and innovative performance (Soo and Devinney, 2004). The quality of knowledge exchanged comprises two factors: usefulness of the knowledge that a firm receives for its innovations and how frequently it receives the knowledge. The context of the knowledge a firm receives directly influences the success of the innovative outcomes if the firm can actually use such knowledge. The knowledge can be new to the receiving firm, but if it cannot be used and contribute to the firm's development of new innovations, then such knowledge has a low knowledge quality for the firm. The frequency of receiving knowledge (knowledge transfer) is also a dimension of the quality of the knowledge because more frequent communication can lead to more effective communication (Reagans and McEvily, 2003). With frequent communication, the receiving firm can better understand the knowledge it receives and the chances are increased that the knowledge is useful for the firm's innovations. Audretsch and Feldman (2004) mention in their study that the marginal cost of transmitting knowledge, especially tacit knowledge, is lowest with frequent social interaction, observation and communication. This leads to the fourth proposition, namely the following:

Proposition 4: The higher the usability of the acquired knowledge and the higher the communication frequency, the better the innovative performance of firms.

2.3.1.5 Diversity of network actors

Many innovators derive their ideas from a diverse set of actors because these provide diverse and non-redundant ideas which are a source of novelty that can trigger new ideas and creativity in the knowledge-acquiring firm. Actors who interact with partners from diverse communities of practice will be able to convey more complex ideas than those individuals who are limited to interactions with a single body of knowledge (Reagans and McEvily, 2003). A diversity of actors in a network is important for innovation because it is not only the size of the network that maximises information, but also those actors found in networks composed of firms with different, but complementary knowledge (Gulati and Gargiulo, 1999; Staber, 2001; Uzzi, 1999). Knowledge building and innovation often require dissimilar, complementary bodies of knowledge from diverse actors (Cohendet and Llerena, 1997). Diversity is defined here as "multiple sources of knowledge such as competitors, customers, suppliers, HEI, etc. that a firm has"[3]. The relationship between diversity and innovation is formulated as follows:

Proposition 5: The higher the diversity of actors that a firm has in its ego network, the better its innovative performance.

The propositions developed so far basically stress the positive sides of interorganisational knowledge exchange relationships and networks for innovating firms in general, and for firms located on science parks in particular. Interorganisational networks enable innovating firms to mobilise, coordinate and combine knowledge resources. Provided that firms have the ability to process the acquired knowledge (see the section below on absorptive capacity),

[3] In this study, the measurement of technological proximity refers to the dyadic level (the distance between two actors), where diversity refers to the portfolio of ties with actors a firm has. In other words, technological proximity refers to a characteristic of one tie, whereas diversity refers to the characteristics of a set of ties.

(geographically clustered) networks are argued to be beneficial to innovating firms. Moreover, it is assumed that the transfer of knowledge is intentional.

Following the above arguments, lower levels of success of science parks and of the firms located there can be explained by, for example, the absence of direct ties, or levels of trust or levels of diversity that are too low. It is argued that such explanations are too simple and that other mechanisms are at work. These mechanisms imply the combined effects of high levels of technological and geographical proximity, as is often the case with firms located on science parks, the fact that knowledge transfer can be unintentional, and the characteristics of knowledge. To start with the latter, one can argue that knowledge has two basic characteristics that make this "commodity" look, to a certain extent, like a public good: rivalry and appropriability. Rivalry refers to the fact the use of a good by an actor does not affect the utility of other actors using the same good. Appropriability refers to the extent to which it is possible to exclude actors from using a good. A purely private good has high levels of rivalry and appropriability, whereas the opposite is true for so-called public goods. It is often argued that knowledge is a pure public good, but this point of view cannot be maintained. After all, the more actors use knowledge generated by another actor, the higher the probability that its economic value decreases over time as more actors have that knowledge. As a result, the competitive advantage firms can derive from this knowledge diminishes. In other words, rivalry is not complete. The same is true for appropriability; depending on the type of knowledge, some actors can be excluded. This is especially true for the more tacit types of knowledge.

It was stated above that many studies on interorganisational networks and science parks assume that knowledge sharing is intentional: a sender deliberately and consciously transmits knowledge to one or more recipients. However, knowledge can also be transferred unintentionally or unintended, which can take place through direct communication (for example, observation of the actions of another actor) or through indirect communication (for example, through (illegal) use of media on which knowledge or information is stored).

A third element in the theoretical argument is access conditions, which are the conditions under which exclusion cannot be accomplished. It is maintained that locations such as science parks create beneficial access conditions for the unintended flow of knowledge. The geographical co-location on a science park makes it easier to observe the activities of other science park firms. Moreover, on average these research-intensive firms are more technologically close to each other, which further eases unintended flows of knowledge.

Combined, the arguments lead to the conclusion that science parks can "facilitate" unintended knowledge flows. As is explained in the next section, this can have both positive and negative effects for science park firms and the networking function of science parks.

2.3.2 Unintended knowledge flows (knowledge spillover)

Some researchers (Fallah and Ibrahim, 2004; Oerlemans and Meeus, 2005; Howells, 2002; Ulrich, 2000) relate unintended knowledge flows to the knowledge spillover literature. They define unintended knowledge flow as the knowledge transmission to other actors on an involuntary and unintended basis, or in other words, unintentional transmission of knowledge to others beyond the intended boundary. This type of knowledge flow can be acquired without the acknowledgement of the sending firms. In various knowledge spillover studies, researchers attribute positive innovation effects to knowledge spillovers (Fallah and Ibrahim, 2004; Oerlemans and Meeus, 2005; Jaffe et al., 1993). Therefore, Proposition 6 is put forward.

Proposition 6: Higher levels of unintended knowledge flows will result in better innovative performance by firms.

Moreover, it is proposed that the relationship between intended knowledge flows (intentional knowledge transfer) and innovative outcomes of science park firms will be negatively influenced by higher levels of unintended knowledge flows because the moment the sender firm realises that its knowledge is "used" without its

approval by the receiving firms, this will lower its willingness to share knowledge in the official collaborations and/or informal networking activities. The proposed argument is not for *any* exchange between firms, but the interorganisational ties in the collaboration between firms. This leads the next proposition.

Proposition 7: The relationship between intended knowledge flows and innovative performance of firms will be negatively moderated by higher levels of unintended knowledge flows/spillovers.

In other words, if the unintentional use of knowledge is observed by the knowledge-producing science park firm, it will damage trust and, consequently, lower the (willingness to) exchange knowledge. Again, technological and geographical proximity play a role, because this makes it easier to observe a misuse, while the network ties between firms on a science park make it easier to communicate the "misbehaviour" of an organisation. The more firms behave in this opportunistic way, the higher the probability that the network processes on a science park can be inhibited. In fact, the poor performance of some science parks that is reported in the literature could be explained by the accumulated negative effects of the use of unintended knowledge transfer. This study takes on a nuanced approach with regard to unintended knowledge flows by proposing a positive main effect in Proposition 6 and a negative moderating effect in Proposition 7.

2.3.3 Absorptive capacity

Resulting from Cohen and Levinthal's study in 1990, firms' fundamental learning processes, that is, their ability to identify, assimilate and exploit knowledge from the environment, is labelled "absorptive capacity" (Cohen and Levinthal, 1990). Zahra and George later proposed additional definitions that separate Cohen and Levinthal's definition of absorptive capacity into two main dimensions: potential absorptive capacity (the capability to acquire and assimilate knowledge) and realised absorptive capacity (the exploitation or use of the knowledge that has been absorbed) (Zahra and George, 2002). Many empirical studies have shown

that there is a positive relationship between absorptive capacity and innovation. Pennings and Harianto's study shows that prior accumulated experience in a certain technological area increases the likelihood of innovation adoption (Pennings and Harianto, 1992). Becker and Peters (2000) and Nelson and Wolff (1997) argue that firms need higher absorptive capacities for scientific knowledge than for other types of knowledge. This shows that absorptive capacity is essential for the use of scientific knowledge, which, in turn, is the base of radical innovation. Hence the next proposition.

Proposition 8: Higher levels of absorptive capacity will result in better innovative performance by firms.

Networking encourages the sharing of tacit and explicit knowledge between actors, but only firms with higher absorptive capacity levels are able to fully assimilate and exploit the absorbed knowledge for their innovations. Similarly, even if a firm is able to access unintended knowledge by monitoring other firms' innovative activities or using their patents, the firm still needs a strong absorptive capacity to understand such knowledge for its own innovations and thus enhance its innovative performance. Therefore, absorptive capacity is included as a moderator in propositions 9 and 10.

Proposition 9: The relationship between intended knowledge flows and innovative performance of firms is moderated positively by higher levels of absorptive capacity.

Proposition 10: The relationship between unintended knowledge flows and the innovative performance of firms is moderated positively by higher levels of absorptive capacity.

The proposition can be summarised in a theoretical model that illustrates the main effects (see Figure 2) and moderating effects (see Figure 3).

Figure 2: The theoretical model showing the main effects

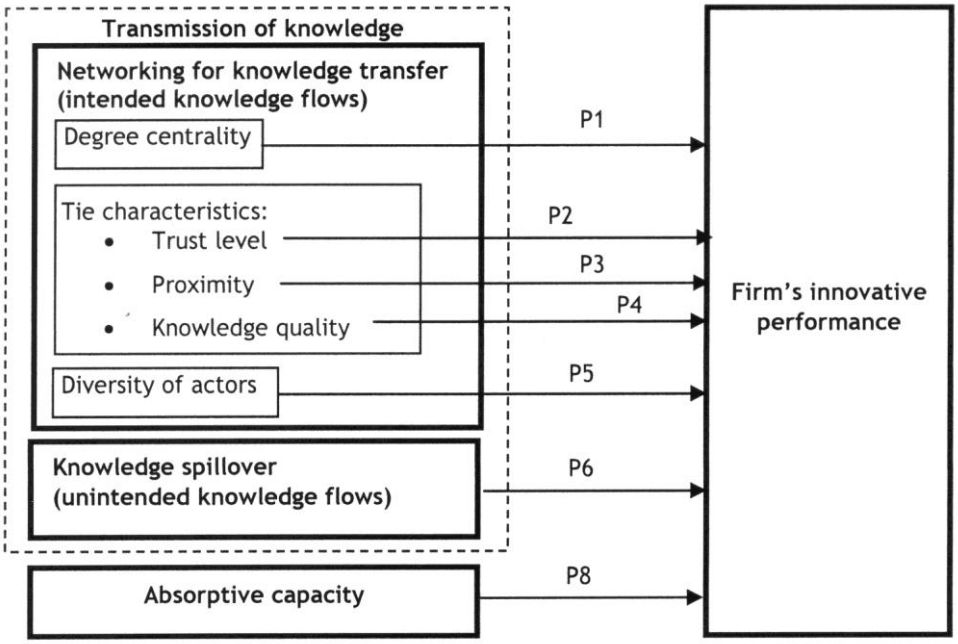
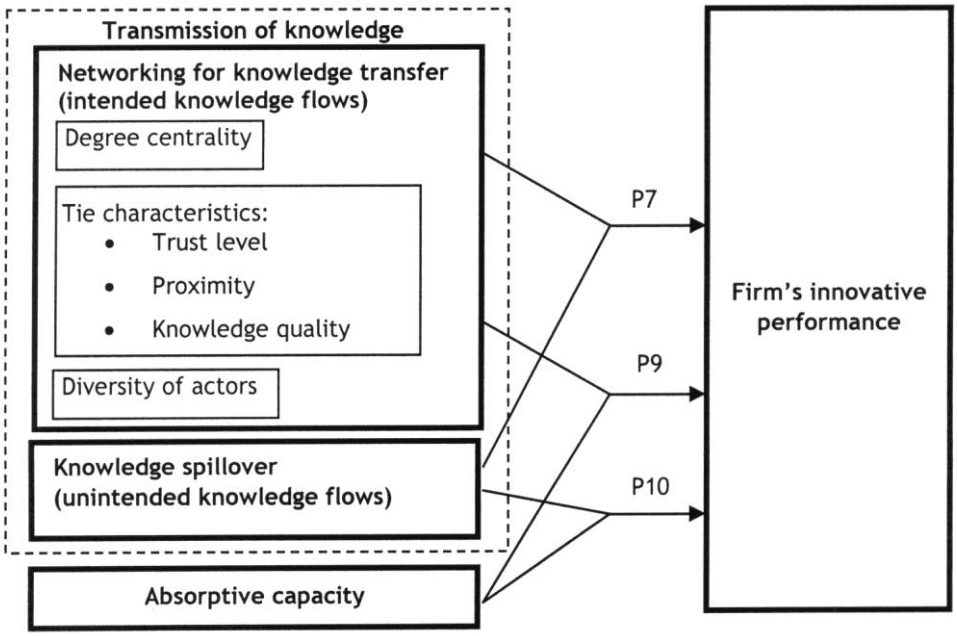


Figure 3: The theoretical model showing the interaction effects



2.4 Conclusions and future research

This study started with the observation that scholars find mixed empirical results on the performance of science park firms and of science parks. It was the aim of this study to develop a theoretical argument to explain why these mixed results are found.

By using a deductive approach in which insights from interorganisational network theory and the economics of innovation are combined, this study proposes that interorganisational networks can have both positive and negative effects for firms located on science parks. One way to deal with the negative effects of unintended knowledge transfer is to (re)locate a firm further away from its partners with similar technological backgrounds or which are in similar industries (Alcacer and Zhao, 2007). However, firms located on science parks do not have a relocation option in the short run. Starting from this assumption, it is argued that the location of firms in related industries on science parks, thus creating high geographical and technological proximity, can both foster and inhibit on-park knowledge flows and collaborations. The reason is that close geographical proximity enables on-park firms to monitor co-located firms' innovation activities, which increases the opportunity for imitation. Sender firms can identify relatively easily which on-park firms imitate their innovations, and, as a result ,this will lower their willingness to share knowledge in formal collaborations and/or informal networking activities with on-park firms. As a result, the innovative performance of firms might suffer, that is, lower innovative performance as a whole might be found on science parks.

The mixed empirical results found in the literature can be explained theoretically by pointing out that the very reason why science parks are established, namely to create a situation in which geographically co-located and technology-related firms can intentionally exchange knowledge through interorganisational relationships and networks, simultaneously creates ideal conditions for unintentional knowledge transfer. If the latter occurs, interorganisational knowledge transfer between science park firms is severely inhibited, resulting in poor(er) science park performance.

From a managerial point of view, one could recommend that science park firms should refrain from acting opportunistically. But that is stating the obvious. It is the researcher's view that there is an important task here for the management of the science park. By creating a positive collaboration culture, for example by stimulating social networking between entrepreneurs, by monitoring the behavior of tenants or by training organisations in intellectual property protection, the propensity of firms to misuse others could be lowered.

So far, the proposed model has not been empirically validated. Results of future studies, coupled with previous findings and the model proposed here, will enhance an understanding of the interrelationships between interorganisational knowledge transfer, absorptive capacity, science park location and the innovative performance of firms.

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Chapter 3

Knowledge exchange behaviours of science park firms: The Innovation Hub case[4]

This study regards the knowledge flows between firms located on a science park as a type of network behaviour, and answers three research questions: What are the knowledge exchange behaviours of on-park firms? Can different types of behaviour be distinguished among these firms? And if so, what are the differences between these groups? A relational approach is taken in which actor and relationship features are studied in a sample of firms located at The Innovation Hub (South Africa). Results show that there are two groups of firms: on-park firms that network with other on-park firms (Group 1) and those that do not (Group 0). Compared with Group 0, Group 1 has more informal ties with off-park firms, is able to gain more useful knowledge from private knowledge sources, and has more access to unintended knowledge that flows in the park. However, the innovative performance of the groups does not differ.

3.1 Introduction

The majority of science park studies state that an important goal of science parks is to meet governments' requests for a greater exchange of knowledge and ideas between on-park firms in general, and between these firms and higher educational institutions such as universities in particular to transform ideas into innovations. It is this kind of innovation that governments believe to be the key to economic development and growth in the region and therefore science parks should be used as a catalyst or engine (Chan and Lau 2005). Firms located on science parks are assumed to profit from the transmission of (tacit) knowledge due to lower communication costs in a dense and knowledge-rich environment. Besides the knowledge exchange between on-park firms, there also can be knowledge

[4] This chapter has been published in a slightly different format as Chan, K.-Y. A., Oerlemans, L.A.G. and Pretorius, M.W., 2010. Knowledge exchange behaviours of science park firms: The Innovation Hub case. *Technology Analysis & Strategic Management*, 22(2), 207-228.

exchanges with off-park firms. This type of knowledge exchange causes spillover effects of science parks so that the government's goal of (regional) economic development is achieved. Many developing countries' governments were keen to invest in new science parks in an attempt to enhance economic competitiveness, and The Innovation Hub (TIH) in Pretoria, South Africa, was one such project by the Gauteng Provincial Government. This initiative has as its primary goals to stimulate and manage the flow of knowledge and technology between universities, R&D institutions, companies and markets so that it becomes the leading knowledge-intensive business cluster in South Africa.

From the above discussion, it is clear that knowledge flows between various actors play an important role at science parks. Therefore, in order to examine science parks, one should take knowledge flows into account and ask: To what extent do these knowledge flows actually occur on a science park? Exchanging knowledge is regarded as a type of network behaviour and therefore, to study different types of knowledge flows, one needs to look at the characteristics of interorganisational relations, as they serve as pipelines for these knowledge flows (Owen-Smith and Powell, 2004). The aim of this study is to obtain insight into the knowledge exchange behaviour of firms on a science park, and, in particular, firms located at TIH. Three research questions will be answered:

1. What are the knowledge exchange behaviours of on-park firms?
2. Do these behaviours distinguish groups among on-park firms?
3. If so, what are the differences between these groups?

By answering these questions, this study adds value to the field in a number of ways. Firstly, many studies take the science park as their level of analysis. This study takes a firm level perspective and investigates the knowledge exchange behaviour of firms located on a science park with other on- and off-park firms. Applying such an approach highlights knowledge diffusion processes in a bounded geographical space. Secondly, and related to the first contribution, this study takes a relational approach in which characteristics of interorganisational ties are thought to be of importance for the performance of organisations. It is a relatively new approach to include tie characteristics in studies of science parks. Thirdly,

while studying the performance of science parks or its firms, many scholars use patents as a performance indicator. This study applies a broader set of performance indicators in which not only inventions, but also innovations (invention + market introduction) are taken into account. Fourthly, recent science park studies tend to focus on parks in Asia (Taiwan, China, and South Korea). This research studies firms located on a science park in (South) Africa. To the researcher's knowledge, this is one of the first studies investigating the functioning and performance of science parks firms on this continent.

The remainder of this chapter is structured as follows. By taking a relational approach, Section 2 gives a brief review of the literature on networking and discusses how characteristics of interorganisational ego networks influence innovations. Section 3 describes the research methodology that is used and how the variables were measured. Section 4 describes the results of a survey of TIH resident companies (on-park firms) which the author carried out in 2008, focusing on the characteristics of knowledge exchange relationships and the actors involved. The discussion in this section includes the possible group distinctions and differences in knowledge exchange behaviours and innovative performances between them. Section 5 provides some concluding remarks.

3.2 Theoretical framework

3.2.1 Introduction

In the introduction of this chapter, it was stated that a relational perspective would be applied to study knowledge exchange behaviours of science park firms. But what is a relational approach? In this approach, organisations are viewed as being embedded in external networks and consisting of networks of relations within teams, with employees, suppliers, buyers, institutional actors such as governments, regulatory bodies, social movements, professional associations, employers organisations and trade organisations. The approach argues that relationships and their characteristics (for example, the level of exchanges, trust or

knowledge transfer) are relevant for understanding organisational behaviour and outcomes. The approach represents a move "away from individualist, essentialist and atomistic explanations toward more relational, contextual and systematic understanding" (Borgatti and Foster, 2003: 991). The forging of productive relations with a highly differentiated set of partners is one of the core activities of organisational decision makers. The sets of relations legitimise organisational actions and strengthen organisations' embeddedness in an organisational field and in society. Relations also co-determine the survival chances of organisations because relations enable access to complementary resources, create potential for avoiding risks, show reputation and status, and hence enable the assets and resources needed to develop adaptive repertoires and innovative strategies to cope with competitive and institutional pressures.

In terms of studying interorganisational relations and networks, a basic building block of any network is an interorganisational relationship, which is also known as a dyad. Per definition, each dyad consists of two actors and a tie. Consequently, when one studies knowledge exchange behaviours of science park firms, one has to focus on the so-called tie and actor characteristics.

In the next two sections, the focus is on a number of tie characteristics related to intended and unintended knowledge exchanges, which are, according to the literature, of importance to innovation. In a subsequent section, a number of actor characteristics are discussed, such as firm age, firm size, years located on a science park and its absorptive capacity, as they also contribute to a firm's innovative performance and network behaviours.

3.2.2 Tie characteristics

Relational characteristics include three categories: tie type (interorganisational knowledge flows), the number of direct ties (degree centrality) and tie strength (trust, proximities, frequency and usefulness of the knowledge flowing in the tie).

3.2.2.1 Intended and unintended knowledge flows

The literature distinguishes between two types of interorganisational knowledge flows: intended and unintended knowledge flows (Fallah and Ibrahim, 2004; Oerlemans and Meeus, 2005). *Intended* knowledge flow refers to flows between two actors who intentionally interact with the aim to exchange their knowledge resources. Researchers relate *unintended* knowledge flows to the knowledge spillover literature (Howells, 2002; Oerlemans and Meeus, 2005). They define unintended knowledge flows as the transmission of knowledge to other actors on an involuntary and unintended basis, or, in other words, the unintentional transmission of knowledge to others beyond the intended boundary. This type of knowledge can be acquired without the acknowledgement of the sending firms[5]. This is a relevant issue in the South African context is shown in several studies. Sawers, Pretorius and Oerlemans (2008) state that there are unintentional knowledge flows from SMEs to their larger partners in South Africa. In the study "*Industrial Innovation in South Africa, 1998-2000"* by Oerlemans and colleagues (2004), it is shown that many South African innovative firms benefit from this type of knowledge flows, which result in an imitation type of innovative behaviour. In other knowledge spillover studies, researchers also attribute innovative performance to knowledge spillovers (Fallah and Ibrahim, 2004; Oerlemans and Meeus, 2005). In this study, two dimensions of unintended knowledge flow are distinguished: the flow between on-park firms and between on-park firms and off-park actors.

3.2.2.2 Number of ties

Through networks, firms are able to access knowledge externally and apply this acquired external knowledge to develop their own innovations. When firms interact formally (by explicit agreement) or informally (on a social basis), knowledge

[5] The measurement of unintended knowledge spillover is based on Howells' study in which he stated that 'unintended knowledge spillovers are much harder to measure and therefore have been largely neglected in knowledge spillovers studies' (Howells, 2002: 877). He has listed some possible sources of unintended knowledge which can be used as measurement for unintended knowledge flows (which this thesis used).

sharing often occurs. Evidence from the literature illustrates that "those firms which do not co-operate and which do not formally or informally exchange knowledge, limit their knowledge base over the long term and ultimately reduce their ability to enter into exchange relationships" (Pittaway et al., 2004: 145). Network position, such as centrality, is an important aspect of a network structure because it conditions the degree to which an actor can have access to resources throughout the network; the more a firm is central in its network, the more it can compare knowledge across multiple knowledge sources and discover new knowledge. Furthermore, firms with a more central position are less likely to miss any vital knowledge and are able to combine knowledge in novel ways to generate innovations (Bell, 2005). In this study, centrality is examined using degree or local centrality that is measured by determining the number of direct relationships a so-called ego firm has with other actors. Various studies have shown that centrality is positively associated with innovation and enhances firm performance (Ahuja, 2000; Zaheer and Bell, 2005).

3.2.2.3 Trust

Studies have identified trust in relationships as an important relational asset that promotes the willingness to exchange knowledge (Abrams et al., 2003). Trust is often desired by knowledge-intensive and information-based firms who require the sharing of sensitive information (Lane and Bachmann, 1998). Zaheer, McEvily and Perrone (1998, 143) conceptualise trust as an "expectation rather than a conviction that reflects an uncertain anticipation of the referent's future behaviour". They define trust as the *expectation* that an actor: (1) can be relied on to fulfil obligations; (2) will behave in a predictable manner; and (3) will act and negotiate fairly when the possibility for opportunism is present (*ibid.*). They distinguished two types of trust: interorganisational and interpersonal. Both dimensions of trust form the foundation for effective interactions between actors and this can be observed by investigating trust deeper in its two forms.

Based on past interactions, when two actors are emotionally involved with each other and trust is eventually built between them, they are willing to put forth more

time and effort on behalf of each other to transfer knowledge. This form of trust is called "intentional trust" (Lazaric and Lorenz, 1998) because it refers to the belief that partners intend to uphold the commitments they make. Another form of trust is "competence-based trust", which refers to the belief that partners have the capability to meet their commitments. In this study, trust refers to the belief that a partner is capable (competence-based trust) of providing the knowledge a firm needs for innovations as well as the belief that a partner is willing to share such knowledge for the benefit of the other partner (intention-based trust). Therefore, higher trust levels are assumed to be conducive to the exchange of knowledge and thus reduce knowledge protection (Norman, 2002).

3.2.2.4 Types of proximity

Gertler (1995: 1) found that “recent work on innovation and technology implementation suggests the importance of closeness between collaborating parties for the successful development and adoption of new technologies”. Two actors are considered to be close because they are alike (Torre and Rallet, 2005) and this closeness between actors can be labelled as "proximity", which refers to "being close to something measured on a certain dimension" (Knoben and Oerlemans 2006, 71). There are various dimensions of proximity and they often overlap in their meanings and dimensions. For this study, the classification of proximity dimensions developed by Knoben and Oerlemans (2006) is used. They discern geographical, technological and organisational proximity.

