Knowledge Flows and Innovative Performances of NTBFs in Gauteng, South Africa: An Attempt to Explain Mixed Findings in Science Park Research

Kai-Ying A. Chan, Leon A.G. Oerlemans and Marthinus W. Pretorius

Abstract**—**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.

Keywords**—**knowledge flows, innovative performances, science parks, new technology-based firms

I. Introduction

SCIENCE parks are not a new phenomenon. The science park concept can be traced back to 1950s when Silicon Valley, with the support of Stanford University, transformed from an agricultural valley into the birthplace of the semiconductor industry. Followed by the USA experience in the 1960s, the developments of Cambridge Science Park (UK) and Sophia Antipolis (France) have set good examples for many European countries. The majority of the existing science parks in the world were created during the 1990's and about 18% of these science parks have been launched in the first two years of the new century. Today 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 the policy makers in industrialized economies, that the establishment of science 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 foundation of a science park is often used as a policy intervention to stimulate high technology start-ups and supporting them [1]. It is where government provides infrastructure, industry provides business skills and funding and universities provide research and new technology development; also known as the Triple Helix of university-industry-government relations for innovation [2]. An important function of any science park is to contribute to the establishment of a knowledge-based economy by fostering market-oriented technological development. This type of economy depends on three interrelated processes: local knowledge creation, transfer of knowledge from external sources and transfer of that knowledge into productive activities [3]. Thus networking amongst firms and between firms and universities to foster collaboration and innovation is a vital process in a science park.

Despite the benefits that science parks might bring, researchers have been studying the science park phenomenon to analyze to what extent science parks are just 'high tech fantasies' [4], [5]. To ascertain the 'added-value' of a science park location, researchers believed comparative studies should be conducted [6], [7]. These studies compare behavior and performance of firms located on a science park with firms not located on a science park to explore the differences between them. In this literature, researchers have reported mixed findings when they evaluate the performance of science park firms. Some researchers found empirical evidence of the 'added-value' from science park location (e.g. [7], [8]) whereas others questioned the assumed benefits of the science park model (e.g. [6], [9]) and found that there are no differences between on-park firms and off-park firms as to their performance. Further details of these comparative studies will be elucidated in a later section. From the observations of these studies we see that there are 'mixed' findings regarding the performances of science parks. The mixed evidence in literature raised a question for this study to explore further: How can we explain these mixed findings? As mentioned earlier, 'knowledge' play an important role in innovations and governments use science parks as their tool to create an

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environment for firms to access and benefit from knowledge flows. Governments have approached the challenge of ‘innovation’ and ‘knowledge transfer’ with a loose assemblage of theoretical concepts [10]. The lacking evidence in the relationship between ‘knowledge transfer’ and ‘innovation’ lead us to look at the knowledge flows between organizations on and off a science park and their impacts on the innovativeness of these firms. Hence, we put forward the research question of this study:

To what extent do intended / unintended knowledge inflows 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-findings that exist in science park literature. Most studies that take an off-park sample into account explore the differences in both samples’ (on-park & off-park firms) characteristics and performances. However, the relationship between these firm characteristics and firm performance are hardly been investigated in these studies. This paper will explore the link between knowledge flows and firm innovativeness to further explain the mixed findings found in literature. Secondly, most studies use ‘patents’ and ‘new products / services’ (e.g. [6], [11], [12]) as indicators for firm innovative performance. In this study, innovative performances is conceptualized as a multi-dimensional construct and thus measured with multiple indicators to explore a more holistic view of innovative performance of science park firms. Thirdly, most science park studies are done in developed countries and this study is done in a country with emerging economies (i.e. South Africa). From this study we can see whether the science park model (originated from developed countries) works the same in the environment of a less developed country.

This empirical article is organized as follows. In the next section, the results of a literature review about the performance of science park firms will be presented. In section 3, the theoretical framework of this study with the hypotheses will be developed. Section 4 describes the research methodology that is applied in this study. Section 5 discusses the results of a survey among new technology based firms (NTBFs) which the authors carried out in Gauteng province of South Africa during the year 2008, focusing on firms’ knowledge exchange behaviours and innovative performances in year 2007. Section 6 provides some concluding remarks and recommendations for policy makers and further studies.

II. Science Park Literature and Mixed Findings

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. The 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 explore the empirical results from the past studies regarding the science park firms. The details of the review are summarized in a table (see Appendix 1). Besides the names of the author(s), the following criteria were included:

- Country & Period: Where and when was the research conducted? In particular we want 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 deduct the various foci the researchers used and where the gaps exist;
- Research methodology: Which research methodologies do studies apply to answer their research questions empirically? From these two columns we explore which research methodology is ‘commonly accepted’ so that we can use (or improve upon) in our study.
- Key results: Under certain aspects studied, do the on- and off-park firms differ from one another? From this column, we can see how do the studies view the SP differently; in other words, are there any ‘mixed findings’?

