CHAPTER 1 INTRODUCTION

1.1 General background of the study

In academia, a demand for increased relevance of research to societal needs has stimulated interest in patentable inventions and many other forms of entrepreneurship. A faculty member has to, for example, concurrently lead enterprises inside or outside the universities; consult, while retaining his or her traditional role of teaching, researching, publishing, etc. A typical scientist entrepreneur generally patents, establishes ties with the industry where he or she seeks funds, transfers and commercialises his or her scientific or technological expertise, etc.

There is also a growing pessimism among some academics and policy scholars that the conduct of innovation-related activities (e.g. patenting, transfer and commercialisation of scientific or technological development) can seriously hamper the production and the dissemination of public science to all (Slaughter & Rhoades 1996:303, Florida & Cohen 1999, Nelson 2001:13).

This work intends to identify the dynamics of patenting activity and the enablers of inventive capacity in South African universities. Considerable attention is devoted to addressing the issue whether patenting technical inventions and publishing scientific papers are in conflict with each other, or whether they can co-exist peacefully or even reinforce each other.

Most studies in this field originate from developed countries. They mainly investigate how physical capital, like R&D size, equipment, and financial capital affect the innovation process (Tether 2002:955; Dussauge et al 1992; Butchart 1987:83; Motohashi 2005:583; Acs et al. 1994:336; Cohen et al 2002:1; RIETI, 2003; Inzelt et al. 2004:776). They generally use patent counts from the USPTO and EPO; the numbers of licences, spin-off firms, and increasingly, consulting, contract research works and research joint ventures, as indicators of innovation. Whereas some claim positive correlations (Hausman et al. 1984:909; Branstetter & Nakamura 2003; Motohashi 2005:591), many others dispute such correlations, and/or rather report inefficiencies across universities (Thursby & Kemp 2002:109; Thursby & Thursby 2002:90).

Fewer studies similar to the above originate from the developing world, particularly from Africa.

Drawing from the recent progress in knowledge management, this work assumes that technical inventions and scientific discoveries are: (1) both the outcomes of the knowledge production process, which is led by human social systems; (2) interconnected despite the differences in the ways they evolve and their writing styles.

This work analyses recent studies on intellectual capital systems and the Kline-Rosenberg model of innovation to address three major issues. First, how does knowledge production relate to the other components of the intellectual capital (social and human capital)? Second, how do basic science and technology intersect? Third, how does innovation unfold and what are the key skills needed at various phases? Finally, the study explores (following the bibliometric model of spillover) the flow of knowledge in order to discover further mechanisms through which science and technology overlap and patent and paper reinforce each other.

1.2 Motivation for the study

Other parameters such as innovation (and not only the raw material availability, the inexpensive labour and the proximity to local markets) are increasingly becoming reliable sources of competitiveness and sustainability in both the public and private sectors. This has given rise, over a century, to developing various forms of Intellectual Property Rights (IPRS), including patents, trade and service marks, copyrights, rights in performances, designs, plant breeder's rights, and utility models, appellation of rights, layout designs and topography which play an important role in most multilateral, bilateral and regional trade agreements. If properly managed, the IP can be a considerable source of wealth.

There is, however, little evidence that these IPS have induced any development in developing countries, particularly in the African continent, though many of those countries have had IPS regimes dating back to 1900. Patent statistics at the USPTO, EPO and WIPO, for example, show that most applicants are from North America and Europe while Africa accounts for less than 2% of the total patent applications (Kameri-Mbote 2005). A related issue is to what extent are South African academics patenting locally?

1.3 Research questions

The following four questions are addressed:

(i) What is the state of patenting activity in South African universities?

(ii) Is the inventive capacity of a university influenced by the previous industry working experience of its researchers?

(iii) Is patenting of technical inventions impeding the publication performance of universities?

(iv) Is patenting of technical inventions in universities impeding the flow of scientific knowledge to the public?

1.4 Aim of the study

The study aims to:

(i) First, investigate the inventive capacity in South African universities by identifying the patent application history at CIPRO and abroad

(ii) Then, investigate the factors that could shape the human and social capital in a way that is likely to promote inventions and research performance in universities

(iii) Next, investigate whether inventiveness and academic performance are in conflict or reinforce each other

(iv) Also, identify and discuss the absorption of South African university inventions in local and foreign industries

1.5 Contribution and implications of the study

This study identifies for the first time the patenting activity in South African universities as reflected first at CIPRO and then at USPTO and WIPO. The work contributes to the literature of science, technology and innovation studies by identifying and discussing some mechanisms that could promote the production and dissemination of patentable inventions and scientific discoveries.