In the study of innovation and knowledge transfer, there is an emphasis on the literature of geographical proximity. It is often defined as geographical distance expressed as a specified radius to a partner (Orlando, 2000) or travel times/perception of these distances (Boschma, 2005). A short distance between two actors facilitates knowledge sharing and the transfer of tacit knowledge in particular. Tacit knowledge transfer is enhanced through face-to-face contacts and these contacts are the richest and most multidimensional contacts available to humans (Desrochers, 2001). Therefore, the spatial dimension becomes essential to enhance the exchange of tacit knowledge for innovative activities and one could

argue that the high level of proximity science parks offer is conducive to the exchange of knowledge.

Furthermore, Desrochers (2001: 29) mentions that “geographical concentration of *related firms* balances cooperative and competitive forms of economic activity, leading to greater innovation and flexibility”. The term “related” points at similarity of technological backgrounds and knowledge between these firms. Technological proximity refers to the similarities between actors’ technological knowledge, in other words, how similar the knowledge bases are between them. The transfer of unrelated knowledge can cause difficulties because the firm that receives the knowledge is not capable of identifying, assimilating and exploiting the knowledge coming from external sources for its own innovative activities (Sapienza, Parhankangasand and Autio, 2004). On the other hand, similar knowledge contributes to efficient communication because knowledge can only be easily exchanged if the two actors share a similar language, codes, and symbols (Grant, 1996). Moreover, similar external knowledge is also likely to be more compatible than dissimilar knowledge, so that the receiving firm is able to *absorb* such knowledge from the sender for its own use (relative absorptive capacity, see Lane and Lubatkin 1988).

The third dimension is "organisational proximity". It is defined as “*the set of routines – explicit or implicit – which allows coordination without having to define beforehand how to do so. The set of routines incorporates organisational structure, organisational culture, performance measurements systems, language and so on*” (Knoben and Oerlemans, 2006: 80). Lane and Lubatkin (1988) state that similarity between the two firms’ organisational structures and policies contributes to firms’ ability to learn interactively from each other. This interactive learning does not only occur at the individual level, but also at the organisational level where its structure and routines represent the codification of the organisation’s historic pattern of roles and the organisation’s communication processes. Collaborating firms that have low organisational proximities have different sets of routines and thus, instead of creating innovations together, they create problems due to these routines; for example, they cannot communicate well due to their different communication

processes. As the worst result of such difference, an unsuccessful collaboration leads to no innovative outputs.

3.2.2.5 Frequency and knowledge usefulness

Soo and Devinney (2004) identified a positive relationship between quality of knowledge transferred and innovative performance. The quality of knowledge transferred comprises two factors: usefulness of the knowledge that a firm receives and how frequently it receives the knowledge. The context of the knowledge that a firm receives directly influences the success of the innovative outcomes if the firm can actually use such knowledge. The knowledge can be new to the receiving firm, but if it cannot be used and contribute to the firm's development of new innovations, then such knowledge has low knowledge quality for the firm. This is in line with Brachos and others (2007), who point out that knowledge transfer actually occurs when received knowledge is used to lead to something new (ideas, products, deeper knowledge, etc.). Furthermore, they suggested that perceived usefulness of knowledge is an adequate proxy of knowledge transfer effectiveness.

The frequency of knowledge exchange is the quality of the knowledge exchange because more frequent communication can lead to more effective communication (Reagans and McEvily, 2003). With repeated interaction, the receiving firm can better understand the knowledge that it receives and this increases the chances that the knowledge would be useful for the firm's innovations. Audretsch and Feldman (2004) state that the marginal cost of transmitting knowledge, especially tacit knowledge, is lowest with frequent interactions, observations and communications. Frequent interactions also enhance the parties' mutual trust, because relationships mature with interaction frequency (Atuahene-Gima and Li, 2002). Studies have shown that mutual trust affects the grade of tacit knowledge utilisation (Koskinen, Pihlanto and Vanharanta, 2003).

3.2.3 Actor characteristics

Actor characteristics contribute to the analysis of network behaviours and innovative performances of firms. These characteristics include the diversity of external actors, firm age and size, duration of location in the science park and a firm's absorptive capacity.

3.2.3.1 Diversity of external actors

Many innovators derive their ideas from a diverse set of actors because these provide diverse ideas that are a source of novelty, triggering new ideas and creativity in the knowledge-acquiring firm. Actors who interact with partners from diverse communities of practice will be able to convey more complex ideas than those individuals who are limited to interactions within a single body of knowledge (Reagans, 2003).

The process of knowledge building often requires dissimilar, complementary bodies of knowledge from diverse actors (Staber, 2001) who interact with each other to share diverse knowledge and take advantage of their "built-in" knowledge diversity to bring about successful projects (Ratcheva 2009) and to achieve a complex synthesis of highly specialised state-of-the-art technologies and knowledge domains for product innovations (Dougherty, 1992). A recent study also showed that knowledge diversity is an important source of productivity at firm level, so that the firm is able to cope with the technological turbulence that is concomitant with the rise of the knowledge economy (Nesta 2008). Diversity is defined here as the use of "multiple sources of knowledge" such as competitors, customers, suppliers, HEIs, etc.

3.2.3.2 Firm age and size

Prior studies have identified a significant positive relationship between firm size and innovativeness and a significant negative relationship between firm age and

innovativeness (Bell, 2005). Firm size in this study is identified by the number of full-time employees, including CEOs and directors, employed by a firm, and firm age is the number of years that have passed since a firm's founding. Small and young firms often face significant risk and uncertainty due to a lack of information and knowledge (Bürgel et al., 2001). For a firm to be innovative and competitive, accumulation of knowledge plays an important role (Malmberg, Sölvell, and Zander 1996) and this needs time and people to acquire knowledge. In particular, firm size determines the level of networking because "people" are at the core of tacit knowledge exchange (Erkuş-Öztürk, 2009). Science parks are designed to encourage the formation and growth of knowledge-based businesses and therefore consist mainly of young and small-size NTBFs.

3.2.3.3 Years of location on SP

Science parks (SPs) are believed to have made many value-adding contributions to firms (Fukugawa, 2006), especially by providing the opportunities (close geographical proximity) and support (from the science park management) to their on-park firms to establish knowledge linkages, and allowing on-park firms to engage in joint research. Firms that have been on a science park for longer are considered to receive more such benefits than those who are latecomers on the park.

3.2.3.4 Absorptive capacity

Following Cohen and Levinthal's seminal study (1990), firms' fundamental learning processes (their ability to identify, assimilate and exploit knowledge from the environment) are labelled absorptive capacity. Zahra and George (2002) propose additional definitions that separate Cohen and Levinthal's definition of absorptive capacity into two main dimensions: potential absorptive capacity (the capability to acquire and assimilate knowledge) and realised absorptive capacity (the exploitation or use of the knowledge that has been absorbed). Many empirical studies have shown that there is a positive relationship between absorptive

capacity and innovation. Pennings and Harianto's study (1992) shows that prior accumulated experience in a certain technological area increases the likelihood of innovation adoption. Nelson and Wolff (1997) and Becker and Peters (2000) argue that firms need higher absorptive capacities for scientific knowledge than for other types of knowledge. More recent literature also explores the positive relationship between absorptive capacity and innovations (Fosfuri and Tribó, 2008), and its relevance for absorbing external knowledge.

3.2.4 Innovative performance

Science parks are closely associated with innovation. In Castells and Hall's (1994) list of motivations for the establishment of technology parks, the "creation of synergies" is described as the generation of new and valuable information through human intervention to the extent that an "innovative milieu", which generates constant innovation, is created and sustained. In addition to the study of on-park firms' knowledge exchange behaviours and also since a science park is the seedbed for innovation, this study investigates the innovative performances of the on-park firms. Innovative performance is based on the definition by Ernst (2001), namely achievement in the trajectory from the conception of an idea up to the introduction of an invention into the market.

3.3 Research methodology and measurements

3.3.1 Research methodology

In this study, the focus is on the knowledge exchange behaviours of firms located on a science park. Therefore, the unit of analysis is firms located on TIH in Pretoria, South Africa. The sectoral distribution of current on-site firms (total = 47) is as follows: Bioscience: 5; Electronics: 2; Engineering: 6; Information, communication and technology (ICT): 28; Smart manufacturing: 1; and Professional services: 5.

This research applies a quantitative research methodology. A questionnaire was distributed to firms located on TIH and the CEOs or directors (units of observation) of these firms were asked to answer questions based on the characteristics of their firms' knowledge exchange behaviours with other on-park firms as well as with off-park firms/organisations (firms not located on TIH). Questionnaires were distributed personally or via emails to all NTBFs and 33 were returned. Twenty-five questionnaires were valid (response rate = 52%), comprising 17 from ICT, four from Engineering, two from Professional services and one from Electronics. Eight responses were invalid due to the firms' characteristics not meeting our criteria for inclusion (selection criteria for NTBFs: firm age of less than 10 years, total employee less than 50 and technology-based firm). The collected data was analysed by applying independent T-tests.

3.3.2 Measurements

This research studies the knowledge exchange behaviours of on-park firms at the ego-network level (an ego-network is a focal firm (the ego) with its direct ties, the alters) rather than at the whole network level (which requires data on the entire set of present and absent linkages between a set of actors).

Table 1 illustrates the items that are used in the questionnaire to measure the variables proposed in the research framework. Table 2 shows the literature that was sourced to construct the measurements, as well as the reliability statistics (Cronbach's alpha) of the scales used. Table 2 shows that several variables are measured by more than one item. Examples are trust, organisational proximity, and relative innovative performance. In these cases, factor analysis was conducted to explore the underlying dimensions of these specific variables. It turns out that there is one factor each for both interorganisational trust and interpersonal trust.

A reliability test was then done on these variables to determine how well the items measure a single, unidimensional latent construct. This procedure was performed

for all relevant variables and the results are shown in the last column of Table 2. Most variables have Cronbach's α's ≥ 0.6, which indicates reliable scales. Note that the Cronbach's α for off-park organisational proximity is 0.442. This means that for off-park organisational proximity, separate items will be used independently to measure this variable.

Table 1: Item(s) of variables

Variables	Item(s)
Direct ties	Formal interorganisational network ties: with how many on-park and off-park organisations does the on-park firm have formal/contractual agreements? Informal interorganisational network ties: with how many on-park and off-park organisations does the on-park firm have interactions on a non-contractual basis (i.e. informal, social basis)? Social network ties: with how many persons of on-park and off-park does the manager of the on-park firm have social interactions?
Trust	<u>Interorganisational trust:</u> Indicate level of agreement with the following statements: In general, the organisations with which my firm exchanges knowledge: (1) keep promises they make to our firm; (2) are always honest with us; (3) provide information that can be believed; (4) are genuinely concerned that our business succeeds; (5) consider our welfare as well as their own when making important decisions; (6) keep our best interests in mind; (7) are trustworthy; (8) it is not necessary to be cautious in dealing with them. <u>Interpersonal trust:</u> Indicate level of agreement with the following statements. In general, the persons with which my firm exchanges knowledge: (1) have always been impartial in negotiations with us; (2) can always be counted on to act as expected; (3) are trustworthy; (4) consider our interests even when it is costly to do so; (5) if their performance was below expectation, a sense of betrayal would be felt. (7-point Likert scale for all above items: 1 = completely disagree, 3 = neither agree nor disagree, 7 = completely agree)
Geographical proximity	Geographical distances with respect to off-park firms: Where are the most important partners situated: (1) same town/city, (2) different city but same province, (3) other province or (4) abroad?
Technological proximity	Technologically similar: To what extent is the knowledge your firm receives from most partners/actors similar to your firm's own knowledge? (7-point Likert scale: 1 = dissimilar to 7 = completely similar)

Variables	Item(s)
Organisational proximity	Our firm has contacts with the same third parties as our partners have Our partners have the same organisational routines and values as our firm Our partners have the same organisational structure as our firm (5-point Likert scale: 1 = completely disagree, 3 = neither agree nor disagree, 5 = completely agree)
Quality of knowledge transferred	Usefulness of knowledge: How useful is the knowledge your firm receives from the most important partners with regard to your firm's innovations? (5-point Likert scale: 1 = not useful to 5= completely useful) Frequency: How often does your firm access knowledge from its most important partners? (5-point Likert scale: never, rarely, sometimes, regularly or always)
Diversity of actors	Respondents were asked indicate which knowledge sources were used: (1) competitors; (2) buyers;(3) suppliers; (4) innovation centres; (5) public research labs; (6) universities; (7) consultants; and (8) sector institutes
Knowledge spillover (Unintended knowledge flows)	How often does your firm use the following sources from other organisations/actors to acquire knowledge for your firm's innovations?: (1) employing key scientists and engineers (including poaching key staff); (2) acquiring key information at conferences and workshops; (3) reverse engineering of technological knowledge embedded in products developed/produced by other firms/organisations; (4) accessing patent information filed by other firms/organisations; (5) knowledge embedded in organisational processes or routines of other firms/organisations; (6) publications in technical and scientific papers by other firms/organisations. (5-point Likert scale: never, rarely, sometimes, regularly or always).
Firm age	Number of years a firm exits.
Firm size	Total number of employees, including the CEOs and directors in 2005 and 2007.
Years on SP	Total number of years that the firm is located on the science park (SP).

Variables	Item(s)
Absorptive capacity	Indicate level of agreement with the following statements: (1) most of our staff members are highly skilled and qualified; (2) we invest a great deal in training; (3) we innovate by improving competitors' products and processes; (4) most of the time we are ahead of our competitors in developing and launching new products; (5) we have the capacity to adapt others' technologies; (6) we innovate as the result of R&D carried out in our own firm; (7) we have considerable resources and own knowledge resources for technological development; (8) we are able introduce into the market innovations that are completely novel on a worldwide scale. (5-point Likert scale: 1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree)
Firm's innovative performance	Five indicators of innovative performance were used: (1) number of patents; (2) number of new products/services that were developed but not yet introduced to the market; (3) percentage of sales of products/services that were technologically improved and technologically new in percentage; (4) percentage of sales of product/services that were not only technologically improved or new but also technologically new or improved in the market (the competitors had not already introduced such product/services); (5) relative innovative performance. For this last item, the following question was asked. To what extent did your firm's product and/or service innovations result in: (a) reduction of development and maintenance costs; (b) quality improvement of products and/or services; (c) increase in production capacity; (d) improvement in delivery times; (e) increase in sales; (f) increase in profits. (5-point Likert scale: 1 = very little, 3 = not little / not much, 5 = very much).
Total sales growth	Relative growth of sales in the period 2005-2007.
Employee growth	Relative growth of employee volume in the period 2005-2007
Labour productivity	Sales volume per employee in 2007
Labour productivity growth	Relative growth of labour productivity in the period 2005-2007

Table 2: Measurements, their sources, and reliability statistics

Variables	Source and Cronbach's α of items in this source, if provided	Measurement and Cronbach's α of items in this research, if applicable
Direct ties	Otte and Rousseau (2002)	Formal interorganisational network ties: count of total number of ties Informal interorganisational network ties: count of total number of ties Social network ties: count of total number of ties
Trust	Interorganisational trust: Lippert (2007) (α = 0.94) Interpersonal trust: Zaheer, McEvily and Perrone (1998) (α = 0.88)	Interorganisational trust: average sum score of all eight items using 7-point Likert scale (α = 0.938) Interpersonal trust: average sum score of all five items using 7-point Likert scale (α = 0.834)
Geographical proximity	Schreurs (2007)	Coding: 1 = same town/city, 2 = different city but same province, 3 = other province, 4 = abroad
Technological proximity	Cassiman et al. (2005)	One item: 5-point Likert scale
Organisational proximity	Knoben and Oerlemans (2008)	Average sum score of all three items using 5-point Likert scale (On-park: α = 0.566; Off-park: α = 0.853)
Quality of knowledge transferred	Soo and Devinney (2004)	One item: Usefulness of knowledge, 5-point Likert scale One item: Frequency, 5-point Likert scale
Diversity of actors	Oerlemans et al. (2004)	Count of total number of different knowledge sources
Knowledge spillover (Unintended knowledge flows)	Howells (2002)	Average sum score of all six items using 5-point Likert scale (On-park: α = 0.566; Off-park: α = 0.853)

Variables	Source and Cronbach's α of items in this source, if provided	Measurement and Cronbach's α of items in this research, if applicable
Firm age	Source: not applicable	2008 (the year when this research was conducted) minus the founding year of the firm
Firm size	Source: not applicable	Count of the total number of employees in years 2005 and 2007
Years on SP	Source: not applicable	2008 (the year when this research was conducted) minus the year when the firm was located on the science park
Absorptive capacity	Nietoa and Quevedo (2005)	Average sum score of all eight items using 5-point Likert scale (α = 0.771)
Firm's innovative performance	Cassiman et al. (2005) Relative innovative performance: Oerlemans and Meeus (2005)	(1) Total number of patents in years 2005 and 2007 (2) Total number of new products/services that were developed but not yet introduced to the market in years 2005 and 2007 (3) Innovative sales: Percentages of sales of products/services that were technologically improved and technologically new (4) Percentage of sales of product/services that were not only technologically improved or new but also technologically new or improved in the market (5) Relative innovative performance: average sum score of all six items using 5-point Likert scale (α = 0.656)
Total sales growth	Source: not applicable	[(Total sales 2007 – Total sales 2005) / Total sales 2005] * 100
Employee growth	Source: not applicable	[(Number of employees 2007 – Number of employees 2005) / Number of employees 2005] * 100
Labour productivity	Source: not applicable	Total sales 2007 / Number of employees 2007
Labour productivity growth	Source: not applicable	[(Labour productivity 2007 – Labour productivity 2005) / Labour productivity 2005] * 100

3.4 Empirical results

In this section the first two research questions are answered by applying descriptive statistics to tie and actor characteristics. The questions are:
(1) What are the knowledge exchange behaviours of on-park firms?
(2) Do these behaviours distinguish groups among on-park firms?.

3.4.1 Descriptive statistics: tie characteristics

As mentioned in the theoretical section, studying knowledge exchange behaviours of science park firms implies that one has to focus on tie and actor characteristics. In Table 3, descriptive statistics are presented on ties of on-park firms with both other on- and off-park firms.

The mean of the number of direct ties of on-park firms with off-park firms is higher than the means of ties with on-park firms in all (formal, informal and social) direct ties categories. On-park firms not only have more ties with off-park firms, they also interact more frequently with these off-park firms. These observations indicate that there are quite a number of respondents that have few and infrequent on-park interactions.

In general, on-park firms have more trust on an organisational level than on a personal level. Since trust enhances commitment to a relationship and trust at the organisational level is a stronger predictor of commitment than at the personal level (Ganesan and Hess 1997), the on-park firms are also slightly more committed to relationships at the organisational level than at the personal level.

As far as geographical proximity is concerned, most off-park partners of on-park firms are located geographically close to them. The relationships with buyers and suppliers seem to be the exception, but even in these cases partners seem to be relatively spatially close.

The variable technological proximity indicates how similar the externally acquired technological knowledge is to the knowledge base of the focal firm. Given the low averages in Table 3, it can be concluded that on-park firms acquire external knowledge

that is largely dissimilar to their own knowledge. This finding shows that interorganisational knowledge exchange relations are often based on a combination of complementary knowledge bases. It is also found that respondents get more similar technological knowledge from off-park firms than from other on-park firms. This implies that, in general, the technological proximity within the Hub is low. In other words, the technological knowledge backgrounds of the on-park firms are fairly different, whereas the knowledge backgrounds between on- and off-park firms are more similar.

This is also the case with organisational proximity: most partners of on-park firms seem to be organisationally distant. Moreover, on-park firms feel more organisationally close to off-park firms on all dimensions of organisational proximity (relational, cultural and structural).

The relatively high levels of organisational and technological distance between the Hub firms may be the explanation for the relatively lower levels of perceived usefulness of knowledge acquired from other on-park firms in the Hub as compared to the usefulness of the knowledge acquired from off-park firms. In terms of diversity of actors, the on-park firms interact more with off-park actors from different categories and the diversity in the Hub is quite limited. This implies that communities in The Innovation Hub are less diverse. This may be attributed to two reasons: the size of the Hub is limited and/or the Hub is *designed* to have communities that are less diverse.

Table 3: Means and standard deviation of variables (N = 25)

Relational characteristics					
Variables		**With on-park firms/organisations**		**With off-park firms/organisations**	
		Mean	**S.D.**	**Mean**	**S.D.**
Direct ties	Number of formal ties	0.48	1.005	19.32	40.197
	Number of informal ties	1.52	1.896	12.08	11.228
	Number of social ties	4.40	6.212	79.84	263.693
	Total number of ties	2	2.29	31.4	40.57
Trust	Interorganisatioal	Mean = 4.9150 S.D.= 1.17245			
	Interpersonal	Mean = 4.4240 S.D. = 1.15372			
		(trust levels in general, no on-park or off-park differentiation)			
Geogra-phical proximity	With competitors	Mean = 1 ; S.D.= 0 On-park firms are all situated in close geographical proximity (1 = same city)		1.04	0.338
	With buyers			1.56	1.158
	With suppliers			1.72	1.487
	With innovation centre			0.44	0.917
	With public research labs			0.20	0.5
	With university			0.72	1.275
	With consultant			0.96	1.020
	With sector institutes			0.36	0.757
Technolo-gical proximity	With competitors	0.96	2.031	2.68	2.911
	With buyers	0.32	1.145	3.88	2.522
	With suppliers	1.56	2.181	3.44	2.694
	With innovation centre	0.72	1.792	1	1.979
	With public research labs	0.16	0.624	0.84	2.035
	With university	0.72	1.990	1.44	2.417
	With consultant	0.48	1.388	2.92	2.857
	With sector institutes	0	0	1.28	2.622
Organisa-tional proximity	same third parties	1.60	1.756	2.88	1.364
	same routines and values	1.64	1.753	3.32	1.069
	same structure	1.76	1.877	2.52	1.122
Frequency	With competitors	0.36	0.860	0.88	1.054
	With buyers	0.24	0.879	2.64	1.319
	With suppliers	1.04	1.338	2.12	1.453
	With innovation centre	0.44	0.961	0.60	1.155
	With public research labs	0.12	0.440	0.32	0.900
	With university	0.2	0.577	0.56	1.121
	With consultant	0.32	0.748	1.68	1.464
	With sector institutes	0	0	0.56	1.261
Usefulness of knowledge	With competitors	0.76	1.640	1.64	1.890
	With buyers	0.40	1.384	3.60	1.848
	With suppliers	1.76	2.107	2.84	1.993
	With innovation centre	0.72	1.542	0.88	1.666
	With public research labs	0.24	1.012	0.60	1.443
	With university	0.52	1.447	1.00	1.732
	With consultant	0.60	1.500	2.36	2.139
	With sector institutes	0	0	0.88	1.833
Diversity of actors		1.32	1.676	3.56	1.583
Unintended knowledge flows		0.6872	0.39179	1.5733	0.7774

3.4.2 Descriptive statistics: Characteristics of on-park firms

Table 4 shows the descriptive statistics of the actor (on-park firms) characteristics. The average firm age and size are 5.28 years and 15.64 employees respectively and show that the on-park firm are small firms. This corresponds with most observations by science park researchers in the past (Löfsten and Lindelöf 2002). The Innovation Hub was opened officially in April 2005, therefore, its age is four years and the on-park companies have been located on the Hub for almost three years on average. This implies that most of the current on-park firms have located in the Hub during the first year of its existence. On-park firms have an average score of 3.74 on a scale of 5 on absorptive capacity. This high absorptive capacity level accounts may be for the higher percentages of innovative sales (percentage of new and improved innovations to the market almost 46%; percentage of sales of improved innovations 44.6%; and percentage of sales of new innovations 35.4%). The average score for other results of innovations is also high on a scale of 5 (3.77).

Table 4: Means and standard deviation of variables (N = 25)

Firm characteristics		
Variables	**Mean**	**S.D.**
Firm age	5.28	3.803
Firm size	15.64	28.269
Total sale growth percentage: 2005 – 2007	382.89	620.4
Employee growth percentage: 2005 - 2007	99.04	102.87
Labour productivity 2007	392.486	285.803
Labour productivity growth: percentage 2005-2007	200.08	439.59
Duration on SP	2.72	1.948
Absorptive capacity	3.74	0.67596
<u>Innovative performance indicators:</u> • Patents • Developed not introduced • Percentage sales of improved innovations • Percentage sales of new innovations • Percentage sales of new/improved-to-market innovations • Other results of innovations	 0.36 1.52 44.6 35.4 45.94 3.7667	 1.254 2.502 36.053 33.320 34.265 0.75615

3.4.3 Comparing knowledge exchange behaviours of on-park firms

3.4.3.1 Introduction

By taking a closer look at the data, two knowledge exchange groups of on-park firms can be distinguished: on-park firms that exchange knowledge with other on-park firms and those that do not. This enables the third research question to be answered: what are the differences between these groups? To answer this question, group comparison on various dimensions is needed. In this research, independent T-tests are used to compare the relational characteristics of the knowledge exchange of these two groups. Group 0 denotes the on-park firms without on-park networks and therefore they only interact with off-park firms; while Group 1 represents those who have both on-park ties and off-park ties. Since there are no relations with on-park firms in Group 0, the relational characteristics of the knowledge exchange are with the off-park only. Although Group 0 does not interact formally or informally with other on-park firms, this group of firms is still able to receive unintended knowledge that is flowing to the Hub. Therefore, the flows for unintended knowledge have two forms: on-park and off-park.