The table in the appendix summarizes 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, with longitudinal data sets (ranging from 3 years to 10 years) which are necessary to examine proxies of firm performance such as the ‘employment growth’ or ‘survival’ of firms over time. The foundation of science parks rises from year 1973 until 1987, after which a decline started, followed by an increase from 1997 onwards. This growth-decline-growth phenomenon in science park creation may be one of the reasons that more researchers, using comparative approaches, investigate to what extent science parks bring benefits.

A majority of studies were conducted in the 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 study in emerging economies. The collaborative culture differs from country to country. Western cultures (Western Europe, North America, and Australia) are characterized as individualistic, whereas some non-Western cultures (Asian, South American, and Africa) often are characterized as collectivistic [13]. Since firms consist of ‘people’ who have a specific culture from their residing country, the collaborative culture (as compared with non-Western countries, firms in Western countries are less collaborative) in firms (whether situated on or off a science park) will differ from country to country.

Studies tend to focus on three areas: (1) Employment growth [12], [14]-[16]; (2) Industry-academic links [7], [8], [12], [17], [18]; and (3) Innovativeness as indicated by R&D inputs, outputs and productivity [6], [11], [12], [15], [19].

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

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 sample. This finding shows a commonly accepted way of sampling. All studies used questionnaires and survey to collect firm-level data. One exception is Yang's study where panel data from a financial databank was used [19]. This shows a trend in 'firm-level' analysis to explore performance of science parks. If one wishes to explore the performance of a science park, the unit of analysis at firm-level (to explore the dynamics amongst firms or within a firm) will be the best fit for a model (as compared to other levels such as industries). Most studies used 'independent samples t-test' for continuous and discrete variables and 'Chi-squared test' for dummy variables. These two statistical analysis tests are commonly used when one needs to compare variables from two independent samples (i.e. a firm can either be on- or off-park) and explore any significant differences between them to realize the 'added-values' of a science park. Moreover, from the observation in these studies, there is a lack of multivariate analysis to explore the relationship between firm characteristics and performance (e.g. using multivariate regression analysis).

A comparison of the research findings in the studies in our 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 [12], [14], [16], whereas others report that on-park firms have higher employment growth [15], [17];

Interactions with universities: Some report no significant difference between on- and off-park firms [9] and others find that on-park firms have higher levels of interactions with (local) universities [7], [8];

R&D outputs and productivity: Some find no significant difference between on- and off-park firms [6], [7], [15], [20], whereas others report that on-park firms have higher R&D outputs and productivity [11], [19].

On specific indicators studies report similar findings, but these do not support the 'promises' that science parks made:

- There are no differences between on- and off-park firms in sales/profitability [16], [17].
- There are no differences between on- and off-park firms regarding R&D inputs [6], [15].

From the mixed findings observed, one can clearly see that, not all science parks deliver their promises of bringing 'added-values' to its on-park firms and regions. Some on-park firms outperform the off-park firms but some make no difference. From these mixed findings this paper asks the question: How can we explain these mixed findings? In other words, we want to know why some on-park firms outperform the off-park firms and some don't. Review in this section shows a lack of multivariate analysis to explore the relationship between firm characteristics and performance; this suggests a need for such an analysis to explain the mixed findings.

III. Research Framework

A. Introduction

Literature identifies 'knowledge' 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 [21]–[23]. In this age of increasing globalization and increasing complexity of technological innovation, internal generated knowledge resources (e.g. from in-house R&D) are no longer sufficient for technology innovation. Firms often acquire external knowledge from outside actors to compliment the internal knowledge base for innovative products/services developments. Researchers have distinguished two categories of knowledge transmission: intended and unintended knowledge flows [24], [25]. Intended knowledge flow is when knowledge is exchanged with the intended people or organizations who are aware that their knowledge is being transferred to another firm. On the other hand, unintended knowledge flow refers to any knowledge that is exchanged unwillingly by the sending firms and outside their intended boundary.

Innovative performance in this study is based on the definition from Ernst [26]: achievement in the trajectory from conception of an idea up to the introduction of an invention into the market. Most studies use single measurement such as 'patent' (e.g. [27]) or number of new products introduced (e.g. [28]) for innovative performance. From Ernst's definition, one should look at innovation from a holistic view, i.e., looking at the whole innovation life cycle (from ideas to commercialization). Thus, in this study, innovative performances are measured with multiple dimensions (e.g. total innovative sales and relative innovative performance).