3.4.3.2 Comparing tie characteristics

The results of the T-test are summarised in Table 5. Some interesting observations can be made. One would expect that on-park firms who do not interact with other on-park firms (Group 0) will put more effort in establishing interactions with off-park firms. However, the result shows that Group 0 firms have fewer direct formal, informal and social ties with off-park firms as compared to Group 1 firms. The difference between the two groups regarding informal direct ties is statistically significant at the *p*-level of 0.05.

Moreover, Group 0 firms have both higher interorganisational and interpersonal trust with the off-park firms, although the differences are not statistically significant. For Group 0 it was found that the technological knowledge from the off-park public knowledge sources (universities, research labs, innovation centres and sector institutions) is more similar and useful, and they interact more frequently with these sources. On the other hand, Group 1

interacts more often with private knowledge sources (competitors, buyers, suppliers and consultants) and finds the knowledge from these sources more useful at a significant level.

One also would expect Group 0 to interact with a more diverse set of knowledge sources. However, the level of diversity of actors that Group 0 interacts with is lower. In other words, Group 0 interacts with fewer categories of knowledge sources. Furthermore, Group 0 has close organisational proximity on the internal aspects (organisational structure, routines and values) but not on the external aspects (sharing similar third partners). Lastly, Group 1 gets more unintended knowledge flows from the on-park firms as compared to Group 0.

Table 5: Results of independent T-tests of relational characteristics of Group 0 and Group 1 firms

Variables (knowledge exchange with off-park firms)		Group 0 (N = 11) On-park firms with no on-park knowledge exchange relations, only with off-park firms		Group1 (N = 14) On-park firms with on-park and off-park knowledge exchange relations		T-test[a] *p*-value[b]
		Mean	S.D.	Mean	S.D.	
Direct ties	Number of formal ties	7.82	11.453	28.36	51.79	-20.539
	Number of informal ties	6.55	9.933	16.43	10.515	***-9.883****
	Number of social ties	24.55	48.757	123.29	349.174	-98.740
Trust	Interorganisational trust	5.068	0.916	4.7946	1.363	0.274
	Interpersonal trust	4.709	1.122	4.2	1.169	0.509
Geographical proximity	Location of actors who provide supplementary knowledge	0.091	1.185	-0.714	0.868	0.162
	Location of actors who provide core knowledge	-0.315	0.816	0.248	1.088	-0.563
Technological proximity	Technological proximity of public knowledge sources	0.566	1.185	-0.045	0.872	0.101
	Technological proximity of private knowledge sources	-0.162	1.115	0.127	0.922	-0.29
Organisational proximity	Internal organisational proximity	0.284	1.068	-0.223	0.92	0.507
	External organisational proximity	-0.008	1.206	0.006	0.853	-0.014
Frequency	Frequency score for public knowledge sources	2.564	1.422	-0.201	0.438	0.458
	Frequency score for private knowledge sources	-0.162	1.09	0.127	0.945	-0.29
Usefulness of knowledge	Usefulness score from public knowledge sources	0.948	1.327	-0.075	0.691	0.169
	Usefulness score from private knowledge sources	-0.453	0.877	0.356	0.972	***-0.81****
Diversity		3.36	1.69	3.71	1.541	-0.351
Unintended knowledge flow off park		1.591	0.8	1.56	0.789	0.031
Unintended knowledge flow on park		0.472	0.222	0.833	0.429	***-0.361****

a. Mean differences between two groups
b. Significance at the 5 percent level (p-value < 0.05)
* mean difference is statistically significant at p<0.05

3.4.3.3 Comparing actor characteristics

Besides the relational characteristics, the firms' characteristics between Group 0 and Group 1 are also analysed. The results of independent T-tests are shown in Table 6.

There are no significant differences between Group 0 and Group 1 in terms of their firm characteristics. This result may be due to the fact that the firm entry criteria provided by the science park management have resulted in the similarities among SP firms' characteristics (firm age and size are restricted to a certain level). What is really surpising in Table 6 is that there are no statistically significant differences between the two groups as far as innovative sales and patents filed are concerned. One would expect that firms more strongly embedded in knowledge exchange networks (Group 1 firms) would outperform firms without such strong embeddedness (Group 0 firms). Moreover, the fact that on-park firms have knowledge exchange relations with other on-park firms does not seem to have added value to them as far as innovative outcomes are concerned. These findings give reason to believe that there are some indications that The Innovation Hub does not provide the knowledge exchange environment (yet) that many have hoped for.

Table 6: Results of independent T-tests of firm characteristics

Variables	Group 0 (N = 11) On-park firms with no on-park knowledge exchange relations, only with off-park firms		Group1 (N = 14) On-park firms with on-park and off-park knowledge exchange relations		T-test[a] *p*-value[b]
	Mean	S.D.	Mean	S.D.	
Firm age	5.27	3.894	5.29	3.911	-0.013
Firm size	24	41.96	9.07	3.931	14.929
Total sale growth percentage	558.43	883.84	265.87	361.05	292.57
Employee growth percentage	85.07	110.37	109.78	99.89	-24.71
Labour productivity 2007	365.691	312.577	409.711	278.012	-44.019
Labour productivity growth percentage	433.39	732.51	83.42	129.46	349.96
Years in SP	2.45	1.036	2.93	2.464	-0.474
Absorptive capacity	3.739	0.526	3.741	0.794	-0.002
Firms' innovative performance					
• Patents	0.55	1.809	0.21	0.579	0.331
• Developed not introduced	1.09	1.30	1.86	3.159	-0.766
• Percentage sales of improved innovations	43.18	37.435	45.71	36.314	-2.532
• Percentage sales of new innovations	35.91	38.524	35	30.128	0.909
• Percentage sales of total innovations	79.09	35.342	80.71	25.484	-1.623
• Percentage sales of new/improved-to-market innovations	33.18	41.126	26.43	31.097	6.753
• Other results of innovations	3.561	0.814	3.929	0.694	-0.302

a. Mean differences between the two groups

b. Significance at the 5 percent level (p-value < 0.05)

* mean difference is significant at p<0.05

3.5 Conclusions and discussion

Policy makers often regard science parks as important drivers of regional economic development because they provide firms with a facilitating environment in which they can more easily set up and maintain knowledge-intensive interorganisational relationships. The knowledge flows between the various actors are supposed to play an important role in science parks and the purpose of the study is to examine the knowledge exchange behaviour of on-park firms in order to answer three main research questions:

1. What are the knowledge exchange behaviours of on-park firms?
2. Do these behaviours distinguish groups among on-park firms?
3. If so, what are the differences between these groups?

In this section, the most important findings of this study are summarised and discussed. After carefully describing the theoretical and methodological background of the study, the empirical analyses consisted of two parts. In the first part, the focus was on the knowledge exchange behaviour of on-park firms and the characteristics of their knowledge exchange relationships. It was found that, compared with on-park knowledge exchange relationships:

- The knowledge exchange relationships with off-park firms occur more frequently. This is especially true for social ties.
- The knowledge exchange relationships with off-park firms are more technologically similar.
- The knowledge exchange relationships with off-park firms are more organisationally close.
- The knowledge exchange interactions with off-park firms are more frequent.
- The knowledge exchange relationships with off-park firms are assessed as generating more useful knowledge.
- The off-park actors involved are of a more diverse nature.
- More unintended knowledge flows take place in exchange relationships with off-park firms.

An interesting finding is the importance of off-park social ties as relevant sources for on-park firms. This has often been observed in the literature, especially for young, new and high-tech organisations (Maurer and Ebers, 2006). Using their social capital is a way to deal with the "liability of newness" (Freeman, Carroll and Hannan, 1983), that is, new and young firms experience a higher probability of failure due to a lack of external resources, access to formal financial funding, and internal routines. By capitalising on their social network ties, which provide informal funding and advice, this liability is mitigated.

The finding that on-park firms interact more often with off-park than with on-park firms is not a surprise as such. After all, the number of off-park firms with which knowledge exchange relationships can be established is much higher than the number of on-park firms. However, the results indicate that the quality and effectiveness of knowledge exchange relationships with off-park firms seem to be far better than those with on-park firms. A negative interpretation of these findings is that The Innovation Hub does not perform its functions well. However, this might be a too harsh an interpretation. Research has shown that most knowledge exchange relationships are reciprocal (Chiu, Hsu and Wang, 2006; Watson and Hewett, 2006). If the assumption is made that the same is true for the off-park relationships, then the off-park firms profit from the knowledge developed by the on-park firms. In this sense, the Hub could be regarded as focal driver of technological development.

The second part of the analyses answered research questions two and three. It could be shown that two groups of on-park firms exist, namely a group of on-park firms that have knowledge exchange relationships only with off-park firms (Group 0) and a group of on-park firms with both on- and off-park relationships (Group 1). More specifically, it was found that:

- Group 1 firms have more (informal) direct ties.
- Group1 firms get more useful knowledge from private knowledge sources.
- Group 1 firms have a higher inflow of unintended knowledge from other on-park firms.
- There are no differences between the two groups as far as firm characteristics are concerned.

How can these results be interpreted? One interpretation could be that the technologies of Group 0 firms are at an earlier stage of the technology life cycle than the technologies of Group 1 firms. The data give some indications that Group 0 firms are in the early stages of this cycle, because they interact especially with organisations who form part of the public knowledge infrastructure (universities, research labs) to which they feel organisationally and technologically close. Moreover, they assess the knowledge acquired from these sources as being more useful and the firms in this group generate twice as many patents as firms in the other group. All of this could imply that Group 0 firms are primarily technology developers that use the more fundamental knowledge generated by actors in the public knowledge infrastructure that cannot be found on-park. Group 1 firms, however, interact more with organisations who form part of the private knowledge infrastructure (buyers, suppliers) to which they feel more organisationally and technologically close. In the South African situation, Oerlemans and Pretorius (2006) have shown that the knowledge acquired from buyers and suppliers is often used for the incremental innovation of already existing products and services. This would imply that Group 1 firms are closer to commercialising their innovations or are already doing so.

A different interpretation could be that a science park such as the Innovation Hub serves other purposes for on-park firms in Group 0. Location on a science park is not primarily for networking and knowledge exchange, but also for reputation-building and creating an image of an innovative firm, which might give these firms an advantage in the market. A striking finding is that there are no differences between the two groups concerning their innovative outcomes, despite the fact that Group 1 firms have a more extended knowledge transfer network. The literature contains ample evidence that higher levels of network embeddedness are beneficial to the innovation outcomes of organisations (Ahuja, 2000). However, the firms in Group 1 seem not to be able to reap the benefits of their more extended network, which might be due to fact that their absorptive capacity is insufficiently high. Having more knowledge transfer ties with external actors implies that more knowledge and information have to be processed by the focal firm, which asks for higher levels of absorptive capacity. In view of the finding that

there are no differences between the absorptive capacity levels of the two groups, it might indeed be the case that this ability is not high enough for the Group 1 firms.

Even though the findings provided valuable insights, the study has limitations. The sample covers a large part (52%) of the firms located on this science park. Nevertheless, given a number of specifics of the South African economy (high unemployment, high crime rates, high dependency on foreign technology) and the relatively small sample, it is difficult to make general claims. In other words, the external validity of the findings is not high and is thus only applicable to The Innovation Hub situation.

As far as future research directions are concerned, it is suggested that researching the knowledge in- and outflows of science park-based firms could provide additional insights. In this research, only the inflows were explored, but by adding the knowledge outflows, a more complete picture of the (regional) impact of a science park could emerge. Furthermore, this research model could be extended by using a matched sampling approach in which on-park firms and comparable off-park firms are included. This allows for a comparison of the performance of on-park firms while controlling the performance of off-park firms. Consequently, a truer picture of the performance of on-park firms will emerge. In future research, the approach can also be used for benchmarking the knowledge exchange behaviours of firms located on science parks in emerging and developed economies. Such a comparison will increase the insights in the differences between the functioning of science parks in these regions and help to identify innovation bottlenecks.

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Chapter 4

A relational view of knowledge transfer effectiveness in small new technology-based firms: an empirical view from South Africa[6]

The open innovation model often neglects the frictions that external knowledge flows may encounter when crossing organisational boundaries. This study recognizes such barriers and investigates the impact of these barriers on knowledge transfer effectiveness by using data on small new technology-based firms located in the emerging South African economy. Empirical results show that the characteristics of interorganisational knowledge exchange relationships (organisational, technological similarity and contact frequency) do have an impact on the effectiveness of knowledge transfer. The findings stress the relevance of a relational approach, as factors derived from it act as barriers to effective knowledge transfer for small firms.

4.1 Introduction

Proponents of the so-called open innovation model argue that for most of the 20th century, firms innovated in an 'old' model of 'closed innovation' where an innovating firm 'generates, develops and commercializes its own ideas' (Chesbrough, 2006: 129). Due to globalisation and increasing complexity of technological innovation, competition has increased and in order to remain competitive, firms have shifted to an 'open innovation' model (also labelled as a 'networked' or 'distributed' innovation model) where they also draw on external sources of knowledge (Teirlinck and Spithoven, 2008; Scarbrough and Amaeshi, 2009) to complement their in-house innovative activities (Teirlinck and Spithoven, 2008). These interactions with external partners in an open collaborative

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innovation model allow knowledge and innovations to be distributed among various partners for mutual benefits (Baldwin and von Hippel, 2009). Moreover, firms that are more open to their external search of knowledge tend to be more innovative (Laursen and Salter, 2006).

Transferring knowledge between partners implies that knowledge has to cross organisational boundaries. This boundary crossing of knowledge may be less unproblematic as proponents of the open innovation model often believe, as firms may encounter frictions such as differences in organisational cultures, structures and knowledge bases inhibiting interorganisational flows of knowledge. A recent special issue of the Journal of Management Studies on interorganisational knowledge transfer (see Easterby-Smith et al., 2008) proposes that future research in interorganisational knowledge transfer should focus on the role of organisational boundaries. There, it is stated that the arduous relationship between the source and recipient of knowledge was one of the most important barriers to knowledge transfer and this arduous relationship is more likely to be present between two organisations than between two organisational units. Consequently, conducting a study on these crossing boundaries issue is relevant and timely.

The study of interorganisational knowledge flows asks for a relational perspective because the characteristics of the sender and receiver and their dyadic relationship matter for the outcomes of knowledge transfer (Cumming and Teng, 2003). In such a perspective, organisations are viewed as embedded in and consisting of internal and external networks of relations. Moreover, in this relational perspective it is believed that relationships and their characteristics (the quality of exchanges, trust or knowledge transfer, etc.) are relevant for understanding organisational behaviour and outcomes. This perspective represents a move "away from individualist, essentialist and atomistic explanations towards more relational, contextual and systematic understanding" (Borgatti and Foster, 2003: 991) and will be applied in this study, which is conducted in South Africa.

Most empirical studies on interorganisational knowledge transfer are conducted in developed economies and there is a lack of such studies on small firms in emerging economies in general and in South Africa in particular. A literature search[7] resulted in very few studies about knowledge transfer for this emerging economy. The study by Van Zyl et al. (2007), for example, identified nine factors that drive knowledge transfer for R&D collaboration between university departments and industry, namely: (a) the need to extract appropriate knowledge at the right time to make critical decisions; (b) the perception that knowledge is a valuable resource; (c) the emphasis on getting a return on investment in research; (d) the need to protect knowledge for competitive advantage; (e) the need to close the knowledge gap; (f) international trade; (g) the need to protect intellectual property such as patents and trademarks; (h) geographic proximity between the knowledge source and recipient; and (i) war, terrorism and natural disasters. These drivers were identified from the literature and 74 respondents ranked the level of significance based on their experience. One of the future research directions proposed in this paper concerns the need for increasing the understanding of the effects of barriers on knowledge exchange. Three other papers found do not directly relate to knowledge transfer per se (because they are focused on technology transfer, South African MNEs and learning networks), but do, however, indicate that firms in South Africa seek and acquire knowledge across organisational boundaries (Marcelle, 2003; Morris et al., 2006; Klein and Wöcke, 2009). In Marcelle's (2003) study of technological capability accumulation in South Africa, it was found that during technology acquisition, firms use different mechanisms during technology acquisition to acquire codified and tacit knowledge. Klein and Wöcke (2009) demonstrate how four companies from South Africa progressed from their domestic base to become successful MNEs, and have found that MNEs from less competitive economies, like South Africa, are driven by the transfer of intangible knowledge across national boundaries from foreign companies in order to expand their firms internationally. Morris et al. (2006) report on the ways in which learning networks were set-up. They conclude that the interactive nature of joint cluster activities enable firms to lock into a network of

[7] Databases used were Google Scholar, SA ePublications, ScienceDirect, Swetswise, Proquest and Sabinet using the following keywords: South Africa, knowledge transfer, knowledge flows, inter-firm learning, interorganisational learning.

learning. These studies show that knowledge flows are important to South African firms, but, due to their specific foci, only give a partial picture of knowledge exchange practices. Moreover, from a methodological point of view, it can be observed that most of these studies used small N case study methodologies and only the study by Van Zyl used descriptive statistical analyses. Consequently, it is hard to draw generalisable conclusions about the knowledge exchange behaviour of firms in South Africa because large N studies on interorganisational knowledge transfer that use more advanced statistical methods are lacking.

Drawing from the arguments presented above, the research question addressed in this study reads: To what extent do characteristics of interorganisational relationships between sender and receiver of knowledge influence the effectiveness of knowledge transfer for NTBFs in South Africa? New technology-based firms (NTBFs) are chosen as the unit of analysis because they are often regarded as knowledge-intensive organisations for promoting developing countries' knowledge-based economies. This study defines NTBFs as "young small companies founded by an entrepreneur or a team of entrepreneurs with a strong educational or professional background which are involved in the development, application and commercial exploitation of an innovative idea based on technological know-how" (Livieratos, 2009: 247).

By answering the above research question, this study contributes to the field in five ways. Firstly, it adds value to the studies on interorganisational knowledge transfer. In Becker and Knudsen's (2003) review on knowledge transfer literature in high-impact and key journals, it is stated that the majority of papers (60%) focus on intra-firm knowledge transfer. This is clearly a sign of a lack of studies of knowledge transfer in an interorganisational context. Moreover, regarding the level of the dyad, it was suggested that a more fine grained description of the characteristics of the relationships be developed. This will be done in this study. Secondly, this empirical study uses a relational approach to understand the effectiveness of knowledge transfer. Many studies in interorganisational knowledge transfer have focused on characteristics of knowledge that hinder or ease the transfer of knowledge (Mclnerney, 2002; Argote et al., 2003; Simonin, 2004), structural characteristics of knowledge networks (for example, sizes of

networks, node members in the network structure, linkage patterns; see: Fukugawa, 2005; Tang et al., 2008) and mechanisms that facilitate transfer of knowledge, for example, communication media types and team structures (Persson, 2006; Schwartz, 2007). Focusing on the characteristics of knowledge exchange relationships extends the knowledge of this field. Thirdly, previous studies are primarily focused on knowledge transfers of firms in developed countries such as the USA and the UK. This study will contribute to the knowledge transfer studies in emerging economies. Fourthly, this study focuses on the knowledge effectiveness in small NTBFs. Effective knowledge inflows are of crucial importance to such firms, because, due to a liability of smallness, these firms often lack valuable (knowledge) resources and the resources to manage a large external network (Baum et al., 2000). Fifthly, as compared to previous studies done in South Africa, which used mostly case studies as research methodologies, this study applies more advanced statistical tools (multivariate regression analyses) to explore the relational aspects of interorganisational knowledge transfer between firms in South Africa. The last two contributions add to the further generalisability of findings on interorganisational knowledge transfer.

This empirical chapter is organised as follows. In the next section, the theoretical framework and the hypotheses are developed. Section 3 describes the research methodology used. Section 4 discusses the results of a survey on NTBFs which the authors carried out in the South African province of Gauteng in 2008, focusing on the relational characteristics and the usefulness of knowledge received. Section 5 provides some concluding remarks and recommendations for policy makers and further studies.

4.2 Theoretical framework

Knowledge is often regarded as a type of resource that differs from physical resources. It does not depreciate quickly and is accumulated overtime. It is intangible and dynamic because it is embedded in people and processes. This resource can be acquired and developed within an organisation (for example, between units) or through knowledge transfer between and learning from other

organisations (for example, inter-firm knowledge transfer via joint research). In the past, many researchers have recognised knowledge as a valuable resource for firms (Argote and Ingram, 2000, Ichijo and Nonaka, 2007) because knowledge development and application enhance firm performances and innovativeness (Van Wijk, 2008). Compared to intra-firm knowledge transfer, inter-firm knowledge transfer is more difficult and complex mainly due to the "arduous relationship" between two firms (Easterby-Smith, et al., 2008: 685). Interorganisational knowledge exchange takes place between legally independent organisations and can therefore be viewed as a hybrid arrangement in which goals, identities, and cultures of the exchanging organisations are combined and in which traditional hierarchy governance is absent. The hybrid nature of these transfer relationships has a number of implications for the effectiveness of knowledge transfer. On the positive side, complementarities between exchanging actors can promote learning and synergy as a result of the coming together of experts from different backgrounds. On the negative side, effective transfer can be inhibited due to a number of barriers. For example, when too many competitive elements are present in the exchange relationship, reconciling different organisational identities may turn out to be too complex, levels of receptivity may be too low, or a lack of experience or capacity to acquire and absorb externally acquired knowledge (Child 2001: 659), impedes harvesting the benefits of knowledge transfer. In this study, the focus is on a number of these barriers, as they are regarded as crucial for effective knowledge transfer (Child, 2001).

The theoretical discussion starts with a description of the dependent variable in the model: the effectiveness of knowledge transfer.

4.2.1 Effectiveness of knowledge transfer

When knowledge is transferred from the sender to the recipient, the quality of such transfer can be based on the "level of the knowledge utilisation by the recipients" (Minbaeva et al., 2003: 592) where "utilisation" refers to how a firm uses the received knowledge for its innovative activities. When one evaluates the benefits of the knowledge received by the recipient, one should not only take into account

the quantity of knowledge flow, but also the value of using such knowledge (Soo and Devinney, 2003; Ambos and Ambos, 2009). In the past, researchers used the "usefulness' of transferred knowledge as assessed by the recipients as a key element in knowledge transfer effectiveness. For example, Brachos et al. (2007) proposed the concept of "perceived usefulness of knowledge" to indicate knowledge transfer effectiveness. Pérez-Nordtvedt et al. (2008) construed "comprehension" and "usefulness" as reflecting knowledge transfer effectiveness. Ambos and Ambos (2009) quoted Minbaeva et al. (2003: 587) who stated that “the key element in knowledge transfer is not the underlying knowledge, but rather the extent to which the receiver acquires potentially useful knowledge and uses this knowledge in own operations”. Drawing on the above, in this study the usefulness of knowledge received is used as an indicator to represent the level of effectiveness of knowledge transfer.

4.2.2 Key elements of dyadic relationships and the effectiveness of knowledge transfer

In a relational approach of the transfer of knowledge one can focus on three dimensions: (i) properties of units, (ii) the relationships between units and (iii) the knowledge exchanged between units (Argote et al., 2003). To explain these dimensions and their relationship with the effectiveness of knowledge transfer in more detail, it is necessary to first focus on the distinction between so called attribute and relational variables. Attribute variables are variables that can take certain values in the absence of interorganisational relationships. Examples are the size and age of an organisation or the economic activities a firm conducts. Relational variables are variables that only exist if an interorganisational relationship exists. Examples of the latter are trust, partner confidence, partner similarities, dependencies, and knowledge transfer. Once the relationship seizes to exist, the same happens to a relational variable. In the next subsections, a number of relational and attribute dimensions, namely: partner (dis)similarities, frequency of knowledge transfer, learning culture, are discussed and related to the dependent variable.

4.2.2.1 Partner (dis)similarities as barriers to effective interorganisational knowledge transfer

In a literature study on partner (dis)similarities by Knoben and Oerlemans (2006), three types are distinguished: geographical, technological and organisational (dis)similarities. If one looks at the (dis)similarity between two parties, one assesses the impacts of the distance between certain characteristics of the two exchanging parties. In this study, two relational (dis)similarities are explored: technological and organisational (dis)similarity. Geographical dimensions cannot be included because all firms in the sample are located in Gauteng; consequently this dimension cannot vary.

Relationships between organisational phenomena are fuelled by the effects of aggregated micro-level processes. Therefore, before specific hypotheses are presented, first a general micro-level theoretical mechanism explaining the negative impact of partner dissimilarity on knowledge exchange effectiveness is presented. In other words, partner dissimilarity is regarded as a barrier to knowledge exchange. Basically, the concept of partner (dis)similarity is a specification of the more general concept of differentiation. According to Child (2001), many barriers to knowledge exchange emerge from the external differentiation between organisations. Differentiation forms the basis of distinct social identities and perceptions of competing interests. When two or more independent organisations form a knowledge exchange relationship, such barriers are strengthened by, for example, different organisational or national cultures and knowledge bases. Hamel (1991) argues that these barriers reduce "transparency", that is, the openness of one actor to the other, and its willingness to transfer knowledge. In turn, this is caused by the “divergent ways of sense-making associated with the social identities of the different parties” (Child, 2001: 670) that are involved in a knowledge exchange relationship. When members of different organisations meet to exchange knowledge, they carry their own social identities and backgrounds with them. These identities are sets of meanings that are shaped by an individual’s interaction with different reference groups (work group, organisation, community, nationality, etc.). When these identities are very dissimilar, the knowledge sent by one party will clash with the mental constructs

and norms of conduct of the receiving party. Therefore, the larger the dissimilarity between these identities, the larger the distance between the parties involved, the lower the "transparency", and the more likely it is that the quality of the transfer is impeded.