B. Intended Knowledge Flows and Innovative Performance

Firms establish linkages with the purpose of acquiring and integrating different knowledge assets from external actors to develop technological innovations. A firm can interact with its partners formally to establish formal networks. 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 [29]. The governance of formal collaborations is commonly through mutually accepted contracts to formalize and control the relationship between the parties with the aim to increase the level of success in the knowledge transfer process [30]. Contrary to formal networking, knowledge can be exchanged informally through informal networking activities which are conducted without any formal agreements between two parties. Informal networking can happen at two levels: inter-organizational informal networking (in this study labeled as 'informal networking') or inter-personal informal networking ('social networking'). Informal networks can be created by informal functions arranged between two organizations, such as breakfast/lunch meetings, golf events, etc. On the other hand, 'social networks' consists 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 on how new products are created or innovative ideas can be shared during these social conversations.

In literature, tacit knowledge is valuable for innovation and cannot be codified. It is only gained through face-to-face interactions, i.e., networking [31]. Studies have shown the positive relationship between networks and innovation. For example, in Gay & Dousset's study [32], they have correlated network performance and innovation at global level. Boschma & ter Walt [33] reported that a strong local network position (degree centrality defined as 'number of ties/relationships') of a firm tended to increase their innovative performance in an industrial district. It is through these intended interactions (i.e. ties in networks) where external knowledge is able to flow into a firm. Intended knowledge flows are closely related to innovations. Firms who involve in networks are able to gather more knowledge resources (intended knowledge flows) to perform their innovative activities. Knowledge partners with formalized relationships (e.g. through contracts) or involved in informal relationships are more willingly to share (and less likely to hold back) knowledge due to the trust in the relationships; and as a result the receiver-firm is able to have a better (higher quality) of knowledge resource for successful innovations. Networks also provide opportunities for firms to compare and integrate intended knowledge inflows from various sources so that new knowledge may emerge for technology development. Based on the above theoretical arguments,

Hypothesis 1: The higher the intended knowledge inflows, the higher the firm's innovative performance

C. Unintended Knowledge Flows and Innovative Performance

Unintended knowledge flows are often referred to in the knowledge spillover literature [24], [25], [34] and is defined as 'knowledge received without the acknowledgement of the sending firms'. Firms that do not have knowledge as its competitive advantage can engage in activities to reduce their knowledge disadvantage, e.g., by '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' [35], by imitating other firm's technologies, or by monitoring other firms' innovative activities. Thus, knowledge spillovers (unintended knowledge flows) 'denote the benefit of knowledge to firms not responsible for the original investment of the creation of this knowledge' [36]. Researchers in the past have attributed positive innovation effects to knowledge spillovers / unintended knowledge flows [24], [25], [37], [38]. Learning from knowledge spillover has the same benefits as intended knowledge flows, i.e., more knowledge resources to perform innovative activities. However, the big benefit of unintended knowledge flows / spillovers is the low or no cost involved in gathering such knowledge (e.g. no R&D investments is needed); as compared with the high costs involved (e.g. contract costs) when a firm access intended knowledge flows through formalized relationships. Hence,

Hypothesis 2: The higher the unintended knowledge inflows, the higher a firm's innovative performances

D. Moderating Effect of Intended and Unintended Knowledge Flows

The relationship between intended knowledge flows and innovative performances of firms will be negatively influenced by higher levels of unintended knowledge flows because the moment the sender-firm realizes that their knowledge is 'used' without their approval, this will lower their willingness to share knowledge in formal collaborations and/or informal networking activities. 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) exchange knowledge in formalized and / or informal relationships. From the above argument,

Hypothesis 3: The relationship between intended knowledge flows and innovative performance of firms will be negatively moderated by higher levels of unintended knowledge flows/spillovers.

The above three hypotheses form the research model that this study will explore empirically. The research model is shown in the following figure:

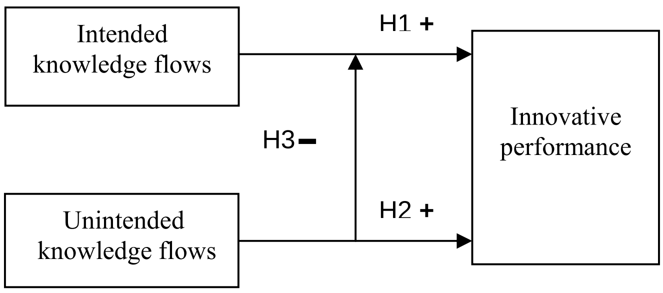

Fig. 1 Research model showing three effects of knowledge flows on innovative performance

IV. Research Methodology

A. Sample and Data Collection

The focus of this study is the relationship between knowledge flows and innovative performance at firm-level. The unit of analysis is NTBFs located in the Gauteng region of South Africa (a developing country with an emerging economy). Gauteng is chosen because it possesses the highest distribution of R&D investments, scientific productions and patents which relate to knowledge [39]. For most countries with emerging economies, in order to fast grow the economy, NTBFs are emerging as knowledge intensive organizations to accelerate the diffusion of technology [7], [40]. Firms chosen for this study full-fill the criteria of NTBFs: small firm size (number of employees including directors/CEOs less than 50), young firm age (less than 10 years since establishment) and highly technology-based (e.g. ICT, Biotech, Electronics industries). This research applies a quantitative research methodology. Data regarding firms' knowledge inflows and innovative performances 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, of which 24 came from NTBFs situated in The Innovation Hub (a science park). The collected data were statistically analyzed by applying multivariate regression analyses in SPSS.