Organisational (dis)similarity is defined as the distance between "the sets of routines – explicit or implicit – which allows coordination without having to define beforehand how to do so. The set of routines incorporates organisational structure, organisational culture, performance measurements systems, language and so on" (Knoben and Oerlemans, 2006: 80). Lane and Lubatkin (1998) state that similarity of firms' organisational structures and policies contributes to firms' abilities to interactively learn from each other. Firms who are similar organisationally share common language or communication processes and are able to reduce the cost associated in transferring the knowledge (Cohen and Levinthal, 1990) and hence possess more resources for trying to understand and use the knowledge received. If organisational dissimilarity acts as a barrier to effective knowledge transfer, the following hypothesis can be formulated:

Hypothesis 1: Organisational similarity is positively related to the usefulness of the knowledge received.

Technological (dis)similarity refers to the extent to which there are differences between exchanging actors' technological knowledge bases; in other words, the level of similarity of their knowledge bases. Transferring knowledge that differs too much in its technology domain can cause difficulties for the recipient in understanding and using the knowledge received because the recipient firm does not have the mutual understanding needed to absorb the knowledge exchanged. In other words, the recipient's prior knowledge base is not relevant to further explore the knowledge received for its innovative use. Technological similarity enhances the likelihood of knowledge transfer between collaborating firms (Rosenkopf and Almeida, 2003) because they are more able to understand common problems and better use the complementary knowledge to solve those innovative challenges. Moreover, alliances with partners who are technologically similar can promote the development of incremental innovations (Quintana-Garcia

and Benavides-Velasco, 2010). Despite the advantages that are brought into the firm by exchanging similar knowledge, too much similarity between knowledge bases may lead to 'lock-in', which may obscure the view on new technologies (Boschma 2005). It is argued that when people with different knowledge bases interact, they help each other to stretch their knowledge (Nooteboom et al., 2007) and provide openness that triggers new ideas (Boschma, 2005). In other words, there is nothing new to learn between partners with too much similarity in their knowledge bases, thus the knowledge they receive may not be so useful for innovative outcomes. Thus, very low and very high levels of technological similarity can act as barriers to effective knowledge transfer, whereas medium levels allow for both newness and understandability. The following hypothesis can thus be formulated:

Hypothesis 2: There is an inverted U-shaped relationship between technological similarity and usefulness of knowledge received.

4.2.2.2 Frequency of knowledge transferred as a barrier

The third relational dimension of knowledge transfer is the frequency with which transfer occurs. Tacit knowledge as compared to explicit knowledge is more difficult to articulate (Polanyi, 1966) because it is difficult to encode by writing and is resided in the firm's system (people and processes). Therefore it is not easy to interpret and transfer from one to another. Yet, tacit knowledge plays an important role in innovation processes (Koskinen and Vanharanta, 2002; Cavusgil et al., 2003; Rebernik and Širec, 2007). Tacit knowledge is viewed as "best delivered through individual, face-to-face contact" (Ganesan et al., 2005: 47). Frequent communication enables the receiving firm better to understand the knowledge that it receives (Szulanski, 1996) and increases the chances that the knowledge is useful for the firm's innovations. Moreover, frequent interactions improve mutual trust between exchanging parties (Atuahene-Gima and Li, 2002; Adobor, 2006) and as a result, the level of tacit knowledge utilisation is enhanced (Koskinen, Pihlanto and Vanharanta, 2003). Conversely, infrequent transfers of knowledge inhibit the understanding of tacit knowledge and the development of trust. Thus,

Hypothesis 3: Frequent knowledge transfer is positively related to the usefulness of the knowledge received.

4.2.3 Attribute variable as a barrier: the knowledge receiver's learning culture

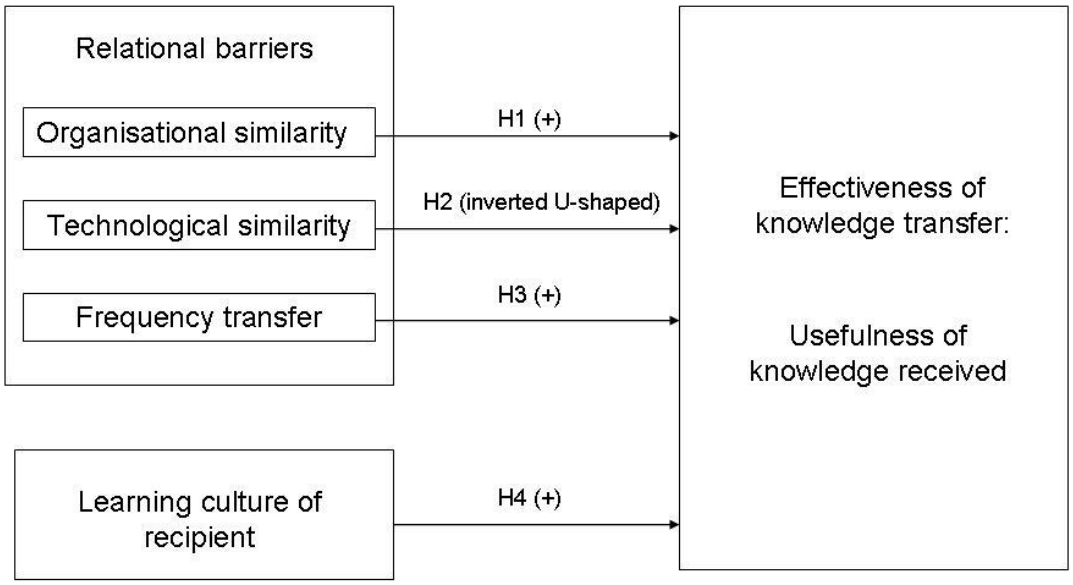
Becker and Knudsen (2003) point out that "absorptive capacity" is an important property of the recipient. This concept was firstly introduced by Cohen and Levinthal in 1990, when they recognised it as firms' fundamental learning processes, that is, their ability to identify, assimilate and exploit knowledge from the environment. In 2002, Zahra and George proposed additional definitions that separated Cohen and Levinthal's definition of absorptive capacity into (1) a broad set of skills needed to deal with the tacit component of transferred knowledge and the need to modify this transferred knowledge and (2) the capacity to learn and solve problems. Cummings and Teng (2003) pointed out that those firms with a supportive learning culture (which corresponds to Zahra and George's second definition: the capacity to learn and solve problems), have more slack to increase the richness of knowledge transferred; do not have the "not-invented-here syndrome" which prevents recipients from accepting outside knowledge; and have the people to retain, nurture and develop the knowledge received. Recipient firms who have a learning culture are therefore more able to explore the received knowledge further and put it into use for better innovative outcomes, whereas the opposite is proposed for recipient firms lacking such a culture. Thus,

Hypothesis 4: The learning culture of the recipient is positively related to the usefulness of the knowledge received.

As depicted in the research framework in Figure 4, the three relational features (frequency of knowledge transferred, organisational proximity and technological proximity) influence the usefulness of knowledge received as assessed by the recipient firm. The learning culture of the recipient firm, as an attribute variable, also impacts on the usefulness of the knowledge received. Some other attribute

variables are included as control variables and described in the methodological section of this chapter.

Figure 4: Research model



4.3 Research methodology

4.3.1 Sample and data collection

This study empirically explores a relational knowledge transfer model in an emerging economy. The unit of analysis is NTBFs located in the Gauteng region of South Africa. This region was chosen because it is one of the few regional systems of innovation that is well developed in the South African context (Lorentzen 2009). This implies that there are minimum levels of linkage among subsystems in this region, which is a necessity for studying knowledge transfer.

This research applies a quantitative research methodology. Questionnaires were used during face-to-face interviews (to assist in the completion of the questionnaires) with 52 NTBFs located in Gauteng. The CEOs or directors (units of observation) of these firms were asked to answer questions based on the relational characteristics of their knowledge transfer links with their external sources (suppliers, buyers, consultants, competitors, universities, public labs, innovation centres and sector institutes). The collected data were statistically analysed by applying multivariate regression analyses in SPSS, which fits the additive research model.

4.3.2 Measurements

Table 7 illustrates the items that were used in the questionnaire to measure the variables proposed in the conceptual model. All of the items were based on previous measures proposed in the literature using a five-point or seven-point Likert scale. Table 8 shows the literature that was sourced to construct the measurements, as well as the reliability statistics (Cronbach's alpha) of the scales used[8]. Most variables have Cronbach's α's ≥ 0.6, which suggests a high level of internal consistency.

The recipient's firm size, age, firm type and (science park) location were included as control variables. Firm size and firm age were controlled, since these two firm attributes have been recognised as important factors in the knowledge transfer literature (for example, Bresman et al., 1999; Agarwal and Gort 2002; Cavusgil et al., 2003). A firm needs time and people to acquire knowledge, therefore these two variables affect the accumulation of a firm's knowledge base, which determines its absorptive capacity to understand and use the knowledge received. Moreover, firm type (either a service provider or not) was included because, in certain industries, firms develop specific knowledge strategies and human resource practices (Laursen and Mahnke, 2004), which, in turn, influence the transfer of knowledge

[8] A reliability test was done on the variables which had multiple items to determine how well the items measured a single, uni-dimensional latent construct. This procedure was performed for all relevant variables and the results are shown in the last column of Table 8.

process. Finally, "science park location: y/n" was controlled because out of 52 NTBFs that were surveyed, 24 firms are situated in The Innovation Hub, which is the first South African science park accredited by the International Association of Science Parks (IASP) in South Africa. In the literature, it is maintained that science parks have many benefits for firms (Fukugawa, 2005). In particular, the knowledge exchange opportunities on science parks, which are due to co-location, are mentioned in the literature. Besides close geographical distance, these science park firms may also benefit from the support of the science park management to establish knowledge linkages. Thus, a science park plays a role in knowledge transfer between the firms located on the science park premises.

Table 7: Item(s) of variables

Independent variables	Item(s)
Frequency of knowledge transferred	How often does your firm access knowledge from its most important partners (suppliers, buyers, consultants, competitors, universities, public labs and sector institutes)? (5-point Likert scale: never, rarely, sometimes, regularly or always)
Organisational similarity	Our firm has contacts with the same third parties as our partners have. Our partners have the same organisational routines and values as our firm. Our partners have the same organisational structure as our firm. (5-point Likert scale: 1 = completely disagree, 3 = neither agree nor disagree, 5 = completely agree)
Technological similarity	To what extent is the knowledge your firm receives from the most partners/actors similar to your firm's own knowledge? (7-point Likert scale: 1 = not similar to 7 = completely similar)
Learning culture	Indicate level of agreement with the following statements: (1) most of our staff is highly skilled and qualified; (2) we invest a great deal in training; (3) we have the capacity to adapt others' technologies; (4) we have considerable resources and our own knowledge resources for technological development. (5-point Likert scale: 1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree)
Dependent variable	**Item(s)**
Usefulness of knowledge received	How useful is the knowledge your firm receives from the most important partners with regard to your firm's innovations? (5-point Likert scale: 1 = not useful to 5= completely useful)
Control variables	**Item(s)**
Firm size	Total number of employees in 2007, including the CEOs and directors.
Firm age	Number of years a firm exists.
Firm type	Is this firm a service provider or does it carry out other activities?
SP location	Is the firm located in The Innovation Hub (a science park in Gauteng)?

Table 8: Measurements, their sources, and reliability statistics

Variables	Source (where applicable)	Measurement and Cronbach's α in this research (where applicable)
Frequency of knowledge transferred	Source not applicable (n/a)	One item using 5-point Likert scale
Organisational similarity	Knoben and Oerlemans (2008)	Average sum score of all three items using 5-point Likert scale Cronbach's α = 0.817
Technological similarity	Cassiman et al. (2005)	One item using 7-point Likert scale
Learning culture	Nietoa and Quevedo (2005) Cummings & Teng (2003)	Average sum score of all four items using 5-point Likert scale Cronbach's α = 0.613
Usefulness of knowledge received	Soo and Devinney (2004)	One item using 5-point Likert scale
Firm size	Source n/a	Count of the total number of employees in 2007
Firm age	Source n/a	2008 (the year when this research was conducted) minus the founding year of the firm

4.4 Data analyses and findings

Means and standard deviations associated with the variables are provided in Table 9. On average, firms in the sample have received useful knowledge, especially from buyers and suppliers (mean value of 1.82). The usefulness of knowledge received from public research labs and sector institutes is regarded as relatively low (mean values of 0.26 and 0.39 respectively). By exploring this table further, it is evident that sample firms interact most frequently with suppliers and buyers (with mean values of 1.3 and 1.35 respectively) and the least with public research labs and sector institutes (with mean values of 0.13 and 0.23 respectively). Similarly, sample firms have higher levels of technological similarity with (are technologically closer to) their suppliers and buyers rather than with

public research labs and sector institutes. The average score for the three items on organisational similarity ranges from 1.71 to 2.21, which shows that the sample firms are close to halfway (on a scale of 1 to 5) similar to their partners organisationally. The averages of firm age and size are 5.13 years and 9.25 employees respectively. This shows that the sample firms are young and small. Of the sample firms, 76.9% come from the service provider industry and 46.2% of the firms are situated in The Innovation Hub.

The analysis aimed to determine if the eight items in the dependent variable "usefulness of knowledge received" could be combined into a single scale, because this would simplify the analyses. The Cronbach's alpha for these eight items is 0.729 and deletion of one of the items does not increase the alpha. This is, therefore, a highly reliable scale and it was decided to take the average sum scores of all eight items to measure "usefulness of knowledge received". Similarly, a reliability test was conducted on the independent variable "technological proximity" and the alpha of 0.573 suggests that the average sum scores of all eight items resulted in a reliable scale. The items in "frequency of knowledge transfer" were entered in a principal component factor analysis that produced a three-factor solution (*KMO* = 0.621; Bartlett = 44.291; *p* = 0.026); within which the third factor only contained one high-loading item. Table 10 shows the results where a new factor analysis was conducted by excluding this item ("frequency of transfer with innovation centres"), as this item has very low communality.

This new factor analysis produces two factors that were further interpreted as "frequency of knowledge transfer with business partners" and "frequency of knowledge transfer with research institutes". The corresponding *KMO* is 0.605 with *p* equalling 0.016, indicating that this solution fits the data well. Factor analysis was also done on the independent variables "organisational proximity" and "learning culture" and both yielded single-factor solutions (*KMO* = 0.573 with *p*= 0.002; *KMO* = 0.656 with *p*=0.000) respectively.

Table 9: Means and standard deviations

Independent variable		Mean	S.D.
Frequency of knowledge transfer	with competitors with buyers with suppliers with innovation centre with public research labs with university with consultant with sector institutes	0.50 1.35 1.30 0.34 0.13 0.55 0.88 0.23	0.69 0.83 0.95 0.73 0.37 0.82 0.89 0.55
Organisational similarity	same third parties same routines and values same structure	2.05 2.21 1.71	1.16 1.01 0.99
Technological similarity	with competitors with buyers with suppliers with innovation centre with public research labs with university with consultant with sector institutes	1.43 1.89 2.14 0.54 0.29 1.21 1.54 0.46	1.81 1.41 1.81 1.19 0.76 1.77 1.55 1.09
Learning culture	presence of slack no not-invented-here syndrome train for retention	3.60 3.94 3.77	1.11 0.80 0.83
Dependent variable		**Mean**	**S.D.**
Usefulness of knowledge received	from competitors from buyers from suppliers from innovation centre from public research labs from university from consultant from sector institutes	0.99 1.82 1.82 0.48 0.26 0.94 1.33 0.39	1.38 1.21 1.44 1.01 0.65 1.36 1.25 0.93
Control variable		**Mean**	**S.D.**
Firm size Firm age Firm type SP location		9.25 5.13 0.77 0.46	9.91 3.61 0.43 0.50

Table 10: Factor analysis for frequency of knowledge transfer

Independent variable		Component	
		1	2
Frequency of knowledge transfer	<u>with business partners:</u>		
	with competitors	0.598	
	with buyers	0.678	
	with suppliers	0.728	
	with consultants	0.676	
	<u>with research partners:</u>		
	with public research labs		0.651
	with universities		0.821
	with sector institutes		0.532

Ordinary multivariate least squares regression was used to test hypotheses 1 to 4. Variables were entered in the models in three steps:

Model 1: Model with only the control variables

Model 2: Model 1 + the two frequency of knowledge transfer variables

Model 3: Model 2 + organisational similarity + technological similarity + learning culture

In Table 11, the Variable Inflation Factor (*VIF*) values associated with variables in the regression models were lower than 10, indicating that serious multicollinearity problems do not exist in these models. In the first model, the main effects of the control variables are shown. Firm size, firm age and firm type do not impact significantly on the usefulness of knowledge received by the recipient firm. Interestingly, the variable SP location was significant at $p < 0.1$, indicating that this version of the model shows that firms located on a science park found the knowledge they received from their partners to be more useful for their innovative activities; whereas firms without a science park location found the knowledge they received from their partners to be less useful. The control variables resulted in an R^2 of 0.062 and an insignificant model (*F*-value change = 0.775, not significant).

Table 11: Regression models

Variables	Dependent variable: Usefulness of knowledge received		
	Model 1	**Model 2**	**Model 3**
Constant	0.932***	1.149***	0.620**
Control variables			
Firm size	-0.047	-0.172**	-0.066
Firm age	0.003	0.088	0.047
Firm type	-0.026	-0.059	0.050
SP location	0.266*	0.136	0.033
Independent variables			
Freq business partners		0.729***	0.360***
Freq research institutes		0.479***	0.196***
Organizational similarity			-0.113*
Technological similarity			-0.086
Technological similarity squared			0.635***
Learning culture			-0.035
R^2	6.2%	77.6%	86.3%
ΔR^2	6.2%	71.4%	8.7%
F-value	0.775	25.946***	25.798***
ΔF-value	0.775	71.629***	6.511***

$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$

Frequency of knowledge transfer with business partners and frequency of knowledge transfer with research institutes were added in the second step (Model 2) and these two variables were statistically significant at the $p < 0.01$ level. In this model, the control variable of "firm size" has a negative and significant impact on the usefulness of knowledge received ($p < 0.05$). Model 2 has a better fit compared to Model 1 because the significance of the regression model as a whole improved to R^2 of 0.714 (F-value change = 71.629, $p < 0.01$). The effects of the independent variables in Model 2 accounted for approximately 71.4% of the variance in the usefulness of the knowledge received.

In the third step (Model 3), adding the other four independent variables (organisational similarity, technological similarity, technological similarity squared and learning culture) resulted in an R^2 of 0.863 (F-value change = 6.511, $p < 0.01$). In Model 3, all control variables are not statistically significant. The two variables for frequency of knowledge transfer remain to have positive and significant ($p < 0.01$) impacts on usefulness of knowledge received, which supports the third hypothesis: frequency of knowledge transfer is positively related to usefulness of knowledge received. However, organisational similarity has a negative value with significant level of $p < 0.10$, which implies a rejection of the first hypothesis. Apparently, focal firms find knowledge received from actors who are organisationally more dissimilar from them more useful. Technological similarity has no significant impact, but its squared term positively influences the usefulness of the knowledge received at a significant level of $p < 0.01$ and thus the second hypothesis is rejected. On the contrary, a U-shaped relationship between technological similarity and usefulness of knowledge received was found. In the next section, this finding will be interpreted. Learning culture is not statistically significant and therefore the last hypothesis is rejected.

4.5 Conclusions and recommendations

The open innovation literature embraces the benefits of external knowledge transfer to the generation of innovations but often neglects that interorganisational knowledge transfer faces frictions and barriers due to the fact that knowledge has to cross organisational boundaries. This study acknowledges the possibility of less effective transfer of knowledge when it crosses organisational boundaries and applies a relational approach to explore knowledge transfer between firms and to build and test a theoretical model in which relational characteristics are connected to the effectiveness of knowledge transfer. The study was guided by the following research question: To what extent do characteristics of the relationships between sender and receiver of knowledge influence the effectiveness of knowledge transfer for firms in South Africa? In this section, a summary of the most important findings of this study is provided and some recommendations are given to policy makers and for future research.

To test the hypotheses, multivariate regression model analyses were performed using data collected in South Africa.

Firstly, the findings indicate that the characteristics of the interorganisational relationships between the sender and receiver of knowledge are of importance to the usefulness of the knowledge received. The fact that all three relational variables have a statistically significant impact, although not always as expected, stresses the point that a relational view contributes to the understanding of knowledge transfer processes and that relational features do act as barriers to knowledge transfer.

Secondly, it turns out that only hypothesis 3 is empirically confirmed. The negative and significant impact of organisational proximity indicates that firms interacting with organisationally more dissimilar partners find the knowledge received more useful. Consequently, hypothesis one is rejected. This finding asks for an interpretation. Possibly the finding has to do with the fact that the sample firms are NTBFs that are young and small. This kind of firm is often confronted with a liability of newness and thus encounters two problems: a lack of a large variety of different resources and a lack of external legitimacy (Singh, Tucker and House, 1986). Interacting with more dissimilar, also probably larger, firms would solve both problems for young and small technological firms because these firms will bring them status in the market and are able to provide a variety of useful knowledge. During additional interviews carried out by the authors with sample firms, some expressed their need to interact with larger, dissimilar players in their field. This negative impact of organisational similarity found in this study is actually different from what was found in previous studies (for example, Cummings and Tseng, 2003) where organisational similarity played a positive role. In other words, the South African context seems to bring specific demands in terms of organisational dissimilarity to young technology-based firms.

Technological similarity, the second relational characteristic in the model, turned out to have a U-shaped relationship with the usefulness of the knowledge received. Hence, the second hypothesis is rejected. On the one hand, this finding

showed that the responding South African firms feel that the knowledge they receive from other firms with very similar knowledge bases results in high levels of knowledge usefulness. This may be related to the imitative innovations found among many South African firms (Oerlemans et al., 2004). Generating imitations is relatively easy with external knowledge that is very similar: it is easy to understand and can be applied quickly. In this study it is found, on the other hand, that, in the South African environment, external knowledge from a 'totally different' knowledge base is also perceived to be highly useful. One can interpret this right-hand part of the U-shaped curve as representing a firm that may wish to explore the possibilities of totally different ideas for innovation. Thus, totally new knowledge may bring novel ideas for the receiving firm. The result also suggests that a mixture of external knowledge from similar and distant knowledge bases will result in the lowest level of usefulness. Perhaps if a firm has a mixture (similar and distant) of knowledge, then it is indecisive as to which area it should focus on for its innovative direction. The above interpretations can be validated in the future research by asking open questions to South African firms with regards to the reasons for their choices on various degrees of technologically proximate or distant partners.

The third relational feature in the model, frequency of knowledge transfer, impacts positively on the effectiveness of knowledge transfer, which confirms hypothesis three. This holds in particular for the frequency of interaction with buyers and suppliers. When two partners exchange knowledge more often, they are able to gain more information from their partner, which reduces uncertainty about future behaviour, increases trust, and brings about clarity on how partners will deal with each other. As a result, partners can exchange knowledge more easily and effectively. Similar results were reported in a meta-study by Palmatier, Dant, Grewal and Evans (2006).

Learning culture had no significant impact on the usefulness of knowledge received and thus hypothesis four was not supported. South African firms often innovate by imitating other firms (Oerlemans et. al., 2004). Even though the firms may have, on average, a satisfactory learning culture (for example, they invest in training, have highly qualified staff, and have a context in which sharing knowledge

is valued), the use of these capabilities is often not directed at developing organisational learning, but directed at applying the knowledge developed by others.

Recommendations to policy makers in emerging economies, including South Africa, are threefold. Firstly, the governments were advised to put more efforts into attracting more (key) players from other economies to their targeted regions of technology and science development in order to increase the number of possible partners and thus providing more opportunities to the NTBFs in the region to network. Secondly, from this study it can be concluded that there is a lack of interaction between NTBFs and research institutions such as public research labs or universities where fundamental scientific knowledge lies for radical innovations. Therefore, countries with emerging economies should take the initiative more in linking the industry and the research institutions, not only in a limited manner in the context of science parks, but also in the entire region to enhance regional innovations. Thirdly, the results of the study show that collaborating with technologically similar and organisationally dissimilar partners increases the effectiveness of knowledge transfer. From a managerial perspective, this means that relationship management is important because selecting and maintaining effective relationships with partners is crucial (Rothaermel and Deeds, 2006). Training programmes for developing capabilities for relationship management or appointing network brokers could be beneficial to young, technology-based firms.

This research model focuses on "intentional" knowledge transfer, in other words, both parties are aware that knowledge is been transferred during their interactive activities (for example, during formal or social interactions). However, due to the imitative behaviours of most South African firms, "unintentional" knowledge spillover can be observed. In the previous studies, it was shown that unintentional flow of knowledge also brings innovative benefits to recipient firms (Fallah and Ibrahim, 2004; Oerlemans and Meeus, 2005). One could apply this model by taking "usefulness of unintentional knowledge received" as a dependent variable to explore the knowledge spillover in regions of developing countries.

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Chapter 5

Knowledge transfers between and innovative performances of NTBFs in South Africa: an attempt to explain mixed findings in science park research[9]

Science parks are often established to drive regional economic growth, especially in countries with emerging economies. However, mixed findings regarding the performances of science park firms are found in the literature. This study tries to explain these mixed findings by taking a relational approach and exploring (un)intended knowledge transfers between new technology-based firms (NTBFs) in the emerging South African economy. Moreover, the innovation outcomes of these NTBFs are examined by using a multi-dimensional construct. Results show that science park location plays a significant role in explaining innovative sales, but is insignificant when a different indicator of innovation outcomes is used. Furthermore, only for innovations that are new to the firms, both science park location and intended knowledge transfer via informal business relationships have a positive impact; whereas social relationships have a negative impact.

5.1 Introduction

Science parks are not a new phenomenon. The concept can be traced back to the 1950s when Silicon Valley, with the support of Standford University, transformed from an agricultural valley into the birthplace of the semiconductor and ICT industry. Following the USA experience in the 1960s, the development of Cambridge Science Park (UK) and Sophia Antipolis (France) have set good examples for many European countries. The majority of the science parks currently existing in the world were created during the 1990s and about 18% of these science parks werelaunched in the first two years of the new century. Today

[9] This chapter has been submitted in a slightly different format as Chan, K.Y., Oerlemans, L.A.G. and Pretorius, M.W. (submitted). Knowledge transfers between and innovative performances of NTBFs in South Africa: an attempt to explain mixed findings in science park. *South African Journal of Economic and Management Sciences.*

there are over 400 science parks in the world, primarily concentrated in developed economies, with over 140 founded in North America.

The reason behind this rapid growth of science parks around the world is the belief, mostly by policy makers in industrialised economies, that the establishment of these parks will promote economic growth and competitiveness of cities and regions by creating new business, adding value to companies, and creating new knowledge-based jobs (The International Association of Science Parks). The founding of a science park is often used as a policy intervention to stimulate high-technology start-ups (McAdam and McAdam, 2008). It is where government provides infrastructure, industry provides business skills and funding, and universities provide research knowledge and new technology development; also known as the Triple Helix of university-industry-government relations for innovation (Etzkowitz and Leydesdorff, 2000). An important function of any science park is to contribute to the establishment of a knowledge-based economy by fostering market-orientated technological development. This type of economy depends on three interrelated processes: local knowledge creation, transfer of knowledge from external sources and transformation of that knowledge into productive activities and valued outcomes (Chen and Choi, 2004). Consequently, networking between firms and between firms and universities to transfer knowledge and foster collaboration and innovation are vital processes for science parks.

Despite the benefits that science parks might bring, researchers have been studying the science park phenomenon to analyse to what extent science parks are just "high tech fantasies" (Massey et al., 1992; Bakouros 2002) or not (Yang et al., 2009). To ascertain the "added value" of a science park location, researchers believed comparative studies should be conducted (Westhead, 1997; Lindelöf and Löfstsen 2004). These studies compared behaviour and performance of firms located on a science park with those of firms not located on a science park to explore the potential differences between them. Interestingly, in this literature researchers have reported mixed empirical findings on the performance of science park firms. Some researchers found empirical evidence of the "added value" of science park location (for example, Felsenstein, 1994; Lindelöf and Löfstsen, 2004), whereas others clearly questioned the assumed benefits of the science

park model (for example, Westhead, 1997; Malairaja and Zawdie, 2008). The latter group of scholars found that there are no differences between on-park firms and off-park firms in terms of their performance. Further details of these comparative studies will be elucidated in a later section. From the observations of these studies it can be concluded that there are mixed findings regarding the performance of science park firms. The mixed evidence in the empirical literature inspired the following question to be asked: How can one explain these mixed findings? While contemplating this question, it came to mind that two general types of knowledge transfers reach science park firms: intended and unintended. It might be that the interplay of the two could lead to an answer to the question. Perhaps the occurrence of unintended, thus unsolicited, knowledge transfers impact negatively on the level of intended knowledge transfers between firms. Consequently, this interplay leads to lower overall interorganisational knowledge transfers, and probably to lower performance levels. Hence, the research question of this study was put forward:

To what extent do intended/unintended knowledge transfers explain the innovative performance of science park firms?

This study contributes to the science park literature in three ways. Firstly, the most important contribution of this study is the explanation of the mixed empirical findings that exist in the science park literature. This chapter will explore the link between knowledge transfers and firm innovativeness to explain the mixed findings found in the literature. In this way, two largely separate branches of literature, on interorganisational knowledge transfers and on knowledge spillovers, are combined in one study. Secondly, most science park studies use "patents" and "new products/services" (for example, Westhead, 1997; Siegel et. al., 2003; Akçomak and Taymaz, 2004) as indicators of firms' innovative performance. These indicators only give a partial view of innovative firm performance. In this study, innovative performance is conceptualised as a multidimensional construct and is thus measured with multiple indicators to obtain a more holistic view of innovative performance of science park firms. Thirdly, most science park studies are conducted in developed economies, whereas this study is performed in an emerging economy (South Africa). In developed economies, science parks are

often more easily and better connected to the rest of the system of innovation. In many cases, this is not true for emerging economies (Lorentzen, 2009) that often lack a well-developed and connected system of innovation. Consequently, firms located on science parks in emerging economies have to focus more strongly on interaction with partners located on the same science park. Interaction with spatially proximate partners brings certain benefits, but also some potential disadvantages (Knoben and Oerlemans, 2006). By sorting out these benefits and disadvantages, this study adds to the literature on geographical proximity.

This empirical chapter is organised as follows. In the next section, the results of a literature review on the performance of science park firms will be presented. In Section 3, the theoretical framework of this study and relevant hypotheses will be developed. Section 4 describes the research methodology that is applied in this study. Section 5 discusses the results of analyses of data on new South African technology-based firms (NTBFs), focusing on firms' knowledge transfer behaviours and innovative performances in 2007. Section 6 provides concluding remarks and recommendations for policy makers and further studies.

5.2 Science parks and mixed findings: a literature review

What is known in the recent literature about the performance of science park firms? To answer this question, a literature search was conducted using Google Scholar, Science Direct, Swetwise and Proquest as search engines. Key words used were "on-park firms", "off-park firms", "science park performance", "science park evaluation", "benefits of science park" and "added values of science park". The main purpose of this literature review was to get an overview of the empirical results from past studies regarding science park firms. The details of the review are summarised in this study (Appendix 2). Besides the names of the author(s), the following criteria were included:

- Country and period: Where and when was the research conducted? In particular it was important to know in which country a study was conducted, as collaborating cultures differ between countries.

- Research focus: Which research questions do studies try to answer? From this column one can deduce the various foci the researchers used and where gaps might exist.
- Research methodology: Which research methodologies do studies apply to answer their research questions empirically? From these two columns the most commonly used research methodology could be explored. This gives an indication of the maturity of the field. Moreover, one can learn from these approaches in the study.
- Key results: Regarding the aspects studied; do on- and off-park firms differ from one another? From this column, one can see which findings on science park performance are reported in the literature.

The table in Appendix 2 summarises 13 comparative studies. One can see that Westhead, Lindelöf and Löfsten are very active researchers in this field of study. Most of the studies were conducted in the period between 2002 and 2004, using longitudinal data sets (ranging from three years to ten years), which are necessary to examine proxies of firm performance such as the "employment growth" or "survival" of firms over time. The founding of science parks increased from 1973 (IASP website) until 1987, after which a decline occurred, followed by an increase from 1997 onwards. This growth-decline-growth phenomenon in science park creation may be one of the reasons why more researchers use comparative approaches to investigate to what extent science parks have benefits.

The majority of studies were conducted in Western countries (UK, Sweden, and Italy) and only a few stem from emerging economies (Israel, Malaysia, and Taiwan). There seems to be a lack of comparative studies from emerging economies. The collaborative culture differs from country to country. Western cultures (Western Europe, North America, and Australia) are characterised as individualistic, whereas some non-Western cultures (Asian, South American, and Africa) are characterised as collectivistic (Green et al., 2005). Thus, these cultures may have an influence on how firms in a specific country interact with one another.

Studies tend to focus on three areas: (1) Employment growth (Westhead and Cowling, 1995; Colombo and Delmastro 2002; Ferguson and Olofsson, 2004;

Akçomak and Taymaz, 2004); (2) Industry-academic links (Felsenstein, 1994; Löfsten and Lindelöf, 2002; Lindelöf and Löfsten, 2004; Akçomak and Taymaz, 2004; Dettwiler et. al., 2006); and (3) Innovativeness as indicated by R&D inputs, outputs and productivity (Westhead 1997; Colombo and Delmastro 2002; Siegel et al., 2003; Akçomak and Taymaz, 2004; Yang et al., 2009).

As far as knowledge transfers are concerned, the focus is mainly on the knowledge links with local universities. Other linkages such as with business partners (for example, buyers or suppliers) or with other science park firms are often not taken into account. Moreover, researchers seem to focus on intended knowledge transfers, paying little attention to unintended knowledge transfers (knowledge spillover).

From a methodological perspective, it can be noted that most studies used a matched-sampling approach to select comparable off-park firms in line with the properties of on-park firms. The two sample sizes are more or less equal, ranging from 40 to 139 for each paired sample. This finding shows a commonly accepted way of sampling. All studies used questionnaires and surveys to collect firm-level data. One exception is Yang's study where panel data from a financial databank was used. This shows a trend in firm-level analysis to explore the performance of science parks. Most studies used the independent sample t-test for continuous and discrete variables and the Chi-squared test for dummy variables. These two statistical analysis tests are commonly used when one needs to compare variables from two independent samples and explore any significant differences between the groups of firms to show the added-value of science parks. Moreover, from this literature review it can be concluded that there is a lack of use of multivariate analysis to explore more fine-grained and complex relationships between firm characteristics and performance (for example, using multivariate regression analysis).

A comparison of the research findings in the studies in the review reveals that there are mixed findings regarding the added value to firms of science park location:

- Employment growth: Some find no significant difference between on- and off-park firms (Westhead and Cowling, 1995; Akçomak and Taymaz, 2004; Ferguson and Olofsson, 2004), whereas others report that on-park firms have a higher employment growth (Löfsten and Lindelöf, 2002; Colombo and Delmastro, 2002).
- Interactions with universities: Some report no significant difference between on- and off-park firms (Malairaja and Zawdie, 2008) and others find that on-park firms have higher levels of interaction with (local) universities (Felsenstein, 1994; Lindelöf and Löfsten, 2004).
- R&D outputs and productivity: Some find no significant difference between on- and off-park firms (Westhead, 1997; Colombo and Delmastro, 2002; Lindelöf and Löfsten, 2003 and 2004, whereas others report that on-park firms have higher R&D outputs and productivity (Siegel et al., 2003; Yang et. al., 2009).

On specific indicators studies report similar findings, but these do not support the "promises" that science parks often make:

- There are no differences between on- and off-park firms in sales/profitability (Löfsten and Lindelöf, 2002; Ferguson and Olofsson, 2004).
- There are no differences between on- and off-park firms regarding R&D inputs (Westhead, 1997; Colombo and Delmastro, 2002).

From the mixed findings observed, one can clearly see that studies show that not all science parks deliver their promises of bringing added value to their firms and connected regions. Wondering about these mixed findings, this study asks the question: How can these mixed findings be explained? In other words, why do some on-park firms outperform the off-park firms and some do not? In the next section, a framework is presented to explain these mixed findings from a theoretical point of view.

5.3 Theoretical framework

5.3.1 Key concepts defined

Knowledge is identified as a key resource for a technology-based firm's competitive advantage because it is difficult to replicate and is critical to the process of innovation (Murmann, 2003; Thornhill, 2006; Ichijo and Nonaka, 2007). In this age of increasing globalisation and complexity of technological innovation, the use of internal generated knowledge resources (for example, from in-house R&D) is no longer sufficient for technological innovation. Firms often acquire and use knowledge from external actors to complement their internal knowledge bases for innovative product or service development. Researchers have distinguished two categories of knowledge transfers: intended and unintended knowledge transfers (Fallah and Ibrahim 2004; Oerlemans and Meeus, 2005). An intended knowledge transfer is a conscious and deliberate transfer of knowledge between two or more organisations. On the other hand, unintended knowledge transfer refers to any knowledge that is transferred unwillingly by the sending firms.

In this study, the definition of innovative performance is based on one proposed by Ernst (2001): an achievement in the trajectory from the conception of an idea up to the introduction of an invention into the market. Many studies use one-dimensional conceptualisations only and thus single measurements of innovative performance such as patents (for example, Bottazzi and Peri, 2003) or the number of new products introduced (for example, Stock et al., 2002). From Ernst's definition, one should look at innovation from a holistic perspective, that is, looking at the whole innovation cycle (from ideas to commercialisation). Thus, in this study, innovative performance is measured with multiple dimensions (e.g. total innovative sales and relative innovative performance).

5.3.2 Intended knowledge transfers and innovative performance

Firms establish linkages with other organisations with the intended purpose of accessing and acquiring different knowledge assets from external actors to develop technological innovations. A firm can interact with its partners on a formal basis. One of the common strategies is through formal collaborations such as joint R&D as effective ways to employ outside knowledge resources and increase the effectiveness of innovations (Du and Ai, 2008). The governance of collaborations of this type is commonly through mutually accepted contracts to control the relationship between the parties with the aim of increasing the level of success in the knowledge transfer process (Mentzas et al., 2006). Knowledge also can be transferred between organisations on a non-contractual basis through so-called informal networking activities that are conducted without any formal agreements between two parties. Informal networking can happen at two levels: interorganisational informal networking (labelled as "informal networking" in this study) or inter-personal informal networking (labelled as "social networking"). Informal networks can be created by informal functions arranged between two organisations, such as breakfast/lunch meetings, golf events, etc. On the other hand, social networks consist of informal/social ties of employees with employees of other firms (they may be friends or previous colleagues) and through these social ties the knowledge of how new products are created or innovative ideas can be shared during these social conversations.

Studies have shown the positive relationship between intended formal and informal interorganisational network activity and innovative performance. For example, a study by Jensen, Johnson, Lorenz and Lundvall (2007) shows that firms that applied a so-called doing, using and interacting mode (informal processes of learning) in combination with a mode of accessing and using codified knowledge, outperform firms relying predominantly on one of the two modes. Moreover, Boschma and Ter Walt (2007) report that a strong local network position (high number of formal interorganisational relationships) of a firm tends to increase its innovative performance in an industrial district. It is through these intended interactions (that is, ties in networks) that external knowledge is able to transfer to an innovating firm. Intended knowledge transfers fuel innovations.

Firms involved in interorganisational networks are able to gather more knowledge resources to perform their innovative activities. Partners who have formalised relationships (for example, through contracts) with a focal firm or who are involved in informal relationships are more willing to share (and less likely to hold back) knowledge due to the trust present in these relationships, and as a result the receiver firm is able to access better or more knowledge resources for successful innovations. Networks also provide opportunities for firms to compare and integrate intended knowledge flows from various sources so that new knowledge can emerge for technology development. Based on the above theoretical arguments Hypothesis 1 is proposed:

The higher the number of intended knowledge transfer relationships, the higher the firm's innovation outcomes

5.3.3 Unintended knowledge transfers and innovative performance

Unintended knowledge transfers are often referred to as knowledge spillovers (Fallah and Ibrahim, 2004; Oerlemans and Meeus, 2005; Erbas et al., 2008) and can be defined as "knowledge received without the permission of the sending firms". Firms that do not have the proper resources to develop a competitive advantage can engage in activities to reduce their resource deficits, such as "hiring away well placed knowledgeable managers in a firm with a competitive advantage or by engaging in a careful systematic study of the other firm's success" (Barney, 2000: 214), by imitating other firm's technologies, or by monitoring other firms' innovative activities. Thus, knowledge spillovers (unintended knowledge transfers) "denote the benefit of knowledge to firms not responsible for the original investment of the creation of this knowledge" (Almeida and Kogut, 1999: 905). In the past, researchers have attributed positive innovation effects to knowledge spillovers or unintended knowledge transfers (Jaffe et al., 2000; Fallah and Ibrahim 2004; Oerlemans and Meeus, 2005; Mukoyama 2003) at different levels (the receiving firm; the region; the industry; the nation). Learning from knowledge spillovers has similar benefits as intended knowledge transfers, namely more knowledge resources to perform innovative activities (Alcácer and

Chung, 2007). In the past, researchers like Nelson (1959) and Arrow (1962) maintained that information and knowledge are almost completely costless to acquire and use. From their point of view, it follows that the benefit of accessing and using knowledge spillover is that it is almost free of costs. However, more recent literature such as Cohen and Levinthal (1989) and Griffith et al. (2000) defend the opposite position. They argued that a firm needs to invest in its own R&D to access and successfully use ("absorb") other firms' R&D outcomes. In this sense, accessing either intended or unintended knowledge flows requires a firm to invest in costly R&D for external knowledge absorption. The benefit of accessing unintended knowledge is the absence of establishing and maintaining relationships with other firms which may be costly. Hence, Hypothesis 2 reads:

The higher the unintended knowledge transfers, the higher a firm's innovation outcomes.

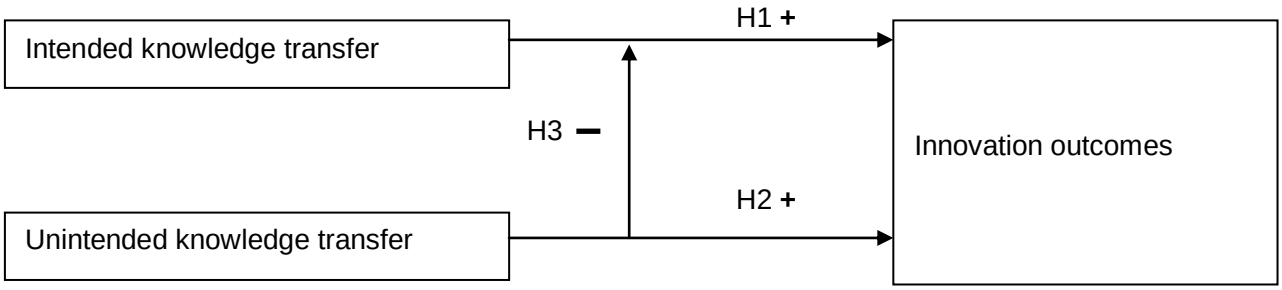
5.3.4 Moderating effect of unintended knowledge transfers

In a previous section, a literature review showed that there is mixed empirical evidence as to the (innovative) performance of firms located on science parks. In this study, it is proposed that the innovative performance of science park firms is lower in instances where unintended knowledge transfers occur. In other words, the mixed findings are due to the moderating effect of unintended knowledge transfers. Therefore, the relationship between intended knowledge transfers and the innovative performance of firms will be negatively influenced by higher levels of unintended knowledge transfers because the moment the sender firm realises that its knowledge is used without its approval, this will dramatically lower its willingness to share knowledge in formal collaborations and/or informal networking activities, as the unintended transfer may lead to an erosion of its competitive advantage (Easterby-Smith et al., 2008). In other words, if the unintentional use of knowledge is observed by the knowledge-producing firm, it will damage trust and, consequently, lower the willingness to transfer knowledge in a formalised or informal knowledge-transfer relationship. From the above argument, Hypothesis 3 can be derived:

The relationship between the number of intended knowledge transfer relationships and innovation outcomes of firms will be negatively moderated by higher levels of unintended knowledge transfers.

The above three hypotheses form the research model that this study will explore empirically. This research model is shown in Figure 5:

Figure 5: Research model



5.4 Research methodology

5.4.1 Sample and data collection

The focus of this study is on the relationship between knowledge transfer relationships and innovation outcomes at the firm level. The units of analysis are NTBFs located in the Gauteng region of South Africa. Gauteng was chosen because it has one of the few well-functioning systems of innovation in South Africa (Lorentzen, 2009). Firms chosen for this study fulfil the criteria of NTBFs: small firm size (number of employee including directors/CEOs less than 50), young firm age (less than 10 years since establishment) and highly technology-based (for example, ICT, biotech, electronics industries). This research applies a quantitative research methodology. Data regarding firms' knowledge transfer

relationships and innovative performance were gathered through questionnaires sent to CEOs or directors of NTBFs. To assure the quality of feedback, most questionnaires were distributed personally with short interviews to assist the completion of the questionnaires. A total of 52 valid questionnaires were returned, 24 of which came from NTBFs situated in The Innovation Hub (a science park) and 28 came from independent NTBFs not located on a science park. The collected data were analysed by applying multivariate regression analyses using SPSS software.

5.4.2 Measurement of variables

Table 12 lists the items that were used in the questionnaire to measure the variables proposed in the research framework. The items were based on measures proposed in the literature and some were measured using a five-point Likert-type scale. Moreover, Table 12 shows the literature that was sourced to construct the measurements, as well as the reliability statistics (Cronbach's alphas) of the scales used.

Reliability tests were done for the independent variable "unintended knowledge transfers" and the dependent variable "relative innovative performance", which were measured using multiple items (both have six items using a 5-point Likert scale). Cronbach's alphas of these two variables are 0.702 and 0.656 respectively. Cronbach's alpha of 0.6 was used as a threshold value and this is sufficient for exploratory studies. Thus, these two variables can be measured with a single, uni-dimensional latent construct.

Table 12: Item(s) of variables and their sources

Independent variables		**Item(s)**
Intended knowledge transfers (Otte and Rousseau, 2002)	Formal relationships	Number of organisations (suppliers, buyers, consultants, competitors, universities, public labs and sector institutes) with which the respondent firm has formal/contractual agreements to acquire knowledge.
	Informal relationships	Number of organisations (suppliers, buyers, consultants, competitors, universities, public labs and sector institutes) with which the respondent firm interacts on a non-contractual basis (i.e. informal, social basis) to acquire knowledge.
	Social relationships	Number of persons in organisations (suppliers, buyers, consultants, competitors, universities, public labs and sector institutes) with whom the CEO/director of the respondent firm interacts socially to acquire knowledge.
Unintended knowledge transfers Howells (2002)		How often does your firm use the following sources from other organisations/actors to acquire knowledge for your firm's innovations? (1) employing key scientists and engineers (including poaching key staff); (2) acquiring key information at conferences and workshops; (3) reverse engineering of technological knowledge embedded in products developed/produced by other firms/organisations; (4) accessing patent information filed by other firms/organisations; (5) knowledge embedded in organisational processes or routines of other firms/organisations; (6) publications in technical and scientific papers by other firms/organisations. (5-point Likert scale: never, rarely, sometimes, regularly or always; α = 0.702)
Dependent variable		**Item(s)**
Firm's innovation outcomes Sales items: Laursen and Salter (2006) Scope item: Oerlemans and Meeus (2005)		Three indicators of innovative performance were used: (1) Innovative sales 2008 new to the firm: the percentage of sales of product/services that were technologically new to the firm. (2) Total innovative sales 2008: the percentage of sales of products/services that were technologically improved and technologically new. (3) Scope of innovation outcomes 2008: other results of innovative performance. For last item, the following question was asked: To what extent did your firm's product and/or service innovations result in: (a) reduction of development and maintenance costs; (b) quality improvement of products and/or services; (c) increase in production capacity; (d) improvement in delivery times; (e) increase in sales; (f) increase in profits? (5-point Likert scale: 1 = very little, 3 = not little / not much, 5 = very much; (α = 0.656)).
Control variables		**Item(s)**
Firm size		Total number of employees, including the CEOs and directors, in 2007.
Firm age		Number of years a firm exists.
SP location		Is the firm located in The Innovation Hub (y/n)?

5.4.2.1 Dependent variables

In this study innovation outcomes are conceptualised as a multidimensional construct. This study distinguishes two types of innovation outcomes: innovative sales (Laursen and Salter, 2006) and the scope of outcomes (Oerlemans and Meeus, 2005). The innovative sales aspect captures the economic outcome of innovations expressed as the percentage of sales of innovated products and services. The scope of innovation outcomes is a qualitative dimension indicating that "part of the innovative efforts of firms are directed at, for example, a reduction of cost prices, quality improvements or the speeding up of internal processes" (Oerlemans and Meeus, 2005: 96). The three indicators used in this study as proxies to innovation outcomes are:

- Innovative sales new to the firms: measured as the percentage of sales of products and services that were technologically new to the firm.
- Total innovative sales: measured as the percentage of sales of products and services that were technologically improved and technologically new.
- Scope of innovation outcomes: measured as other results due to innovations, for example, reduction in production capacity.

5.4.2.2 Independent and control variables

This study distinguishes between "intended knowledge transfers" and "unintended knowledge transfers" as specification of the general concept of "knowledge transfers". Intended knowledge transfers are measured by taking three types of knowledge relationships into account: after all a firm can acquire intended knowledge via formal, informal and social relationships.

Unintended knowledge transfers are observed by the firm’s "imitative" or "opportunistic" behaviours, such as "reverse engineering" or "monitor other firms' innovative activities".

The recipient's firm size, firm age and science park location (yes/no) are included as control variables. "Firm size" and "firm age" are controlled, given that these two firm attributes have been important factors for the propensity of firms to acquire and exploit knowledge resources (Bresman et al., 1999, Agarwal and Gort, 2002, Cavusgil et al., 2003). Smaller and younger firms often face significant risk and uncertainty due to lack of knowledge resources (liability of newness). In this study "science park location" was also controlled because out of the 52 NTBFs that were surveyed, 24 firms are situated in The Innovation Hub, which is the first internationally accredited science park in South Africa. In the literature, science park location (SPL) is believed to make many value-added contributions to firms (Fukugawa 2006). Science park firms are thought to have more networking opportunities with other resident firms due to close geographical distance. Besides close geographical distance, which provides the possibility of face-to-face encounters, one of the tasks of a science park management team is to organise networking activities such as seminars and social events for on-park firms as well as with organisations located outside the science park premises. Thus, science park location plays a role in facilitating knowledge transfers and the innovative performance of firms.

5.5 Empirical results

5.5.1 Descriptive statistics

Means and standard deviations associated with the variables under study are provided in Table 13. On average, NTBFs access intended knowledge from 8.75 partners formally and 10.42 partners informally. Directors or CEOs of the NTBFs interact socially on average with 25 people to access intended knowledge. The average of the unintended knowledge transfer score is close to 1 on a scale of 5, showing that on average NTBFs rarely access unintended knowledge transfers. In general, NTBFs report that 72.21% of their sales come from innovated products and services, which is high but not usual for young, high-tech firms. In 2007, about 30% of sales was generated with products or services that were technologically

new to the firm, whereas about 42% of innovative sales was generated with products and services which were technologically improved.