B. Measurements of Variables

Table 1 illustrates the items that are used in the questionnaire to measure the variables proposed in the research framework. The items were based on previous measures in literature and some were measured using a 5-point Likert type scale. Table 2 shows the literature that was sourced to construct our measurements, as well as the reliability statistics (Cronbach's alpha) of the scales used. Reliability tests were done on the independent variable 'unintended knowledge flows' and the dependent variable 'relative innovative performance' which were measured using multiple items (both have 6 items using 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, unidimensional latent construct.

Dependent variables

In this study we conceptualize innovative performance as a multi-dimensional construct. This study distinguishes two types of innovative performances: innovative and relative [25]. The innovative aspect captures the physical outcome of innovations expressed in percentage of sales of innovative products / services. The relative scope of innovative performance 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 [25]. The three indicators used in this study as proxies to successful innovative outcomes are as follows:

- new innovation; measured as percentage of sales of products/services that were technologically new;
- total innovation; measured as percentage of sales of products/services that were technologically improved and technologically new; and
- relative innovation; measured as other results due to innovations, e.g. reduction in production capacity.

Independent and Control Variables

There are two independent variables in the research model. In the literature discussion earlier, this study distinguishes between 'intended knowledge flows' and 'unintended knowledge flows' under the general term of 'knowledge flows'. Intended knowledge flows are measured by looking at the three types of knowledge networks because a firm can acquire intended knowledge via formal, informal and social networks. Unintended knowledge flows are observed by the firm's 'imitative' or 'opportunistic' behaviours such as 'reverse engineering' or 'monitor other firm's innovative activities'.

The recipient firm size, firm age and science park location are included as control variables. We controlled for 'firm size' and 'firm age' given that these two firm attributes have been important factors for firms to acquire and exploit knowledge resources (e.g. [41]-[43]). Small and young firms often face significant risk and uncertainty due to lack of knowledge resources (a liability of newness). For a technology-based firm to be innovative it is vital to build up its knowledge resources, which is path dependent (over a period of time) and require people. In this study we also controlled for 'science park location' because out of 52 NTBFs that we surveyed, 24 firms are situated in The Innovation Hub which is the first internationally accredited science park in South Africa [44]. Science park location (SPL) in literature is believed to have many value added contributions towards firms [45]. Firms with SPL have more networking opportunities with other resident firms due to close geographical distance (these firms are located in a bounded space). Besides close geographical distance which provides face-to-face encounters, one of the tasks of a science park management team is to organize networking activities such as seminars and social events amongst on-park firms as well as with organizations located outside the science park premise. Thus science park location plays a role in facilitating knowledge flows and innovative performance of firms.

TABLE I
ITEM(S) OF VARIABLES

Independent Variables		Item(s)
Intended knowledge flows	from formal networks	Number of organizations (suppliers, buyers, consultants, competitors, universities, public labs and sector institutes) the respondent firm interacts under formal/contractual agreements to acquire knowledge.
	from informal networks	Number of organizations (suppliers, buyers, consultants, competitors, universities, public labs and sector institutes) the respondent firm interacts on a non-contractual basis (i.e. informal, social basis) to acquire knowledge.
	from social networks	Number of persons in organizations (suppliers, buyers, consultants, competitors, universities, public labs and sector institutes) the CEO/director of the respondent firm interacts socially to acquire knowledge.
Unintended knowledge flows		How often does your firm use the following sources from other organizations/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/organizations; (4) accessing patent information filed by other firms/organizations; (5) knowledge embedded in organizational processes or routines of other firms/organizations; (6) publications in technical and scientific papers by other firms/organizations. (5 point Likert scale: never, rarely, sometimes, regularly or always).
Dependent Variable		**Item(s)**
Firm's innovative performance		Three indicators of innovative performance were used: (1) New innovations: percentage of sales of product/services that were technologically new (2) Total innovation: percentage of sales of products/services that were technologically improved and technologically new; (3) relative innovation: 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 points Likert scale: 1 = very little, 3 = not little / not much, 5 = very much).
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 (a science park in Gauteng)?

V. EMPIRICAL RESULTS AND DISCUSSION

A. Descriptive analysis

Means and standard deviations associated with study variables are provided in Table 3.