The scores for the scope of innovation outcomes (other results due to innovations) is 3.68, indicating a relatively high level. The averages of firm age and size are 5.13 years and 9.25 employees respectively. This shows that the sample firms are young and small. About 46% of the firms in the sample are located on a science park location.

Table 13: Means and standard deviations

Variables	Mean	S.D.
Independent variables		
Intended knowledge transfer through formal relationships	8.75	12.516
Intended knowledge transfer through informal relationships	10.42	10.273
Intended knowledge transfer through social relationships	25.04	30.497
Unintended knowledge transfer	0.987	0.480
Dependent variables: innovation outcomes		
Innovative sales 2007 new to the firm	30.10	30.33
Total innovative sales 2007	72.21	31.567
Scope of innovation outcomes	3.680	0.682
Control variables		
Firm size	9.25	9.91
Firm age	5.13	3.61
SP location?	0.46	0.50

5.5.2 Multivariate regression analysis

The models in this study were estimated by using SPSS to perform Ordinary Least Square-based hierarchical regression analyses. All variables mentioned in the previous section were entered in three steps:

Model 1: Model with only the control variables;

Model 2: Model1+ intended knowledge transfers+unintended knowledge transfers;

Model 3: Model 2 + moderator effect.

Model 1 contains the control variables, including firm size (FS), firm age (FA) and science park location (SPL). Next, intended knowledge transfers (IKT) and unintended knowledge transfers (UKT) are entered in Model 2 to test hypotheses 1 and 2. To investigate Hypothesis 3, the moderating effect of unintended knowledge transfer on the relationship between intended knowledge transfers and innovative performances, a product term of the original variables (IFT*UKT) is included in Model 3. For each indicator of innovation outcomes, there are three sets of models: for formal, informal and social knowledge transfer relationships respectively. Tables 14 to 16 show the results of the regression analyses.

5.5.2.1 Innovation outcomes: total innovative sales 2007

In Table 14, only the Models 1 (with the control variables) have statistically significant F-values ($p < 0.1$), so it can be confidently assumed that the proposed regression models fit the data. In these models, science park location has a positive relation with total innovative sales in 2007. The related coefficients are highly statistically significant ($p < 0.05$). This variable explains about 13% of the variance in total innovative sales 2007. In other words, firms located on this science park are more innovative (from a sales perspective) as compared to comparable firms not located on a science park. Interestingly, none of the interorganisational variables turned out to generate statistically significant results. This implies that network activity does not impact on total innovative sales (including technologically improved products and services). As has been seen in the previous paragraphs, these relationships do matter for innovations with a higher level of newness. Overall, for this type of outcome, it can be concluded that none of the hypotheses is confirmed.

Table 14: Results of regression analysis for total innovative sales 2007

Variables	Dependent variable: total innovative sales in 2007								
	Formal relationships			Informal relationships			Social relationships		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Constant	69.880***	71.859***	65.946***	69.880***	68.683***	65.668***	66.130***	64.586***	66.287***
FS	-0.167	-0.189	-0.191	-0.167	-0.159	-0.175	-0.081	-0.076	-0.057
FA	0.056	0.039	0.047	0.056	0.068	0.070	0.031	0.035	0.052
SPL	0.367***	0.369**	0.378**	0.367***	0.378**	0.390**	0.395***	0.395**	0.389**
IKT		0.055	0.253		-0.062	0.1		-0.032	-0.287
UKT		-0.016	0.090		0.029	0.082		0.030	-0.007
IKT*UKT			-0.254			-0.205			0.283
R^2	13.3%	13.5%	14.2%	13.3%	13.5%	13.8%	15 %	15.1%	15.3%
ΔR^2	13.3%	0.2%	0.7%	13.3%	0.2%	0.3%	15%	0.1	0.3%
F-value	2.448*	1.433	1.239	2.448*	1.438	1.198	2.760*	1.597	1.329
ΔF-value	2.448*	0.055	0.370	2.448*	0.065	0.135	2.760*	0.025	0.143
VIF	1.059-1.155	1.188-1.460	1.200-9.138	1.059-1.155	1.163-1.597	1.165-16.326	1.042-1.149	1.122-1.451	1.219-29.196

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

5.5.2.2 Innovation outcomes: innovative sales 2007 new to the firm

In Table 15, the results of regression analysis for the innovation outcome indicator "innovative sales 2007 new to the firm" are shown. The discussion will start by looking at the indicators of model fit (F-value and its level of significance), followed by the statistically significant coefficients of the independent variables in the models (only for those models that fit the data).

With the exception of Model 2 and Model 3 of the estimations for formal knowledge transfer relationships, all proposed regression models fit the data. All other models have F-values at significant levels of $p<0.1$ to $p<0.01$ The exception is Model 2 for informal knowledge transfer relationships, which represent the best fitting model with significant level of $p<0.01$. R squares range from 14.1% (Model 1: social knowledge transfer relationships) to 28.5% (Model 2: informal relationships).

- ***Formal knowledge transfer relationships***

Formal knowledge transfer relationships turn out to have little importance for the innovative sales of products and services new to the firm. This conclusion can be drawn from the finding that only the model with the control variables is statistically significant. The implication is that Hypothesis 1 is rejected in the case of the relationship between formal ties and innovative sales (new to the firm).

Table 15: Results of regression analyses: innovative sales 2007 new to the firm

Variables	Dependent variable: innovative sales 2007 new to the firm								
	Formal relationships			Informal relationships			Social relationships		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Constant	43.754***	32.159**	28.653	43.754***	22.511*	21.464	43.128***	27.197*	30.656**
FS	-0.310**	-0.279*	-0.28*	-0.310**	-0.222	-0.228	-0.283*	-0.236	-0.196
FA	-0.05	-0.034	-0.029	-0.05	0.047	0.048	-0.055	-0.019	0.016
SPL	0.28**	0.224	0.23	0.28**	0.292**	0.296**	0.282**	0.276*	0.263*
IKT		0.003	0.124		0.426***	-0.368		-0.287*	-0.814
UKT		0.168	0.234		0.391**	0.410*		0.304*	0.228
IKT*UKT			-0.157			-0.074			0.586
R^2	14.6%	17.1%	17.3%	14.6%	28.5%	28.5%	14.1%	22.6%	23.8%
ΔR^2	14.6%	2.4%	0.3%	14.6%	13.8%	0.0%	14.1%	8.5%	1.2%
F-value	2.740*	1.893	1.572	2.740*	3.658***	2.987**	2.563*	2.625**	2.285*
ΔF-value	2.74*	0.677	0.146	2.74*	4.446**	0.021	2.563*	2.477*	0.678
VIF	1.059-1.155	1.188-1.460	1.200-9.138	1.059-1.155	1.163-1.597	1.165-16.326	1.042-1.149	1.122-1.451	1.219-29.196

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

- ***Informal knowledge transfer relationships***

Model 1 shows that smaller firms and firms located at the science park generated a higher proportion of their sales in 2007 with products and services new to the firm. The addition of the variables "intended knowledge transfer through informal relationships" and "unintended knowledge transfer" in Model 2 leads to additional insights. The firm size variable loses its significance, whereas science park location holds its positive impact. Interestingly, a higher number of informal knowledge transfer relationships and a higher level of unintended knowledge transfer are associated with a higher percentage of innovative sales from products and services new to the firm. Consequently, hypotheses 1 and 2 are confirmed for this type of knowledge transfer relationships. The inclusion of the moderator variable results in an insignificant model, which means a rejection of Hypothesis 3.

- ***Social knowledge transfer relationships***

As for social knowledge transfer relationships, one finds again that smaller firms and firms located on a science park generate a higher proportion of sales with innovated products and services which are new to the firm (see Model 1). In Model 2, it shows that higher levels of unintended knowledge transfer are positively associated with higher levels of innovation outcomes, whereas a higher number of intended knowledge transfer relationships of a social nature has a negative impact on innovation outcomes. In a next section, an attempt will be made to explain this counterintuitive finding. Also, in these models, science park location seems to be beneficial and no moderator effects could be noted. In sum, for this type of knowledge transfer relationships Hypothesis 2 is confirmed, whereas hypotheses 1 and 3 are rejected.

5.5.2.3 Innovation outcomes: scope of innovation outcomes

A first observation from Table 16 is that the models for informal and social knowledge transfer relationships are not statistically significant. This implies that none of variables indicating interorganisational network activity of these types impacts on this dimension of innovation outcomes.

Table 16: Results of regression analysis for the scope of innovation outcomes

Variables	Dependent variable: scope of innovation outcomes								
	Formal relationships			Informal relationships			Social relationships		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Constant	3.685***	4.070**	4.199	2.346***	2.7***	2.948***	2.281***	2.554***	2.621***
FS	-0.252*	-0.410**	-0.408**	0.080	0.051	0.078	0.106	0.090	0.105
FA	0.255	0.136	0.129	0.053	0.021	0.018	0.044	0.029	0.043
SPL	0.160	0.193	0.184	0.208	0.205	0.184	0.214	0.204	0.199
IKT		0.363**	0.164		0.141	-0.136		0.148	-0.054
UKT		-0.172	-0.280		-0.130	-0.221		-0.117	-0.147
IKT*UKT			0.256			0.351			0.225
R^2	9.9%	19.7%	20.4%	6.3%	7.8%	8.6%	7.0%	8.8%	9.0%
ΔR^2	9.9%	9.7%	0.7%	6.3%	1.5%	0.8%	7.0%	1.8%	0.2%
F-value	1.766	2.252*	1.920*	1.074	0.780	0.703	1.188	0.874	0.727
ΔF-value	1.766	2.784*	0.404	1.074	0.381	0.372	1.188	0.444	0.084
VIF	1.059-1.155	1.214-1.420	1.210-9.138	1.059-1.155	1.226-1.597	1.165-16.326	1.042-1.149	1.122-1.451	1.219-29.196

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Apparently this is not the case for the models of formal knowledge transfer relationships. From Model 2, it follows that the smaller the responding firm, the broader the scope of its innovation outcomes. Moreover, it is found that the more formal interorganisational relationships the focal firm has in which intended knowledge transfer takes place, the broader the scope of its innovation outcomes is.

5.6 Conclusions and discussion

5.6.1 Findings and implications

The primary objective of this study was to explain the mixed findings on the performance of firms located on science parks by investigating the effects of different knowledge transfer on firms' innovation outcomes. Two types of knowledge transfer were explored in this study: intended and unintended knowledge transfers. Using these two types of knowledge transfer, this study tried to answer the research question: To what extent do intended and unintended knowledge transfers explain the innovative performance of science park firms? Based on a review of the literature, three hypotheses were formulated.

In the empirical section of the chapter a sample of NTBFs located in the Gauteng region, which is the economic engine of South Africa (a country with an emerging economy), was used. Data were collected at the firm level by structured interviews with questionnaires targeted at the directors or CEOs: 52 valid questionnaires were obtained and about 50% of these firms were located on a science park. Statistical analysis using multivariate regression models, presented several interesting findings, which will be discussed below.

The discussion of the results of this study starts by reflecting on the extent to which firms in the sample used knowledge exchange channels. One interesting result is that the number of social knowledge transfer relationships is much larger than the other two channels that were distinguished. Comparable results were

presented by Mitchell and Co (2004), who investigated the networks of a sample of entrepreneurs in South Africa. They found that South African entrepreneurs predominantly maintain social ties. However, having mainly relationships of this kind is not necessarily beneficial to firm performance (see below).

The main question to be answered in this study was how the mixed findings in the science park literature could be explained. Unfortunately, the study did not come up with a straightforward answer to this question. As a matter of fact, two answers are possible, depending on the view one takes.

The first answer to the question is that the theoretical explanation (Hypothesis 3) was not empirically confirmed. It was proposed that the positive relationship between intended knowledge transfer and innovation outcomes would be negatively influenced by higher levels of unintended knowledge transfer. However, this hypothesis was rejected in all empirical models. Apparently, this negative effect does not hold. Alternatively, this spillover effect is not observed by the responding firms, leading to no behavioural consequences and performance impacts.

The second answer to the same question is that science park location does play a significant role in the models in which innovative sales is the dependent variable, but not in models in which a different indicator of innovation outcomes is used. From the study, it can be concluded on the one hand that science park location brings these NTBFs the "right" environment and apparently enables them to use their resources more efficiently (for example, with the help of the science park management team) in order to generate higher levels of innovative sales. On the other hand, whether or not science park firms are regarded as successful depends on the way success is measured.

Are higher innovation outcomes also the results of interorganisational knowledge transfer? The findings show that this is especially the case for innovations with a higher level of newness (new to the firm). In these models, both science park location and intended knowledge transfer via informal business relationships have a positive impact. The latter finding supports Hypothesis 1. In some cases,

Hypothesis 2 was also confirmed. Interestingly, social relationships have a negative impact. One explanation is that social relationships often are maintained with actors who are very similar. This so-called homophily effect (McPherson et al., 2001) in networks has a negative effect on innovation because similar actors have similar knowledge. An alternative explanation is related to the quantity and quality of the knowledge and information acquired through social relationships. As has been seen, NTBFs have many social ties, which could lead to an information overload, whereas at the same time the knowledge possessed by these external social actors is not necessarily the most relevant from a business perspective. In general, it must be concluded, however, that there is only weak support for the hypotheses on interorganisational knowledge transfer.

The findings of this research have important implications for managerial practice. The success of NTBFs relies heavily on the success of new product or service innovations, due to the increasing market competition. This study shows that different types of knowledge transfer can help to achieve certain innovation outcomes. The practical value of the findings of this study enables managers of NTBFs in South Africa to understand how the configuration of knowledge transfer channels affects innovative performance. Unintended knowledge transfers (often a result of opportunistic behaviour) are important to innovation outcomes in the South African context. This corresponds to findings in a study by Oerlemans and Pretorius (2006), where they report that South African firms tend to be imitative in nature. This is not necessarily a bad thing in an economy that lacks all kinds of (knowledge) resources. As Yamamura, Sonobe and Otsuka (2005) show for the Japanese motorcycle industry, an imitation strategy can be beneficial in the early growth stages of firms and industries.

5.6.2 Limitations and direction for future research

Although this study reveals valuable insights in the relationship between (un)intended interorganisational knowledge transfers, science park location and innovation outcomes at the firm level, some limitations remain. First, these findings are limited to the case of small technology-based firms in South Africa. Therefore,

it would be worthwhile to examine the relationships proposed in this study in other contexts. Second, the dependent variable in the models (innovation outcomes) does not take *process* innovations into account. However, from the preliminary data analysis, the business and innovation activities of most firms in the sample are not focused on process development, but more focused on product or service development. Thus, although the results of this study do not give a complete picture of technological innovation in NTBFs, they still are valid in the South African context. Third, although this research took a differentiated approach by distinguishing between formal, informal and social knowledge transfer relationships, only the *number of direct ties* was taken into account. This is a commonly accepted approach in the field (Ahuja, 2000) but it implies that other relevant aspects of network are not included in the models. Examples are the strength of ties (Gilsing and Nooteboom, 2005) and the characteristics of partners in the networks (Tether, 2002).

This research raises a number of directions for future research. First, the third hypothesis on the moderating effect of unintended knowledge transfer was not empirically supported in this study. Other moderator variables may be explored to further examine which factors may have an influence on the relationship between intended knowledge transfers and innovative performance. An example could be the type of partner, because the probability of unintended knowledge transfer is higher when the collaborative partner is, for example, a competitor (Hamel, 1991). Second, this research was performed in an emerging economy. Similar studies can be done in other countries with emerging economies to benchmark the results of this research. Third, as mentioned earlier in the limitations of this study, other aspects of network characteristics can be included in future studies. For example, knowledge from networks established with "technological similar" partners may enhance incremental innovations, whereas, with partners who have totally different technologies (for example, ICT versus biotech), radical innovations could open up an entirely new market (Laursen and Salter, 2006).

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Chapter 6

Conclusions

6.1 Introduction

One of the initiatives that South Africa implemented in its National System of Innovation policy was the establishment of a science park in the Gauteng region, known as The Innovation Hub. It is the first internationally accredited science park in South Africa (IASP) and aims at contributing to the transformation of Gauteng into a "smart province" by actively supporting technology-rich and innovation-based businesses. Science parks stimulate and enable the management of the flows of knowledge and technology between science park firms (that is, firms locating on the science park premises), universities, research centres and the market, so that innovations are viable to sustain the knowledge-based economy. Despite all the great assumed benefits a science park location promises, many researchers questioned the positive effects of science park location by conducting comparative studies examining the presence of performance differences between science park and off-park firms (firms without a science park location). Some researchers reported that firms with a science park location perform better, whereas others reported that firms perform the same, regardless of location (more details in Chapter 5). The scientific relevance of this research is to provide explanations for these mixed findings found in the literature review. Therefore, the following main research question can be stated:

"*How does one explain the mixed findings found in previous research studies regarding innovative performances by science park firms?*"

To answer the above over-arching research question, a *relational* approach was used in four studies reported in Chapter 2 to Chapter 5, in which *inter-firm relationships* are explored. Each study addresses a specific subquestion:

- Chapter 2 answers the theoretical subquestion: *Which theoretical explanations can be given for the mixed findings regarding the performance of science park firms?*
- Chapter 3 answers the empirical subquestion 1: *Which knowledge exchange behaviours do science park firms show?*
- Chapter 4 answers the empirical subquestion 2: *If science park firms behave differently with regard to knowledge exchange, do these differences matter for firm performance?*
- Chapter 5 answers the empirical subquestion 3: *How can one explain the mixed findings from an empirical point of view?*

The next section of this concluding chapter will provide a summary of the research framework and the theoretical explanations for the mixed findings. The subsequent section will discuss the main outcomes of the empirical studies reported in chapters 3 to 5. Section 6.4 addresses the relevance of the extended resource-based view model as well as the addition of geographical dimension for this study. Based on the findings and interpretations of the empirical studies, some policy recommendations will be proposed and discussed in Section 6.5. Lastly, the limitations of this study and possible future research directions will be addressed in Section 6.6.

6.2 Theoretical framework: an introduction

The concepts of NSI and knowledge-based economy focus on *knowledge* flowing between elements of the system. In the literature, knowledge is regarded as an intangible resource of a firm, which can enhance a firm's performance and innovativeness (van Wijk, 2008). In the past, many researchers have asked the question: Why do firms perform differently? The resource-based view (RBV) model was developed to answer this question.

To answer the research question on the mixed findings reported in the science park literature, knowledge is considered as a resource of a firm, which is a node characteristic, and the RBV is used as this study's theoretical framework.

However, another important dimension of NSI is the *relationships* between elements; in other words, the interorganisational *relationships*. This relational dimension is not part of the conventional RBV, which does not take into account the "network resources" that a firm may gain from interfirm interactions. In Lavie's extension of the RBV model, he includes the benefits the alliance partners bring to the focal firms in interfirm networks. According to his extended RBV model, a focal firm may gain "appropriated relational rent" (that is, "intended knowledge flows" in the study) as well as "inbound spillover rent" ("unintended knowledge flows"). If one wishes to use this extended version of the RBV model in the study of the performance of science park firms, one finds that another dimension is missing and should be included, namely geographical distance between knowledge-exchanging firms. The rationale behind this argument is that most actors (firms, universities and research centres) in a science park are *geographically* concentrated within space. In the literature, geographical distances (or so-called *geographical proximity*) impact on the relationships between actors (for example, Baptista and Mendonça, 2009) because proximity is thought to facilitate the exchange of, especially, tacit knowledge. Chapter 2 developed a research framework by using a relational approach and by adding the geographical dimension to Lavie's extension of the RBV model. Adding the latter dimension signals the theoretical relevance in this study.

As discussed in Chapter 2, two types of knowledge flows can be distinguished: intended (knowledge transfer through networking) and unintended (knowledge spillovers) knowledge flows. The theoretical framework is developed with the research aim of explaining the mixed findings found in science park literature. The main hypothesis, providing a theoretical explanation of the mixed findings, of this research framework is:

The positive relationship between intended knowledge flows and innovative performance of firms will be negatively moderated by higher levels of unintended knowledge flows. This moderating effect is stronger for on-park firms as compared to off-park firms due to close geographical distance.

The rationale for the above main hypothesis is that when firms are closer to each other, it is easier for firms to observe any misuse of their knowledge or technology by their partners. Once this misbehaviour of their partners is realised, the already existing relationship (a formal or informal tie) between them may be weakened or even broken. The poor performance of some science parks, which is reported in the literature, could be explained by the accumulated negative effects of the use of unintended knowledge transfer.

To explore the framework further, three empirical studies were performed (using the relational approach developed) to address three topics: *knowledge exchange behaviours* (Chapter 3), *knowledge transfer effectiveness* (Chapter 4) and *knowledge transfers and innovative performances* (Chapter 5). The next section will provide a summary of the empirical findings and interpretations of these three empirical studies.

6.3 Main empirical findings and interpretations

6.3.1 Knowledge exchange behaviours

The results of the first empirical study were reported in Chapter 3. It explored the knowledge exchange behaviours (framework developed in Chapter 2) of on-park firms (firms with SP location) located in The Innovation Hub in Gauteng. The descriptive analysis in the first part yielded interesting findings: off-park ties are more frequent, more technologically similar, more organisationally close, knowledge received from off-park actors is more useful, off-park actors are of a more diverse nature, and more unintended knowledge flows come from off-park firms. In other words, off-park ties are relevant sources for on-park firms, rather than ties between each other (on-park ties) in The Innovation Hub. A negative interpretation is that The Innovation Hub does not perform its function of stimulating and supporting the knowledge flows in the park to the fullest. This resulted in on-park firms seeking for knowledge outside the park rather than co-operation between on-park firms. However, as is proposed in the literature, most

knowledge exchange relationships are reciprocal, thus, The Innovation Hub could be regarded as focal driver of technological development to off-park firms.

The second part of the analysis discovered that there were two groups among on-park firms: a group that did not interact with other on-park firms and who interacted only with off-park firms (denoted as Group 0) and a second group that interacted both with other on-park firms and off-park firms (denoted as Group1). The most interesting finding when comparing these two groups' knowledge exchange behaviours was that Group 0 interacts more with public knowledge sources (such as universities and research centres) where as Group 1 interacts with private knowledge sources (such as suppliers, buyers and consultants). An interpretation of this finding is that firms in Group 0 are in the early stages of the innovation cycle (research and development) because they use more fundamental knowledge and Group 1 firms are in a later stage (commercialisation). Another interpretation is that for Group 0, The Innovation Hub is not primarily for networking purposes, but more for a reputation-building purpose (as it creates an image of an innovative firm). Moreover, Group 0 firms have higher patent outputs as compared to Group 1. This may be due to the fact that knowledge received by Group 0 firms (from public knowledge sources such as universities or research centres) is scientific knowledge, which is important for new or radical innovations where patents are necessary and worthwhile to invest to protect such innovations. On the other hand, the knowledge that firms in Group 1 received (from private knowledge sources such as competitors or suppliers) is more market-related. This kind of knowledge supports the development of incremental innovations. Patenting this kind of innovation may not be cost-effective and could be the result of the fewer patent outputs found in Group 1.

6.3.2 Knowledge transfer effectiveness

A relational view of knowledge transfer effectiveness was applied in Chapter 4. It is argued that knowledge transfer is not a frictionless process. Therefore, three types of barriers to effective interorganisational knowledge transfer were discussed: partner (dis)similarities (seen as organisational and technological

similarities), frequency of knowledge transferred, and the knowledge receiver's learning culture. Research models to study the relationship between these barriers and knowledge transfer effectiveness were developed and explored within small new technology-based firms in the Gauteng region. The effectiveness of knowledge transfer was measured as the *usefulness* of knowledge received by a focal firm. The findings supported the hypothess that frequent knowledge transfers was positively related to the usefulness of knowledge received. In other words, firms should interact more frequently to find more useful knowledge. The study found a U-shaped relationship between technological similarity and the usefulness of knowledge received. The finding suggests that firms should interact with partners with very similar technological knowledge bases so that the knowledge is easier to absorb and use for innovation or with very dissimilar knowledge bases so that novel ideas can be generated. The mixture of very similar or very dissimilar knowledge bases should be avoided because firms may be indecisive about their innovative direction. Moreover, this study showed a negative impact of organisational proximity on usefulness of knowledge received. An interpretation of this result, looking from the perspective of a dissimilarity in the firm sizes of two partners, may explain such finding. The sampled firms in this study are small technology-based firms (also known as new technology-based firms (NTBFs)). When they interact with partners who are larger, in principle they exchange with organisations that are organisationally different. An important reason for small firms to interact with larger firm may be to counteract the problem of liability of newness that is encountered by NTBFs, so that larger firms may: (i) bring NTBFs image or status in the market, and (ii) provide NTBFs with useful knowledge, due to their larger and richer knowledge bases. The hypothesis on the positive importance of the learning culture of the receiving organisation is not supported in this study. The non-significant role of learning culture can be interpreted by looking at the South African firms' innovative nature, namely that they often innovate by imitation. Furthermore, this research result shows that firms have a satisfactory learning culture and that the learning capabilities may not aim at learning "new knowledge", but at learning the "already existing technologies" (which can be imitated) from other firms.

6.3.3 Knowledge transfers and innovative performance

The relationship between knowledge transfers and innovative performance was investigated in Chapter 5 to empirically explain mixed findings in science park research. In that chapter, a multidimensional construct for innovative performance was proposed. Three hypotheses were formulated to answer the research question of this chapter: To what extent do intended and unintended knowledge inflows explain the innovative performance of science park firms?