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 unintended knowledge flow score is close to 1 on a scale of 5 showing that on average NTBFs rarely access unintended knowledge flows. In general, NTBFs have 72.21% for their innovative performances. This shows that out of 100% of products/ services they sold, 72.21 % were technologically improved and new to the firm and only 27.79% were from products / services from their existing technologies. 30.1% were products / services sold that were technologically new to the firm, i.e., 3 out of every 10 products / services sold are new innovations. The score for relative innovation (i.e. other results due to innovations) is 3.68; this is above average on a scale of 5. 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. 46.2% of the firms in the sample are with a science park location (situated in the Innovation Hub).

TABLE II
MEASUREMENTS, THEIR SOURCES, AND RELIABILITY STATISTICS

Variables	Source (where applicable)	Measurement and Cronbach's α in this research (where applicable)
Intended knowledge flows from formal networks	Otte and Rousseau (2002) [46]	count of total number of formal ties.
Intended knowledge flows from informal networks	Otte and Rousseau (2002) [46]	count of total number of informal ties.
Intended knowledge flows from social networks	Otte and Rousseau (2002) [46]	count of total number of social ties.
Unintended knowledge flows	Howells (2002) [47]	Average sum score of all 6 items using 5 point Likert scale (α =0.702)
Firm's innovative performance	Cassiman et al. (2005) [48] Relative innovative performance: Oerlemans and Meeus (2005) [25]	(1) Total innovative sales: percentage of sales of products/services that were technologically improved and technologically new; (2) New innovative sales: percentage of sales of products/services that was technologically new. (3) Relative innovative performance: average sum score of all 6 items using 5 point Likert scale (α = 0.656)
Firm size	Source n/a	Count of the total number of employees in year 2007
Firm age	Source n/a	2008 (the year when this research was conducted) minus the founding year of the firm

TABLE III
MEANS AND STANDARD DEVIATIONS

Variables	Mean	Std. dev.
Independent Variables:		
Intended knowledge flow from formal network	8.75	12.516
Intended knowledge flow from informal network	10.42	10.273
Intended knowledge flow from social network	25.04	30.497
Unintended knowledge flow	0.987	0.480
Dependent Variables: Innovative performance		
New innovation	30.10	30.33
Total innovation	72.21	31.567
Relative innovation	3.680	0.682
Control Variables:		
Firm size	9.25	9.91
Firm age	5.13	3.61
SP location	0.46	0.50

B. Multivariate regression analysis

The models in this study are estimated by using SPSS to perform OLS-based hierarchical regression analysis. All variables mentioned in the previous section are entered with three steps:

Model 1: Model with only the control variables
Model 2: Model 1 + intended knowledge flows + unintended knowledge flows
Model 3: Model 2 + product term

Model 1 contains several control variables, including firm size (FS), firm age (FA) and science park location (SPL). Then, intended knowledge flows (IKF) and unintended knowledge flows (UKF) are entered in Model 2. Note that in this study we distinguish three ways a firm can acquire intended knowledge, i.e. via formal, informal and social networks. To test Hypothesis 3, the moderating effect of unintended knowledge flow on the relationship between intended knowledge flows and innovative performances, a product term of the original variables (INF*UNF) is included in Model 3 as the basis of testing whether moderating effect is present in this study. For each indicator of innovative performances, there are three sets of models 1~3 to account the three types of networks that a firm uses to acquire intended knowledge. Table 4 and 5 show the results of the regression analysis.

Innovative performance: new innovations

In Table 4, the results of regression analysis for the innovative performance indicator 'new innovation' are shown. The discussion will start by looking at the confident level of model fits, followed by the significant impacts of variables on the dependent variable in the models (only those models that fits the data).

TABLE IV
RESULTS OF REGRESSION ANALYSIS FOR NEW INNOVATIONS (N=52)

Variable	Dependent variable: new innovative product / services sales in 2007								
	Formal Network			Informal Network			Social Network		
	Model1	Model2	Model3	Model1	Model2	Model3	Model1	Model2	Model3
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*
IKF		0.003	0.124		0.426***	-0.368		-0.287*	-0.814
UKF		0.168	0.234		0.391**	0.410*		0.304*	0.228
IKF*UKF			-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 %	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

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

All proposed regression models fits the data, except Model 2 and Model 3 in formal networks with non significant F-values. All other models have F-value at significant level of p<0.10 to p<0.01, with the exception of Model 2 in informal network which represent the best model fit with F-value significant at p<0.01. In Model 2 of informal network, by adding the two types of knowledge flows (IKF and UKF), the change in R^2 is 13.8%, indicating that both knowledge flows are accounted for approximately 13.8% of the variance in new innovations (new innovative products/ services sales). Compared with social networks, ΔR^2 in Model 2 is 8.5%. The change in F-values of both Model 3 in informal and social networks are not significant. This means that the product term (IKF*UKF) do not account any change in the variance of new innovations.

In all three cases of Model 1, with only the control variables, FS has a negative impact and SPL has a positive impact on the new innovations (both at significant level of 5%, except FS in Social Network is significant at 10%). This implies that a firm with many employees (bigger firm) will have a positive impact on its new innovations as well as having a science park location. However, firm size has no impact on new innovations in Model 2 where both types of knowledge flows (IKF & UKF) are added. SPL is not significant in formal networks but has significant and positive influence on new innovations in informal (p<0.05) and social (p<0.1) networks. This implies that when firms (despite their sizes) are networking informally or socially, having a SPL plays a role in their new innovation outcomes.

Adding the intended and unintended knowledge flows (IKF & UKF in Model 2) to the model with only controls (Model 1) increases the R^2 by about 2.4 %, 13.8 % and 8.5% in the formal, informal and social networks respectively. Model 2 of informal network has a better fit than the other two models, as two knowledge flows in this model accounted for approximately 13.8% of the variance in new innovations. Moreover, the F-value (4.446) for the incremental R^2 values in Model 2 of informal network achieves a statistical significance at the 5% level. An inspection of the coefficients in all three of model 2 show that IKF and UKF have no impact in formal network; however, both types of knowledge flows have significant impact on new innovations in informal and social network. In informal network, IKF and UKF have positive impacts ($p<0.001$ and $p<0.05$ respectively). However, in social network, UKF still has a positive impact ($p<0.05$) but IKF has a negative impact at significant level of 10%.

Adding the product term (Model 3) to Model 2 does not increase the R^2 in formal network or increase only by 0.3% and 1.2% in informal and social network respectively with no significant change in F-values. This result shows that there is no moderating effect of UKF on the relationship between IKF and new innovation in any types of networks.

Innovative performance: total innovations

In Table 5, only Model 1 (with control variables) in formal, informal and social networks have significant F-values ($p<0.1$) so we are confident that the proposed regression model 1 fits the data. However, the other two models (Model 2 & 3) do not represent good model fits with non significant F-values. In all Model 1, SPL plays a very significant positive role in a firm's total innovations (i.e. improved innovative sales plus new innovative sales) at significant level of 1%. In both organizational formal and informal networks, SPL accounts for 13% of the variation in total innovative products/ services sales (with F-value = 2.448; $p<0.1$). But in personal social network, SPL plays a slightly more important role to total innovative performance with R^2 increased to 15.1% (F-value = 2.760; $p<0.1$). This result implies that a firm with science park location is able to benefit slightly more (from total innovation perspective) from the location when it is embedded in a social network as compared with formal or informal networks.

TABLE V
RESULTS OF REGRESSION ANALYSIS FOR TOTAL INNOVATIONS (N=52)

Variable	Dependent variable: total innovative product / services sales in 2007								
	Formal Network			Informal Network			Social Network		
	Model1	Model2	Model3	Model1	Model2	Model3	Model1	Model2	Model3
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**
IKF		0.055	0.253		-0.062	0.1		-0.032	-0.287
UKF		-0.016	0.090		0.029	0.082		0.030	-0.007
IKF*UKF			-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

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

Innovative performance: relative innovation

In Table 6, all models in informal and social networks do not have best model fits; only Model 2 in formal network have the best model fit with F-value at significant level of 10%.

In formal network, FS plays a significant ($p<0.05$) and negative role in relative innovations. This implies that for a small (few employees) firm, its relative performance due to innovations, e.g. reduction in development / maintenance costs, will be poor.

In Model 2 of formal network only the coefficient of IKF is significant ($p<0.05$) and has positive impact on relative innovations. ΔR^2 of this model is 9.7% indicating that IKF is accounted for 9.7% of variation in relative innovations. UKF has negative impact in this model but however not significant. The coefficient of the product term (IKF*UKF) in Model 3 is not significant; this implies that the expected moderating effect does not exist in this model.

TABLE IV
RESULTS OF REGRESSION ANALYSIS FOR RELATIVE INNOVATION (N=52)

Variable	Dependent variable: relative innovations								
	Formal Network			Informal Network			Social Network		
	Model1	Model2	Model3	Model1	Model2	Model3	Model1	Model2	Model3
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
IKF		0.363**	0.164		0.141	-0.136		0.148	-0.054
UKF		-0.172	-0.280		-0.130	-0.221		-0.117	-0.147
IKF*UKF			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

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

VI. CONCLUSION AND RECOMMENDATION

A. Findings and implications

The primary objective of this study is to explain the mixed findings in the science park literature by investigating the effects of different knowledge flows on firm innovative performances. Two types of knowledge flows are explored in this study: intended and unintended knowledge flows. Based on these two types of knowledge flows, this study try to answer the research question: to what extent do intended and unintended knowledge inflows explain the innovative performance of science park firms? and thus three hypotheses are formulated after literature studies:

H1: The higher the intended knowledge inflows, the higher the firm's innovative performance;
H2: The higher the unintended knowledge inflows, the higher a firm's innovative performances; and
H3: The relationship between intended knowledge flows and innovative performance of firms will be negatively moderated by higher levels of unintended knowledge flows/spillovers.