The findings yielded interesting insights. Not all intended knowledge inflows impact positively on a firm's innovative performance. Intended knowledge inflows via formal and informal networks have a positive impact on firms' relative and new innovations respectively. On the other hand, the intended knowledge inflows via social networks have a negative impact on firms' new innovations. To interpret this finding, it was proposed that, compared to informal interorganisational network relationships, inter-personal social network ties are less able to transfer high-quality knowledge, due to social conversations that may mislead the direction of innovative activities; this could be as a result a poor innovation outcomes. Unintended knowledge inflows have a positive impact on a firm's new innovation outcomes only when the firm is involved in informal and/or social networks. This implies that knowledge spillovers happen through informal networking activities. The main hypothesis stating that "the relationship between the number of intended knowledge transfer relationships and innovation outcomes of firms will be negatively moderated by higher levels of unintended knowledge transfers" was not supported empirically in this study. In other words, this assumed moderating effect by spillovers was not observed by the responding firms. Consequently, no behavioural consequences and performance impacts could be measured.

Despite the fact that the theoretical explanation proposed for the mixed findings in science park research was not empirically confirmed at this stage, this research has provided a sequence of empirical studies which also investigated the factors that relate to performance heterogeneity (differences in patents outputs, knowledge transfer effectiveness, and firms' innovative performances).

6.4 Theoretical relevance of the study

This research is theoretically relevant because it proposes and uses a further extension of the extended RBV framework by adding a geographical dimension. Based on the findings in previous chapters, two questions relating to the theoretical relevance can now be answered:

1. Does the extended RBV framework work?

The answer is a clear "yes". It was empirically shown that networking with partners enhances the effectiveness of knowledge transfer (Chapter 4) and specific innovative performances (Chapter 5). Moreover, Chapter 4 pointed out three relational features that are of importance. Firstly, more *frequent* interactions with partners have a positive impact on usefulness of knowledge received. Secondly, if firms network with partners that are very *technologically* similar or distant, the knowledge they acquire will be perceived to be more useful. Moreover, NTBFs that partner with firms that are *organisationally* different (in this case, bigger firms) will be able to get rid of the problem of being “new” in the market and also at the same time obtain knowledge from their partners who have already accumulated their own knowledge bases.

Chapter 5 revealed the benefits of intended and unintended knowledge inflows through various network relationships. When firms interact with partners through formal networks, the intended knowledge inflow they receive will enhance their relative innovations. Additionally, these knowledge inflows via informal networks will enhance firms' new innovations. Moreover, when a firm is involved in informal and/or social networks, the unintended knowledge inflows (or so-called "inbound spillover rent" in Lavie’s study) will benefit a firm’s new innovations. The abovementioned benefits can be regarded as the "appropriated relational rent" that is proposed in Lavie’s study.

2. Does the extended RBV and its addition (that is, including a geographical dimension) work?

The answer is "no". SP location (SPL) does not play a significant role. No significant results appeared in models 2 and 3 in chapters 4 and 5. SPL is entered as control variable in the models developed in chapters 4 and 5 in which on- and off-park firms appear. In Chapter 4, the results showed that SPL was statistically significant in Model 1 (the model with only the control variables). In other words, this version of the model showed that firms with SPL, as compared to those without SPL, found the knowledge they received from their partners to be more useful for their innovative activities. However, SPL becomes statistically insignificant in models 2 and 3. This means that the three relational features, namely frequency of knowledge transfer, organisational similarity and technological similarity, outperform the importance of SPL with regard to the usefulness of knowledge received by firms.

In Chapter 5, SPL is again entered as a control variable in all models empirically explored. Although SPL does play a significant role in the models in which innovative sales is the dependent variable, it does not in models in which a different indicator of innovation outcomes is used. This shows there is little evidence that for this set of South African firms SPL (as a geographical dimension) matters when one looks at innovative performance from multidimensional aspects.

6.5 Policy recommendations

The empirical findings presented in this study lead to a number of policy recommendations. Below are the main recommendations that policy makers could take into account.

Chapter 3 pointed out two important issues. Firstly, firms located in The Innovation Hub had more and stronger interactions with off-park firms than with colleague science park firms. Since science parks are established with the aim of facilitating knowledge flows between on-park firms, it is recommended that the management

team should pay more attention to establishing links between on-park firms, for example, by scanning new tenant firms in terms of their potential to partner with other resident firms. Moreover, the management team could investigate knowledge problems that innovating SP firms encounter and introduce other SP firms that may solve these problems by a joint effort between them. However, intellectual property issues have to be taken into account, as they often act as barriers to joint problem-solving activities (for example, Sawers et al., 2008). SP management could try to involve lawyers who specialise in intellectual property rights to overcome the problems caused by intellectual property rights between the two partnering firms. Secondly, it turned out that there are two groups of on-park firms. One group could be regarded as technology developers whereas another group appeared to be closer to commercialising their innovations. Based on the observations that these two groups are at different stages of the innovation process, The Innovation Hub management team could tailor their services to these two groups' needs. For technology developers, more research seminars could be organised on the park, whereas for the other group, which is closer to commercialising their innovations, more strategic marketing campaigns, for example, to build a closer link with venture capitalists, could be provided by the park management team.

In Chapter 4 it was discovered that technological proximity and frequency of interaction enhance the effectiveness of knowledge transfer. So, when designing a science park or evaluating new tenants, select firms that are very technologically similar (for example, in the same sector) and/or totally technologically dissimilar (for example, from completely different sectors). Moreover, a management team could arrange networking activities between them with the purpose of contributing to problem-solving rather than increasing general knowledge from guest speakers.

The empirical results further showed that there is a lack of interactions between NTBFs and research institutions such as public research labs or universities where fundamental scientific knowledge lies. Therefore, policy makers could pay more attention to establishing a closer industry-academic link, which is necessary to improve innovative outcomes. This could, for example, be done by giving government subsidies to those firms or university departments that collaborate in

joint research projects, thereby increasing the willingness to establish such links. Moreover, universities could improve the efficiency of their boundary organisations that are supposed to advance these collaborations with SP firms. This could also be done by improving the structure of the boundary organisations, for example, a separate team could be added to the structure to monitor the progress of the joint projects between the assigned university personnel and SP firms.

Chapter 5 indicated that one could take into account the configurations of knowledge transfer channels as well as the multidimensional construct of innovation outcomes. In other words, certain configurations of knowledge transfers could help to achieve certain dimensions of innovation outcomes. For firms which have the aim of achieving innovations with higher levels of newness, it is recommended that intended or unintended knowledge transfer via informal business relationships should be the focus. This could be done by organising strategic (only R&D researchers are invited) informal business lunches or golf event with partnering firms.

6.6 Limitations and future research

There are several limitations to this research. Firstly, the results of this study cannot be generalised to all other emerging economies, because samples were taken from firms located in a specific region of South Africa. Therefore, all findings, interpretations and recommendations are only valid for the Gauteng region. To draw a bigger picture that can be generalised, similar studies should be conducted on the effects of science park location in other regions of South Africa (for example, the Western Cape where Technopark Stellenbosch is situated) or other emerging economies of developing countries. Then a truer picture of science park phenomenon would be established.

Secondly, the data collected in this study are cross-sectional and thus not longitudinal. In countries like South Africa where supporting academic research is not on the top priority list of businesses, collecting longitudinal data from them would be a problem. In order to fine grain the analysis, one could seek evidence

from longitudinal case studies as a research methodology in many other studies (for example, Stevens and Dimitriadis 2004, Corso et al, 2009). Longitudinal research is important, since SP firms are usually very young firms that need time to develop and grow. Moreover, most SP firms generate innovations and the innovation process takes time to show results (from an idea to R&D to prototype to commercialising products).

Thirdly, this study focuses only on egocentric networks, that is, on a focal firm and its direct ties, as it is assumed that the boundary of the network of science park firms is difficult to determine because on-park firms could also have many links with off-park firms and the network structure of this latter group of firms is hard to determine. It is therefore only the *degree centrality* that is investigated as an indication of structural network characteristics. However, if one looks only at firms located on a science park and only investigates the direct interactions of firms, several other structural network characteristics, for example, density *structural holes* and their effects on innovation outcomes (Kenis and Oerlemans, 2008), cannot be investigated. Consequently, their influence on innovative performances of science park firms is disregarded.

Finally, the off-park samples were chosen on the assumption that they had not previously been located on any SP. It could be interesting to investigate those who have left a SP, to determine the process that led to their decision to leave the park. Such studies could reveal the problems that SP firms may encounter and thus provide further suggestions for improving the functioning of SPs. Moreover, such studies could also explore whether a previous SPL experience still has an effect on the performance of firms who have left a SP.

This research used a relational approach to investigate the role that SPL plays in an emerging economy. Although the theoretical explanation of the mixed findings found in SP literature is not empirically supported, this research has investigated interorganisational network relationships and reported various factors that significantly impact at different levels of firm performances (that is, factors behind performance heterogeneity). Moreover, the discussion in the recommendation section pointed out certain issues that could account for the mixed findings. In

other words, the mixed findings in SPs (some researchers found SPs to be important and some think otherwise) may be accounted for by the differences in their scanning processes of new entrant firms, the nature of networking activities, services provided by the SP management team, academic-industry links and configurations of knowledge flows.

Although SPs are often seen as engines for a rapidly growing economy, this study pointed out that SPL, as a geographical phenomenon in which knowledge interactions take place, is only significant in certain aspects (namely innovative sales) of innovative outcomes and not when one takes other aspects of innovation outcomes into account. More empirical studies are needed to investigate the role of SPs from various approaches so that a richer and fuller picture of SPs in the knowledge economy can be painted. Future empirical studies may also help policy makers to further improve the designs of SPs and enhance their roles of supporting innovative activities in emerging economies.

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APPENDIX 1

GUIDING DIAGRAM

Chapter 2: a theoretical chapter
"Explaining mixed results on Science Parks performance: Bright and dark sides of the effects of inter-organizational knowledge transfer relationships"
Variables identified in the paper are shown below:

Direct ties	Formal ties
	Informal ties
	Social ties
Trust	Organizational trust
	Personal trust
Proximities	Geographical proximity
	Technological proximity
	Organizational proximity
Knowledge quality	Knowledge usability DV
	Frequency of transfer
Diversity of actors	
Unintended knowledge flows	
Absorptive capacity	
Innovative performance DV	

DV: Dependent Variable

Chapter 3: an empirical chapter "Knowledge exchange behaviours of science park firms: The Innovation Hub case"

Chapter 4: an empirical chapter "A relational view of knowledge transfer effectiveness in small new technology- based firms: An empirical view from South Africa"

Chapter 5: an empirical chapter "Knowledge transfers between and innovative performances of NTBFs in South Africa: An attempt to explain mixed findings in science park research from South Africa"

APPENDIX 2

Evaluation of SCIENCE PARKS in literature

WITH THE FOCUS ON A COMPARISON BETWEEN ON- AND OFF-PARK FIRMS

Author(s)	Country and period	Research focus	Research methodology		Key results
			Sampling approach	Data collection and analysis techniques	
Felsenstein (1994)	Israel (period of study not known)	To examine the role of science parks as "seedbeds" of innovation by looking at the effects of seedbed (as indicated by level of interaction with a local university and the entrepreneur's educational background) on a firm's innovation level	stratified sampling On-park: 72 Off-park: 90	Questionnaire survey at firm level Log-linear modelling	(1) The level of interaction between on-park firms and local universities is generally low, however, it is higher than the level of interaction exhibited by off-park firms; (2) Seedbed effects are not necessarily related to a firm's innovative level; (3) Science park location has only a weak and indirect relationship with innovation level
Westhead and Cowling (1995)	UK (1986-992)	• To assess the employment growth in the "surviving" firms located on- and off-park • To identify factors that are associated with employment growth	Matched sampling On-park: 49 Off-park: 44	Questionnaire survey at firm level Longitudinal data set (1986-1992) Bivariate and multiple correlation and regression	No difference in the employment growth of on- and off-park firms; (2) Education and technical experience and financial sources are associated with employment growth
Westhead (1997)	UK (1986-1992)	To assess the R&D inputs and outputs between firms located on- and off-park	Matched sampling On-park: 41 Off-park: 40	Questionnaire survey at firm level Chi-square test	• No significance differences in the R&D inputs (R&D expenditure and percentage of qualified scientists and engineers) of on- and off-park firms • No significance differences in the R&D outputs (patents, copyrights, new products/services) between on- and off-park firms

Author(s)	Country and period	Research focus	Research methodology		Key results
			Sampling approach	Data collection and analysis techniques	
Löfsten and Lindelöf (2002)	Sweden (1996-1998)	To assess the performance (sales, employment and profitability) of firms located on- and off-park	Matched sampling On-park: 134 Off-park: 139	Questionnaire survey at firm level Chi-square test, Independent t-test	• On-park firms cooperate more with universities • On-park firms have higher employment and sales growth • No significant difference in the profitability of on- and off-park firms
Colombo and Delmastro (2002)	Italy (2000)	To determine if SPs are successful in fostering the establishment and growth of NTBFs by comparing on- and off-park firms in terms of: • Characteristics of founder • Growth and innovativeness of firms • Access to public subsidies	Matched sampling On-park: 45 Off-park: 45	Questionnaire survey at firm level Chi-square test, Independent t-test	• On-park founders are mainly motivated by innovation-related factors • No differences in the innovative inputs • No difference in the innovative outcomes (patents) • On-park firms have higher employee growth and easier access to public subsidies
Siegel, Westhead and Wright (2003)	UK (1986-1992)	To study the impact of SP on research productivity by comparing on- and off-park firms	Matched sampling On-park: 89 Off-park: 88	Questionnaire survey at firm level Independent t-test	• For two of the three R&D outputs measured (new products and patents), the output elasticity is positive and statistically significant for on-park firms • On-park firms have slightly higher research productivity

Author(s)	Country and period	Research focus	Research methodology		Key results
			Sampling approach	Data collection and analysis techniques	
Lindelöf and Löfsten (2003)	Sweden (1996-1998)	To assess the performance of SP by comparing on- and off-park firms in their strategic approaches	Matched sampling On-park: 134 Off-park: 139	Questionnaire survey at firm level Independent t-test	• On-park firms showed significantly greater emphasis on firm characteristics such as innovation ability, competitor- and market-orientation, sales and employment growth, high profits, etc. • Off-park firms reported proximity to other firms to be of higher importance than the on-park sample in their choice of location • No significant difference in new products (before competitors) and patents
Lindelöf and Löfsten (2004)	Sweden (1996-1998)	To examine the level of interactions with local universities during innovation process	Matched sampling On-park: 134 Off-park: 139	Questionnaire survey at firm level Independent t-test, correlation, factor analysis	• On-park firms have higher technological innovation (product development) than off-park firms • Off-park firms have higher R&D outputs (patents) • On-park firms have low level of interactions with universities, but it is still higher than off-park firms

Author(s)	Country and period	Research focus	Research methodology		Key results
			Sampling approach	Data collection and analysis techniques	
Ferguson and Olofsson (2004)	Sweden (1991-2000)	To investigate the survival and growth of NTBFs located on and off two Swedish science parks	Stratified sampling Total on- and off-park firms: 66	Questionnaire survey at firm-level Longitudinal data set (1991-2000) Correlations	• On-park firms have a higher survival rate than off-park firms • No differences in the sales of on- and off-park firms • No differences in the employment growth of on- and off-park firms • On-park firms reported higher image benefits and benefits in cooperation with universities
Akçomak and Taymaz (2004)	Turkey (2000-2002)	To assess the effectiveness of incubators in Turkey	Matched sampling On-park: 48 Off-park: 41	Questionnaire survey at firm level Chi-square test, Independent t-test	• On-park firms have higher economic performance (employment growth) than off-park firms • No differences in the innovative output (new product/service development) of on- and off-park firms • On-park firms give more importance to interaction with universities as opposed to their off-park counterparts

Author(s)	Country and period	Research focus	Research methodology		Key results
			Sampling approach	Data collection and analysis techniques	
Dettwiler, Lindelöf and Löfsten (2006)	Sweden (1999)	To relate location to facilities management and how it can affect the growth and performance of NTBFs.	Stratified sampling On-park: 134 Off-park: 139	Questionnaire survey at firm-level Descriptive analysis	• On-park firms rank proximity to university to be important as compared with off-park firms • Facilities management indirectly contributes to interactions, inter-firm relations and networks in on-park firms
Malairaja and Zawdie (2008)	Malaysia (period of study unknown)	To examine the effectiveness of science parks as a strategy to promote university-industry collaboration	Matched sampling On-park: 101 Off-park: unknown	Questionnaire survey at firm-level Chi-square test, Independent t- test	On-park firms have (not at statistically significant level) more links with universities than off-park firms
Yang et al. (2009)	Taiwan (1998-2003)	To compare the R&D productivity of NTBFs located within and outside of science parks by measuring the elasticity of R&D with respect to output	Matched sampling On-park: 57 Off-park: 190	Panel data from databank of the Taiwan Economic Journal & Taiwan Intellectual Property Office Independent t-test, regression analysis	On-park firms have significantly higher R&D spending, R&D intensity and patents than off-park firms On-park firms have higher elasticity of R&D with respect to outputs (as the indicator of R&D productivity) than off-park firms, i.e. on-park firms invest more efficiently in innovations

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APPENDIX 3

QUESTIOINNAIRE FOR ON-PARK FIRMS

Impacts of networks [illegible] **nology-based firms**

GENERAL INFORMATION

A. Contact information	*Please provide an answer where applicable*
Name of your firm:	
Name of parent and/or daughter firm:	Parent firm: Daughter firm(s):
Name of contact person in your firm:	
Contact telephone number:	
Email address:	

B. Type of firm and main activities	
B.1 Your firm is: *When answering this question, use as the criterion the activity in which the highest percentage of sales was realised in 2007.*	*Please tick only one answer, or provide an answer where applicable* □ A manufacturing firm □ A service provider □ Other type of firm ----------
B.2 What is the main activity of your firm?	*Please tick (can be more than one answer) or provide an answer where applicable* □ Production of consumer goods □ Development of consumer goods □ Production of raw and refined materials □ Development of raw and refined materials □ Production of product parts and components □ Development of product parts and components □ Production of product equipment □ Development of product equipment □ Transport (services) □ Communication (services) □ Financial services □ Business services (engineering, IT) □ Other ----------

C. Firm age and size	*Please provide an answer where applicable*
In which year was your firm established?	Year: ----------
In which year did your firm locate to The Innovation Hub?	Year: ----------
Have you participated in the Maxum Business Incubator programme?	□ Yes, I am **currently** joining the programme □ Yes, I have **graduated** from the programme □ No, I have not been to this programme before
Total number of employees (including directors/managers) in your firm in 2005 (if applicable) and 2007?	**2005** --------- **2007** ---------
Total sales (if any) of your firm in 2005 (if applicable) and 2007? (if sales volume is 1 million, please write 1,000,000)	**2005** R--------- **2007** R---------

D. Services provided by your science pa

Please tick where appropriate

To what extent are you satisfied with the following services provided by your science park?

		Do not use the service	*If you use the service, please indicate the level of satisfaction on a scale of 1 (totally dissatisfied) to 5 (totally satisfied)* 1	2	3	4	5
1.	Overall impression on pleasant environment (e.g. of site security, car parking with space for visitors, self-contained and lockable units with power and heating, possibility to expand into additional/adjacent units)	□	□	□	□	□	□
2.	Sharing office equipment, administrative support (e.g. meeting rooms, library, reception area)	□	□	□	□	□	□
3.	Organising marketing events, exhibitions, press conferences	□	□	□	□	□	□
4.	Provision of legal (by Adams & Adams), accounting, business, technical advice at low cost (or free of charge)	□	□	□	□	□	□
5.	Well-established image due to location on the science park	□	□	□	□	□	□
6.	Access to partnership opportunities with other technology firms located on the science park, knowledge sharing/dissemination	□	□	□	□	□	□
7.	Development of a pool of skilled labour, benefits from logistic arrangements, benefits from support network (e.g. emergence of complementary industries)	□	□	□	□	□	□
8.	Access to market, research centres, universities	□	□	□	□	□	□
9.	Rental subsidies, subsidies on telecom/computer network access, other subsidies related to cost reduction (only in Maxum)	□	□	□	□	□	□
10.	Access to venture capital funding, banking facilities, other sources of funding	□	□	□	□	□	□

INNOVATIVE OUTCOMES

1. Innovated product/services

Please tick where appropriate: only one answer is possible

Between 2005 and 2007, has your firm introduced **products** and/or **services** onto the market that were technologically **improved** or **new** to your firm?

Improved: *an existing product/service which has clearly improved technical specifications or increased usability compared to a previous version*

New: *a product/service incomparable with previous products or services of your firm and in which new technology is embodied*

□ Yes, products/services developed mainly **by a third party**

□ Yes, products/services developed together **with a third party**

□ Yes, products/services developed mainly **by my own firm**

□ No. Please go to **Question 4**

2. Product and/or service innovation and sales

Please tick or provide an answer where applicable

A. How many patents did your firm file in 2005 (if applicable) and 2007 respectively?

2005 _____ **2007** _____

B. How many new products and/or services did your firm develop in 2005 (if applicable) and 2007 but did not yet introduce to the market in 2005 and 2007 respectively?

2005 _____ **2007** _____

C. Do you have products and/or services on the market in 2007?

□ Yes. Please continue with **Question D**
□ No. Please go to **Question 3**

D. For 2007, give an indication of the distribution of sales of products and/or services of your firm that:

Distribution of total sales 2007

Did not change ____ %
Were technologically improved ____ %
Were technologically new ____ %

→ Total has to add up to 100%

E. In 2007, did your firm sell products/services that were not only technologically new or improved for your firm, but **also** technologically new or improved in the **market**? (*i.e. your competitors had not already introduced such products/services*)

□ Yes → Share of total sales of *these* products/services in 2007 was approximately: _____ %

□ No

3. Other results of product/service inno	*Please tick where appropriate*				
Please indicate to what extent your firm's product and/or service innovations in 2007 resulted in:	*Please indicate the extent on a scale of 1 (very little), 3 (not little / not much) to 5 (very much)*				
	1	**2**	**3**	**4**	**5**
A. Reduction of development and maintenance costs	□	□	□	□	□
B. Quality improvement of products and/or services	□	□	□	□	□
C. Increases in production capacity	□	□	□	□	□
D. Improvement in delivery times	□	□	□	□	□
E. Increase in sales	□	□	□	□	□
F. Increase in profits	□	□	□	□	□

4. Innovated processes	*Please tick where appropriate: only one answer is possible*
Between 2005 and 2007, did your firm bring production processes into use that were technologically **improved** or **new** to your firm? ***Improved:*** *an existing production process, but with clearly higher performance, less cost or improved production reliability* ***New:*** *a process incomparable with previous processes of your firm and in which new technology is embodied*	□ Yes, processes developed mainly **by a third party** □ Yes, processes developed together **with a third party** □ Yes, processes developed mainly **by my own firm** □ No. Please continue with **Question 6**

5. Other results of process innovations	*Please tick where appropriate*				
Please indicate to what extent your firm's process innovations in 2007 resulted in:	*Please indicate the extent on a scale of 1 (very little), 3 (not little and not much) to 5 (very much)*				
	1	**2**	**3**	**4**	**5**
A. Reduction of development and maintenance costs	□	□	□	□	□
B. Quality improvement of products and/or services	□	□	□	□	□
C. Increases in production capacity	□	□	□	□	□
D. Improvement in delivery times	□	□	□	□	□
E. Increase in sales	□	□	□	□	□
F. Increase in profits	□	□	□	□	□

6. Firm's level of knowledge and experience	*Please tick where appropriate*				
To what extent do the following statements apply to your firm?	*Please indicate on a scale of 1 (strongly disagree), 3 (neither agree nor disagree)to 5 (strongly agree)*				
	1	**2**	**3**	**4**	**5**
A. Most of the staff in our firm is highly skilled and qualified	□	□	□	□	□
B. Our firm invests substantially in training	□	□	□	□	□
C. Our firm innovates by improving other firms' products and processes	□	□	□	□	□
D. Most of the time our firm is ahead of our competitors in developing and launching new products	□	□	□	□	□
E. Our firm has the ability to adapt other firms' technologies	□	□	□	□	□
F. Our firm innovates as the result of R&D carried out within our own firm	□	□	□	□	□
G. Our firm has considerable resources and own knowlegde resources for technological development	□	□	□	□	□
H. Our firm is able to introduce into the market innovations that are completely novel on a worldwide scale	□	□	□	□	□

7. Trust

7.1 Interorganisational trust

Please tick where appropriate

To what extent do the following statements apply to your firm?
In general, the **organisations** with which my firm **exchanges knowledge**:

Please indicate on a scale of 1 (strongly disagree) , 4 (neither agree nor disagree) to 7 (strongly agree)

		1	2	3	4	5	6	7
A.	keep promises they make to our firm	□	□	□	□	□	□	□
B.	are always honest with us	□	□	□	□	□	□	□
C.	provide information that we can believe	□	□	□	□	□	□	□
D.	are genuinely concerned that our business should succeed	□	□	□	□	□	□	□
E.	consider our welfare as well as their own when making important decisions	□	□	□	□	□	□	□
F.	keep our best interests in mind	□	□	□	□	□	□	□
G.	are trustworthy	□	□	□	□	□	□	□
H.	it is not necessary to be cautious in dealing with them	□	□	□	□	□	□	□

7.2 Interpersonal trust

Please tick where appropriate

To what extent do the following statements apply to your firm?
In general, **the persons** with whom my firm exchanges knowledge:

Please indicate on a scale of 1 (strongly disagree) , 4 (neither agree nor disagree) to 7 (strongly agree)

		1	2	3	4	5	6	7
A.	have always been impartial in negotiations with us	□	□	□	□	□	□	□
B.	can always be counted on to act as we expect	□	□	□	□	□	□	□
C.	are trustworthy	□	□	□	□	□	□	□
D.	consider our interests even when it is costly to do so	□	□	□	□	□	□	□
E.	if their performance were below our expectations, we would feel a sense of betrayal	□	□	□	□	□	□	□

8. Relationship with firms on your science park

Does your firm exchange knowledge with firms/organisations located at your science park?	□ **Yes**. Please continue with **Question 9 and complete the rest of the questions** □ **No**. Please go to **Question 13 and complete the rest of the questions**

NETWORKING FOR INTENDED KNOWLEDGE FLOWS WITH ON-PARK FIRMS

9. Degree centrality

Please write down the number

	In 2007, with how many **organisations** located on your science park did your firm have **formal/contractual** agreements which were aimed at exchanging knowledge?	In 2007, with how many **organisations** located on your science park did your firm have interactions on a **non-contractual** basis (i.e. informal, social basis) which were aimed at exchanging knowledge?	In 2007, with how many **persons** located on your science park did you (as a manager/director) have social interactions which were aimed at exchanging knowledge? Consider persons working for the organisations under these categories.
Competitors			
Buyers			
Suppliers			
Innovation centres			
Public research labs			
University of Pretoria			
Consultants			
Sector institutes			
Others, namely: ----------			

10. Technological proximity — *Please tick where appropriate*

To what extent is the knowledge your firm receives from the **most important** partners/actors located on your science park under the following categories **similar** to your firm's own knowledge?

Similar: *similarity between your firm's knowledge and the knowledge from your most important partners/actors located on your science park*
Example of "completely similar": your firm possesses knowledge on radar technology and your most important partner exchanges with you the same knowledge in this field

Please indicate the level on a scale of 1 (not similar) to 7 (completely similar)

	1	2	3	4	5	6	7
Most important competitors	□	□	□	□	□	□	□
Most important buyers	□	□	□	□	□	□	□
Most important suppliers	□	□	□	□	□	□	□
Most important innovation centres	□	□	□	□	□	□	□
Most important public research labs	□	□	□	□	□	□	□
University of Pretoria	□	□	□	□	□	□	□
Most important consultants	□	□	□	□	□	□	□
Most important sector institutes	□	□	□	□	□	□	□
Others, namely: _____	□	□	□	□	□	□	□

11. Organisational proximity — *Please tick where appropriate*

To what extent do the following statements apply to the relationship between your firm and the most important partners/actors located on your science park?

Please indicate the level on a scale of 1 (completely disagree), 3 (neither disagree nor agree) to 5 (completely agree)

	1	2	3	4	5
A. Our firm has contacts with the same third parties (i.e. buyers, suppliers, etc.) that our partners have	□	□	□	□	□
B. Our partners have the same organisational routines and values as our firm	□	□	□	□	□
C. Our partners have the same organisational structure as our firm	□	□	□	□	□

12. Frequency of accessing knowledge and the usefulness of knowledge

12.1 Frequency — *Please tick where appropriate*

How often does your firm access knowledge from the most important partners located on your science park?

	Never	Rarely	Sometimes	Regularly	Always
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
University of Pretoria	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

12.2 Usefulness	*Please tick where appropriate*				
How useful is the knowledge your firm receives from the most important partners located on your science park with regard to your firm's innovations?	*Please indicate the level on a scale of 1 (not useful) to 5 (completely useful)*				
	1	**2**	**3**	**4**	**5**
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
University of Pretoria	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

13. Use of other knowledge sources	*Please tick where appropriate*				
How often does your firm use the following sources from organisations/actors located on your science park to acquire knowledge for your firm's innovations?	**Never**	**Rarely**	**Sometimes**	**Regularly**	**Always**
1. Employing key scientists and engineers (including poaching key staff) from other firms/organisations located on/related to your science park	□	□	□	□	□
2. Acquiring key information at conferences and workshops organised by the science park management	□	□	□	□	□
3. Reverse engineering of technological knowledge embedded in products developed/produced by other firms/organisations located on/related to your science park	□	□	□	□	□
4. Accessing patent information filed by other firms/organisations located on/related to your science park	□	□	□	□	□
5. Knowledge embedded in organisational processes or routines of firms/organisations located on your science park	□	□	□	□	□
6. Publications in technical and scientific papers by other firms/organisations located on your science park	□	□	□	□	□

Please note that the following questions are targeted at your firm's partners NOT located on science parks

NETWORKING FOR INTENDED KNOWLEDGE FLOWS WITH OFF-PARK FIRMS

14. Degree centrality			*Please write down the number*
	In 2007, with how many **organisations** (**NOT** located on science parks) did your firm have **formal/contractual** agreements which were aimed at exchanging knowledge?	In 2007, with how many **organisations** (**NOT** located on science parks) did your firm have interactions on a **non-contractual** basis (i.e. informal, social basis) which were aimed at exchanging knowledge?	In 2007, with how many **persons** (**NOT** located on science parks) did you (as a manager/director) have social interactions which were aimed at exchanging knowledge? Consider persons working for the organisations under these categories.
Competitors			
Buyers			
Suppliers			
Innovation centres			
Public research labs			
Universities (excluding University of Pretoria)			
Consultants			
Sector institutes			
Others, namely: _____			

15. Geographical proximity — *Please tick only one answer*

What is the location of the most important partner/actor (under the following categories) with whom your firm exchanges knowledge?

With respect to my firm, they are located in:

	Not a partner	Same city	Different city but same province	Other province	Abroad
Most important competitor	□	□	□	□	□
Most important buyer	□	□	□	□	□
Most important supplier	□	□	□	□	□
Most important innovation centre	□	□	□	□	□
Most important public research lab	□	□	□	□	□
Most important university (excluding University of Pretoria)	□	□	□	□	□
Most important consultant	□	□	□	□	□
Most important sector institute	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

16. Technological proximity — *Please tick where appropriate*

To what extent is the knowledge your firm receives from the most important partners/actors (**NOT** located on your science park) under the following categories similar to your firm's own knowledge?

Similar: *similarity between your firm's knowledge and the knowledge from your most important partner/actors (NOT located on your science park)*
Example of "completely similar": your firm innovates on the knowledge base of radar and your most important partner exchanges with you the same knowledge in the field of radar

Please indicate the level on a scale of 1 (not similar) to 7 (completely similar)

	1	2	3	4	5	6	7
Most important competitors	□	□	□	□	□	□	□
Most important buyers	□	□	□	□	□	□	□
Most important suppliers	□	□	□	□	□	□	□
Most important innovation centres	□	□	□	□	□	□	□
Most important public research labs	□	□	□	□	□	□	□
Most important universities (excluding University of Pretoria)	□	□	□	□	□	□	□
Most important consultants	□	□	□	□	□	□	□
Most important sector institutes	□	□	□	□	□	□	□
Others, namely: _____	□	□	□	□	□	□	□

17. Organisational proximity — *Please tick where appropriate*

To what extent do the following statements apply to the relationship between your firm and the most important partners (**NOT** located on science parks)?

Please indicate the level on a scale of 1 (completely disagree), 3 (neither disagree nor agree) to 5 (complete agree)

		1	2	3	4	5
A.	Our firm has contacts with the same third parties (i.e. buyers, suppliers, etc.) that our partners have	□	□	□	□	□
B.	Our partners have the same organisational routines and values as our firm	□	□	□	□	□
C.	Our partners have the same organisational structure as our firm	□	□	□	□	□

18. Frequency of accessing knowledge and the usefulness of knowledge

18.1 Frequency — *Please tick where appropriate*

How often does your firm access knowledge from the most important partners (**NOT** located on your science park)?

	Never	Rarely	Sometimes	Regularly	Always
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
Most important universities (excluding University of Pretoria)	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

18.2 Usefulness — *Please tick where appropriate*

How useful is the knowledge your firm receives from the most important partners (**NOT** located on your science park) with regard to your firm's innovations?

Please indicate the level on a scale of 1 (not useful) to 5 (completely useful)

	1	2	3	4	5
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
Most important universities (excluding University of Pretoria)	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

19. Use of other knowledge sources (with NO relation to science parks) — *Please tick where appropriate*

How often does your firm use the following sources from organisations/actors (**NOT** located on science parks) to acquire knowledge for your firm's innovations?

	Never	Rarely	Sometimes	Regularly	Always
1. Employing key scientists and engineers (including poaching key staff) from other firms/organisations (**NOT** located on your science park)	□	□	□	□	□
2. Acquiring key information at conferences and workshops (**NOT** organised by your science park)	□	□	□	□	□
3. Reverse engineering of technological knowledge embedded in products developed/produced by other firms/organisations (**NOT** located on your science park)	□	□	□	□	□
4. Accessing patent information filed by other firms/organisations (**NOT** located on your science park)	□	□	□	□	□
5. Knowledge embedded in organisational processes or routines of other firms/organisations (**NOT** located on your science park)	□	□	□	□	□
6. Publications in technical and scientific papers by other firms/organisations (**NOT** located on your science park)	□	□	□	□	□

APPENDIX 4

QUESTIOINNAIRE FOR OFF-PARK FIRMS

Impacts of networks on innovative performance of new technology-based firms
~ questionnaire for off-park firms

GENERAL INFORMATION

A. Contact information	*Please provide an answer where applicable*
Name of your firm: Name of parent and/or daughter firm: Name of contact person in your firm: Contact telephone number: Email address:	 Parent firm: Daughter firm(s):

B. Type of firm and main activities	
B.1 Your firm is: *When answering this question, use as the criterion the activity in which the highest percentage of sales was realized in 2007.*	*Please tick only one answer, or provide an answer where applicable* □ A manufacturing firm □ A service provider □ Other type of firm ----------
B.2 What is the main activity of your firm?	*Please tick (can be more than one answer) or provide an answer where applicable* □ Production of consumer goods □ Development of consumer goods □ Production of raw and refined materials □ Development of raw and refined materials □ Production of product parts and components □ Development of product parts and components □ Production of product equipment □ Development of product equipment □ Transport (services) □ Communication (services) □ Financial services □ Business services (engineering, IT) □ Other ----------

C. Location	
Please indicate where is your firm located	□ Pretoria □ Other city, namely: ----------

D. Firm age and size	*Please provide an answer where applicable*
In which year was your firm established?	Year: ----------
Total number of employees (including directors/managers) in your firm in 2005 (if applicable) and 2007?	**2005** --------- **2007** ---------
Total sales (if any) of your firm in 2005 (if applicable) and 2007? (if sales volume is 1 million, please write 1,000,000)	**2005** R--------- **2007** R---------

1. Innovated product/services

Please tick where appropriate: only one answer is possible

Between 2005 and 2007, has your firm introduced **products** and/or **services** into the market that were technologically **improved** or **new** to your firm?

Improved: *an existing product/service which has clearly improved technical specifications or increased usability compared to a previous version*

New: *a product/service incomparable with previous products or services of your firm and in which new technology is embodied*

□ Yes, products/services developed mainly **by a third party**

□ Yes, products/services developed together **with a third party**

□ Yes, products/services developed mainly **by my own firm**

□ No. Please go to **Question 4**

2. Product and/or service innovation and sales

Please tick or provide an answer where applicable

F. How many patents did your firm file in 2005 (if applicable) and 2007 respectively?

2005 _____ **2007** _____

G. How many new products and/or services did your firm develop in 2005 (if applicable) and 2007 but did not yet introduce to the market in 2005 and 2007 respectively?

2005 _____ **2007** _____

H. Do you have products on the market in 2007?

□ Yes. Please continue with **Question D**
□ No. Please go to **Question 3**

I. For 2007, give an indication of the distribution of sales of products and/or services of your firm that:

Distribution of total sales 2007

Did not change ____ %
Were technologically improved ____ %
Were technologically new ____ %

→ Total has to add up to 100%

J. In 2007, did your firm sell products/services that were not only technologically new or improved for your firm, but **also** technologically new or improved in the **market**? (*i.e. your competitors had not already introduced such products/services*)

□ Yes → Share of total sales of *these* products/services in 2007 was approximately: _____ %

□ No

3. Other results of product/service innovations

Please tick where appropriate

Please indicate to what extent your firm's product and/or service innovations in 2007 resulted in:

Please indicate the extent on a scale of 1 (very little), 3 (not little / not much) to 5 (very much)

	1	2	3	4	5
G. Reduction of development and maintenance costs	□	□	□	□	□
H. Quality improvement of products and/or services	□	□	□	□	□
I. Increases in production capacity	□	□	□	□	□
J. Improvement in delivery times	□	□	□	□	□
K. Increase in sales	□	□	□	□	□
L. Increase in profits	□	□	□	□	□

4. Innovated processes

Please tick where appropriate: only one answer is possible

Between 2005 and 2007, did your firm bring production processes into use that were technologically **improved** or **new** to your firm?

Improved: *an existing production process, but with clearly higher performance, less cost or improved production reliability*

New: *a process incomparable with previous processes of your firm and in which new technology is embodied*

□ Yes, processes developed mainly **by a third party**

□ Yes, processes developed together **with a third party**

□ Yes, processes developed mainly **by my own firm**

□ No. Please continue with **Question 6**

5. Other results of process innovations	*Please tick where appropriate*

Please indicate to what extent your firm's process innovations in 2007 resulted in:

Please indicate the extent on a scale of 1 (very little), 3 (not little and not much) to 5 (very much)

		1	2	3	4	5
G.	Reduction of development and maintenance costs	□	□	□	□	□
H.	Quality improvement of products and/or services	□	□	□	□	□
I.	Increases in production capacity	□	□	□	□	□
J.	Improvement in delivery times	□	□	□	□	□
K.	Increase in sales	□	□	□	□	□
L.	Increase in profits	□	□	□	□	□

6. Firm's level of knowledge and experience	*Please tick where appropriate*

To what extent do the following statements apply to your firm?

Please indicate on a scale of 1 (strongly disagree), 3 (neither agree nor disagree)to 5 (strongly agree)

		1	2	3	4	5
I.	Most of the staff in our firm is highly skilled and qualified	□	□	□	□	□
J.	Our firm invests substantially in training	□	□	□	□	□
K.	Our firm innovates by improving other firms' products and processes	□	□	□	□	□
L.	Most of the time our firm is ahead of our competitors in developing and launching new products	□	□	□	□	□
M.	Our firm has the ability to adapt other firms' technologies	□	□	□	□	□
N.	Our firm innovates as the result of R&D carried out within our own firm	□	□	□	□	□
O.	Our firm has considerable resources and own knowlegde resources for technological development	□	□	□	□	□
P.	Our firm is able to introduce into the market innovations which are completely novel on a worldwide scale	□	□	□	□	□

7. Trust

7.1 Interorganisational trust	*Please tick where appropriate*

To what extent do the following statements apply to your firm?
In general, the **organisations** with which my firm **exchanges knowledge**:

Please indicate on a scale of 1 (strongly disagree) , 4 (neither agree nor disagree) to 7 (strongly agree)

		1	2	3	4	5	6	7
I.	keep promises they make to our firm	□	□	□	□	□	□	□
J.	are always honest with us	□	□	□	□	□	□	□
K.	provide information that we can believe	□	□	□	□	□	□	□
L.	are genuinely concerned that our business should succeed	□	□	□	□	□	□	□
M.	consider our welfare as well as their own when making important decisions	□	□	□	□	□	□	□
N.	keep our best interests in mind	□	□	□	□	□	□	□
O.	are trustworthy	□	□	□	□	□	□	□
P.	it is not necessary to be cautious in dealing with them	□	□	□	□	□	□	□

7.2 Interpersonal trust	*Please tick where appropriate*

To what extent do the following statements apply to your firm?
In general, **the persons** with whom my firm exchanges knowledge:

...cate on a scale of 1 (strongly disagree) , 4 (neither agree nor disagree) to 7 (strongly agree)

		1	2	3	4	5	6	7
F.	have always been impartial in negotiations with us	□	□	□	□	□	□	□
G.	can always be counted on to act as we expect	□	□	□	□	□	□	□
H.	are trustworthy	□	□	□	□	□	□	□
I.	consider our interests even when it is costly to do so	□	□	□	□	□	□	□
J.	if their performance were below our expectations, we would feel a sense of betrayal	□	□	□	□	□	□	□

8. Relationship with firms on The Innovation Hub

Does your firm exchange knowledge with firms/organisations located at **The Innovation Hub** (which is situated in Pretoria)?

□ **Yes**. Please continue with **Question 9 and complete the rest of the questions**

□ **No**. Please go to **Question 13 and complete the rest of the questions**

NETWORKING FOR INTENDED KNOWLEDGE FLOWS WITH ON-PARK FIRMS

9. Degree centrality — *Please write down the number*

	In 2007, with how many **organisations** located on The Innovation Hub did your firm have **formal/contractual** agreements which were aimed at exchanging knowledge?	In 2007, with how many **organisations** located on The Innovation Hub did your firm have interactions on a **non-contractual** basis (i.e. informal, social basis) which were aimed at exchanging knowledge?	In 2007, with how many **persons** located on The Innovation Hub did you (as a manager/director) have social interactions which were aimed at exchanging knowledge? Consider persons working for the organisations under these categories.
Competitors			
Buyers			
Suppliers			
Innovation centres			
Public research labs			
University of Pretoria			
Consultants			
Sector institutes			
Others, namely: _____			

10. Technological proximity — *Please tick where appropriate*

To what extent is the knowledge your firm receives from the **most important** partners/actors located on The Innovation Hub under the following categories **similar** to your firm's own knowledge?

Similar: *similarity between your firm's knowledge and the knowledge from your most important partners/actors located The Innovation Hub. Example of "completely similar": your firm possesses knowledge on radar technology and your most important partner exchanges with you the same knowledge in this field*

Please indicate the level on a scale of 1 (not similar) to 7 (completely similar)

	1	2	3	4	5	6	7
Most important competitors	□	□	□	□	□	□	□
Most important buyers	□	□	□	□	□	□	□
Most important suppliers	□	□	□	□	□	□	□
Most important innovation centres	□	□	□	□	□	□	□

	4	5	6	7
Most important public research labs	□	□	□	□
University of Pretoria	□	□	□	□
Most important consultants	□	□	□	□
Most important sector institutes	□	□	□	□
Others, namely: _____	□	□	□	□

11. Organisational proximity — *Please tick where appropriate*

To what extent do the following statements apply to the relationship between your firm and the most important partners/actors located on The Innovation Hub?

Please indicate the level on a scale of 1 (completely disagree), 3 (neither disagree nor agree) to 5 (completely agree)

	1	2	3	4	5
D. Our firm has contacts with the same third parties (i.e. buyers, suppliers, etc.) as our partners have	□	□	□	□	□
E. Our partners have the same organisational routines and values as our firm	□	□	□	□	□
F. Our partners have the same organisational structure as our firm	□	□	□	□	□

12. Frequency of accessing knowledge and the usefulness of knowledge

12.1 Frequency — *Please tick where appropriate*

How often does your firm access knowledge from the most important partners located on The Innovation Hub?

	Never	Rarely	Sometimes	Regularly	Always
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
University of Pretoria	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

12.2 Usefulness — *Please tick where appropriate*

How useful is the knowledge your firm receives from the most important partners located on The Innovation Hub with regard to your firm's innovations?

Please indicate the level on a scale of 1 (not useful) to 5 (completely useful)

	1	2	3	4	5
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
University of Pretoria	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

13. Use of other knowledge sources *Please tick where appropriate*

How often does your firm use the following sources from organisations/actors located on The Innovation Hub to acquire knowledge for your firm's innovations?	Never	Rarely	Sometimes	Regularly	Always
7. Employing key scientists and engineers (including poaching key staff) from other firms/organisations located on/related to The Innovation Hub	□	□	□	□	□
8. Acquiring key information at conferences and workshops organised by the science park management of The Innovation Hub	□	□	□	□	□
9. Reverse engineering of technological knowledge embedded in products developed/produced by other firms/organisations located on/related to The Innovation Hub	□	□	□	□	□
10. Accessing patent information filed by other firms/organisations located on/related to The Innovation Hub	□	□	□	□	□
11. Knowledge embedded in organisational processes or routines of firms/organisations located on The Innovation Hub	□	□	□	□	□
12. Publications in technical and scientific papers by other firms/organisations located on The Innovation Hub	□	□	□	□	□

Please note that the following questions are targeted at your firm's partners NOT located in The Innovation Hub

NETWORKING FOR INTENDED KNOWLEDGE FLOWS WITH OFF-PARK FIRMS

14. Degree centrality *Please write down the number*

	In 2007, with how many **organisations** (**NOT** located on The Innovation Hub) did your firm have **formal/contractual** agreements which were aimed at exchanging knowledge?	In 2007, with how many **organisations** (**NOT** located on The Innovation Hub) did your firm have interactions on a **non-contractual** basis (i.e. informal, social basis) which were aimed at exchanging knowledge?	In 2007, with how many **persons** (**NOT** located on The Innovation Hub) did you (as a manager/director) have social interactions which were aimed at exchanging knowledge? Consider persons working for the organisations under these categories.
Competitors			
Buyers			
Suppliers			
Innovation centres			
Public research labs			
Universities (excluding University of Pretoria)			
Consultants			
Sector institutes			
Others, namely: _____			

15. Geographical proximity *Please tick only one answer*

What is the location of the most important partner/actor (under the following categories) with whom your firm exchanges knowledge?	Not a partner	*With respect to my firm, they are located in:* Same city	Different city but same province	Other province	Abroad
Most important competitor	□	□	□	□	□
Most important buyer	□	□	□	□	□
Most important supplier	□	□	□	□	□
Most important innovation centre	□	□	□	□	□
Most important public research lab	□	□	□	□	□
Most important university (excluding University of Pretoria)	□	□	□	□	□
Most important consultant	□	□	□	□	□
Most important sector institute	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

16. Technological proximity *Please tick where appropriate*

To what extent is the knowledge your firm receives from the most important partners/actors (**NOT** located on The Innovation Hub) under the following categories similar to your firm's own knowledge?

Similar: *similarity between your firm's knowledge and the knowledge from your most important partner/actors (NOT located on The Innovation Hub)*
Example of "completely similar": your firm innovates on the knowledge base of radar and your most important partner exchanges with you the same knowledge in the field of radar

Please indicate the level on a scale of 1 (not similar) to 7 (completely similar)

	1	2	3	4	5	6	7
Most important competitors	□	□	□	□	□	□	□
Most important buyers	□	□	□	□	□	□	□
Most important suppliers	□	□	□	□	□	□	□
Most important innovation centres	□	□	□	□	□	□	□
Most important public research labs	□	□	□	□	□	□	□
Most important universities (excluding University of Pretoria)	□	□	□	□	□	□	□
Most important consultants	□	□	□	□	□	□	□
Most important sector institutes	□	□	□	□	□	□	□
Others, namely: _____	□	□	□	□	□	□	□

17. Organisational proximity *Please tick where appropriate*

To what extent do the following statements apply to the relationship between your firm and the most important partners (**NOT** located on The Innovation Hub)?

Please indicate the level on a scale of 1 (completely disagree), 3 (neither disagree nor agree) to 5 (complete agree)

	1	2	3	4	5
D. Our firm has contacts with the same third parties (i.e. buyers, suppliers, etc.) that our partners have	□	□	□	□	□
E. Our partners have the same organisational routines and values as our firm	□	□	□	□	□
F. Our partners have the same organisational structure as our firm	□	□	□	□	□

18. Frequency of accessing knowledge and the usefulness of knowledge

18.1 Frequency *Please tick where appropriate*

How often does your firm access knowledge from the most important partners (**NOT** located The Innovation Hub)?

	Never	Rarely	Sometimes	Regularly	Always
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
Most important universities (excluding University of Pretoria)	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

18.2 Usefulness	*Please tick where appropriate*				
How useful is the knowledge your firm receives from the most important partners (**NOT** located on The Innovation Hub) with regard to your firm's innovations?	*Please indicate the level on a scale of 1 (not useful) to 5 (completely useful)*				
	1	**2**	**3**	**4**	**5**
Most important competitors	□	□	□	□	□
Most important buyers	□	□	□	□	□
Most important suppliers	□	□	□	□	□
Most important innovation centres	□	□	□	□	□
Most important public research labs	□	□	□	□	□
Most important universities (excluding University of Pretoria)	□	□	□	□	□
Most important consultants	□	□	□	□	□
Most important sector institutes	□	□	□	□	□
Others, namely: _____	□	□	□	□	□

19. Use of other knowledge sources (with NO relation to science parks)	*Please tick where appropriate*				
How often does your firm use the following sources from organisations/actors (**NOT** located on The Innovation Hub) to acquire knowledge for your firm's innovations?	**Never**	**Rarely**	**Sometimes**	**Regularly**	**Always**
7. Employing key scientists and engineers (including poaching key staff) from other firms/organisations (**NOT** located on The Innovation Hub)	□	□	□	□	□
8. Acquiring key information at conferences and workshops (**NOT** organized by The Innovation Hub)	□	□	□	□	□
9. Reverse engineering of technological knowledge embedded in products developed/produced by other firms/organisations (**NOT** located on The Innovation Hub)	□	□	□	□	□
10. Accessing patent information filed by other firms/organisations (**NOT** located on The Innovation Hub)	□	□	□	□	□
11. Knowledge embedded in organisational processes or routines of other firms/organisations (**NOT** located on The Innovation Hub)	□	□	□	□	□
12. Publications in technical and scientific papers by other firms/organisations (**NOT** located on The Innovation Hub)	□	□	□	□	□