This study is based on a sample from NTBFs in Gauteng region which is the economic engine of South Africa (a country with an emerging economy). Data is collected at firm-level by structured interviews with questionnaires targeted at the directors or CEOs and 52 valid questionnaires were obtained. Statistical analysis using multivariate regression models present several interesting findings. Firstly, intended knowledge inflows through informal networking have significant and positive effects on new innovations, but have significant and negative impacts if it is acquired via social networks. This negative impact may be accounted for by the less formal nature that exists in inter-personal social network as compared to inter-organizational informal network. When two people share ideas or research results during informal events organized by two firms, they will share more openly and willingly because they know that their interactions are under their firm's approvals. On the other hand, when two people are just friends or previous colleagues (inter-personal social networks), they might not provide all what they know truthfully or reluctantly with each other because they think they might be leaking their companies' research secrets. Intended knowledge inflows have significant and positive impact on relative innovations only through formal networks. This means that through formally arranged interactions (e.g. joint R&D contracts), the knowledge acquired is more structured (e.g. knowledge sharing is followed by specific protocols) and able to influence more on the other related outcomes due to products / services innovations (such as reduction in development cost or speed up the delivery time) that may be included in the protocols or contracts as one of the requirements to enhance internal process. Thus, for Hypothesis 1, we conclude that:

Conclusion 1: The higher the intended knowledge inflows via formal networks, the higher the firm's relative innovations;
Conclusion 2: The higher the intended knowledge inflows via informal networks, the higher the firm's new innovations; and
Conclusion 3: The higher the intended knowledge inflows via social networks, the lower the firm's new innovations.

Secondly, unintended knowledge inflows only plays a positive and significant role on a firm's new innovations when the firm is involved in informal or social networks; in other words, when a firm is engaged in informal or social networks, then knowledge spillovers will be more valuable for a firm to develop new innovative products/ services. This finding corresponds to past studies which suggest that knowledge spillover happens through informal networking activities (e.g. [49]). Thus, for Hypothesis 2, this study states that:

Conclusion 4: The higher the unintended knowledge inflows when a firm involves in informal and/or social networks, the higher the firm's new innovations.

Thirdly, this study does not support the third hypothesis where the relationship between intended knowledge inflows and innovative performance of firms will be negatively moderated by higher levels of unintended knowledge inflows/spillovers. This may be accounted by two reasons. First, almost half of the sample came from the Innovation Hub which is still quite new and therefore the knowledge spillover effects are not yet been realized by the sending firms. Secondly, the other half of the sample firms is not situated in a park or in a cluster. Therefore the long geographical distance between them and their partners allows them to explore unintended knowledge from their partners while preventing their partners / sending firms (who they have formal or informal networks with) to realize their knowledge is being spilled over and as a consequence to stop any formal or informal networking activities with the receiving firms.

One interesting observation is the significant role that science park location, a control variable, plays in new and total innovations. NTBFs are often considered as the force driving the emergence of new innovations as well as adopting new innovations due to their concentration of resources and intense network with the environment [50], [51]. From this observation, we can interpret that science park location brings NTBFs the 'right' environment (e.g. surrounded by similar firms to establish networks with ease) and use their resources more efficiently (e.g. with the help from science park management team) in order to enhance new and total innovations.

How do we interpret the above results to explain the 'mixed findings' in the science park literature? Firstly, one of the most important issues is the various impacts of the two knowledge flows on the multi-dimensional innovative performance. Not all knowledge flows are beneficial to innovative outcomes of firms. Intended knowledge flows via formal networks is only beneficial to *relative* aspect of innovations (i.e. other results due to innovation such as reduction in the development costs) and not to new or total innovations. On the other hand, intended knowledge via informal networks enhances *new* innovative performance (i.e. sales of new innovative products/services) but if it is accessed via *social* networks, new innovative performance is reduced. Unintended knowledge only plays a positive and significant role to a firm's new innovation only if this firm is involved in informal or social networks. Since firms can behave differently with a specific focus in accessing knowledge (e.g. firms more focused in intended knowledge via formal vs. firms who use informal networks to access intended knowledge) and thus their innovative performances (new, total or relative innovations) will vary accordingly.

Secondly, science park location (SPL) only plays a significant and positive role in new and total innovations and is not significant in relative innovations. In other words, having science park location can enhance the sales of new or total (new and improved) innovative products/services due to the 'networking' benefits that SPL brings to its firm so that they are more able to interact with their buyers (to market their innovations) and with local universities (to access knowledge for new innovations). However, SPL does not have significant impact on a firm's relative innovations, i.e. other results such as decrease development cost or improve delivery time, because these are *internal process* of a firm and mainly rely on how the firm itself operates rather than where it is located.

The findings of this research have important implications for managerial practice. Firstly, the success of NTBFs falls heavily on the success of new products/services innovations due to the increasing market competitions. This study shows that different types of knowledge flows can help to achieve new innovation outcomes. The practical value of the findings in this study allows managers of NTBFs in South Africa to understand how the configuration of knowledge flows affects its own innovative performance. Unintended knowledge flows (via imitative / opportunistic behaviours) is important to new innovations in South African context. This corresponds to findings from the study of Oerlemans et al. [52] where they reported South African firms are imitative in nature. Besides accessing unintended knowledge, managers should be aware of the importance of intended knowledge inflow from formal, informal and social networks. They should prevent knowledge flows via inter-personal social networks as it has negative impact on new innovations, as such knowledge may mislead innovative developments. On the contrary to inter-personal social networks, NTBFs should establish more informal networks on inter-organizational level so that more reliable knowledge can be acquired. If NTBFs develop innovations with the aim to enhance internal processes, such as increase in delivery times or cutting down maintenance costs, then formal networks should be established with other firms and follow the necessary protocols to access intended knowledge to aid internal processes.

Secondly, for NTBFs with science park location, even if SPL plays a positive significant role in new and total innovations, it is not significant in relative innovation outcomes. Similarly as the above suggestion, for NTBFs (even if they have SPL) that rely on innovations to enhance their internal processes, formal networks should be established, e.g. joint R&D agreements with other firms.

B. Limitations and direction for future research

Although this study reveals valuable insights in the relationship between knowledge flows and innovative performances, some limitations remain. First, these findings are limited to the case of South Africa. Therefore, it is worthwhile to examine these relationships in other contexts. Second, the dependent variables in the models do not take *process* innovations into account. However, from the preliminary data analysis, the business activities of most firms in the sample are not focused on process development, but more focused on products/services development. Thus, the results of this study do not give a complete picture of technological innovation in NTBFs, but they are valid in South African context. Third, this research differentiated intended knowledge flows via formal, informal and social networks and focused only on the *number of ties* in these networks. Other aspects of networking are not included in the models, such as the strength of ties or characteristics of partners in the networks. However, firms choose their partners who they would like to collaborate and these partners characteristics may depend on firm characteristics. In this study, firm age and size as firm characteristics are included in the models.

This research raises a number of directions for future research. First, the third hypothesis of moderating effect was not 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 flows and innovative performance. Second, this research is performed in a developing country with an emerging economy. Similar studies can be done in other countries with emerging economies to benchmark the research results. 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 where as with partners who have totally different technologies (e.g. ICT vs. Biotech), radical innovations may open up an entirely new market.

APPENDIX 1

Author(s)	Country & Period	Research focus	Research methodology		Key results
			Sampling approach	Data collection & analysis techniques	
Felsenstein (1994) [8]	Israel (period of study not known)	To exam 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	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; Seedbed effects are not necessarily related to firm's innovative level; Science park location has only a weak and indirect relationship with innovation level
Westhead & Cowling (1995) [14]	UK (1986 - 1992)	To assess the employment growth in the 'surviving' firms located on- and off-park; To identify factors that associate 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; Education & technical experience and financial sources are associated with employment growth
Westhead (1997) [6]	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 % of qualified scientist & engineers) of on- and off-park firms; No significance differences in the R&D outputs (patents, copy rights, new products/services) between on- and off-park firms

Löfsten and Lindelöf (2002) [17]	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 has more co-operations with universities; On-park has higher employment and sales growth ; No significance difference in the profitability of on- and off-park firms
Colombo & Delmastro (2002) [15]	Italy (2000)	To examine 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, and 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 & Wright (2003) [11]	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 output measures (new products and patents), the output elasticity is positive and statistically significant for on-park firms; On-park firms have slightly higher research productivity
Lindelöf and Löfsten (2003) [20]	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 as innovation ability, competitor- and market-orientation, sales and employment growth, high profits etc; Off-park firms reported proximity to other firms to be higher importance than the on-park sample in their choice of location; No significant difference in new products (before competitors) and patents
Lindelöf & Löfsten (2004) [7]	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.
Ferguson & Olofsson (2004) [16]	Sweden (1991-2000)	To investigate the survival and growth of NTBFs located on and off two Swedish science parks	stratified sampling Total on- & off-park firms: 66	Questionnaire survey at firm-level Longitudinal data set (1991 - 2000) Correlations	On-park firms have higher survival rate than off-park firms; No differences in the sales of on- and off-park firms; No differences in the employments growth of on- and off-park firms; On-park firms reported higher image benefits and benefits in co-operations with universities

Akçomak & Taymaz (2004) [12]	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.
Dettwiler, Lindelöf & Löfsten (2006) [18]	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 & Zawdie (2008) [9]	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 has (not at statistical significant level) more links with universities than off-park firms.
Yang et. al. (2009) [19]	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 firm invest more efficiently in innovations.

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