CHAPTER 2 CONTEXT OF THE STUDY

2.1 The South African IPRS and state of innovation in publicly-funded research organisations

The South African IPRS is traceable to the Patent, Designs, Trade Marks and Copyrights Act of 1916. The administration of the Status in South Africa is very close to the British and European Patent Convention legislation; though some changes aimed at unifying the various Acts have been initiated. For example, the Intellectual Property Law Act No 107 of 1996 sought to integrate the IPRS existing in some parts of South Africa to the entire Republic. The Intellectual Properties Laws Amendment Act of 1997 brought South Africa's IPRS legislation into conformity with THRIP. The legislation and formal instruments directly governing IPRS in South Africa mainly include:

1. The Patent Act of 1978
2. The Trade Marks Act of 1993
3. The Copyright Act of 1978
4. The Design Act of 1993
5. The Harmful Business Practices Act of 1988
6. The Merchandise Marks Act of 1941
7. The Business Names Act of 1960
8. The Unauthorised Use of Emblem Act of 1961
9. The Performer's Protection Act of 1967
10. The Registration of Copyright in Cinematography Fiction Act of 1977
11. The Intellectual Property Laws Rationalisation Act of 1977
12. The Medicines and Related Substances Control Act of 1997
13. The Plant Breeder's Rights Act of 1976
14. The Counterfeit Goods Act of 1997
15. The Intellectual Property Laws Amendment Act of 1997
16. The Patents Amendment Act of 1986, 2001 and 2004
17. The Merchandise Marks Amendment Act of 2001

The Department of Trade and Industry (DTI) formulates policies on patents, trademarks, designs and copyrights matters. It provides the framework for registration of IPRS, examination and adjudication. The legislation of the IPRS however emanates from diverse government departments and statutory bodies including:

1) Agriculture
(2) Environmental Affairs and Tourism
(3) Arts, Culture
(4) Science and Technology
(5) Health
(6) Education
(7) Communications
(8) National Advisory Council on Innovation (NACI)
(9) Council for Scientific and Industrial Research (CSIR)

The Company and Intellectual Property Registration Office (CIPRO), which comprises the former South African Companies Registration Office and the South African Patents and Trademarks Office, conducts the Administration of Trademarks, Patents, Copyrights and Design. Among other things, CIPRO maintains current registers of enterprises, trademarks, designs, patents and copyrights; conducts *ex parte h*earings, and adjudicates on infringing parties. Its direction is under a board of directors who act under a director general and the minister of Trade and Industry. It appoints both the company and IPR registrars. The major stakeholders include the:

(1) DTI
(2) National Department of Agriculture
(3) Department of Arts
(4) Culture and Technology
(5) NACI
(6) CSIR
(7) Department of Environmental Affairs and Tourism.

Other stakeholders mainly include:

(1) Universities/Higher Education sectors

(2) Non-Governmental Organisations

Technology transfer activity in South African institutions of higher learning is in its early stages. Some of these institutions, for example, the University of Pretoria, the University of the Witwatersrand, the University of Cape Town, the University of Stellenbosch, etc. have operating Technology Transfer Offices, though they are still in their early stages and not comparable to their sister offices in developed countries.

Technology transfer activities are still small, and that is negatively affecting the performance of innovative activities, such as patenting, licensing, creation of start-up companies in those institutions. The country's industrial R&D intensity is categorised as low, relative to the international standard, and this can partly be attributed to a tax environment that is not conducive to research. A survey conducted by Pouris, interviewing the South African heads of research, managers of technology transfer stations, deans of faculty and university chancellors about issues of technology transfer revealed a low industrial demand for research coupled with low research capacity in the higher education sector. Universities might face capacity constraints in future as both local and international demand for universities' services are increasing above universities' capacity (Pouris 2006).

The higher education sectors' R&D dependence on business enterprise funding is over five times the average of that of the OECD countries. Twenty percent of R&D expenditure of the median institution comes from the business sector. On average, 50% of university expenditure comes from the same business sector. For comparison, the AUTM (2004) survey in the USA revealed that the average dependence on industry is 7.5%. Another survey conducted in the UK shows that university dependence on industry is only 5.8% (Pouris 2006). There is fear therefore, among many university principals, deans, and public policy makers that, in the long-run, such strong dependence can shift the academic R&D away from basic and long-term mission oriented research, towards short-term industry relevant consultancy and research in South Africa (Pouris 2006). These fears could also be driving the asymmetry in incentives devoted to academic excellence outputs, particularly publishing journal articles and innovative excellence output, e.g., patenting, licensing, creation of spin-off firms, and other technology transfer activities. The reward bestowed to academics based on publication alone for example, are wide and certain, ranging from an increase in financial support, i.e., 8% to 75% of the subsidy either for research account or as a supplement to their salaries, recognition, job promotion, etc. These are uncertain and not well defined in the case of technology transfer related activities. This situation can partly explain why academics are more inclined to publishing than to technology transfer activities.

In most institutions, faculties/departments and inventors share the royalties obtained from the IP rights. Other reasons believed to be inhibiting technology transfer activities are: the lack of sufficient time; other duties such as teaching and administration; lack of sufficient government supports; negative perception of university work by industry; lack of broad and sufficient cooperative innovative activities with industry; scarcity among faculties of personnel with prior business and management background and/or experience. By comparison, for example, only 17% of faculties in South African universities have business background while, in the UK 34% are from a business background (Pouris 2006).

Some progress has been achieved. A recent bill that aims to promote the IPR capacity in publicly financed research institutions is noteworthy though still currently under consideration in parliament. The targeted publicly financed institutions include the Agricultural Research Council, the Council for Geosciences, the Council for Industrial and the Scientific Research, the Council for Mineral Technology, the Human Sciences Research Council, the Medical Research Council, the National Research Foundation, the South African Bureau of Standards, and the Water Research Commission. Among other important things, the bill aims to:

(1) Define the regulation about the IP derived from publicly financed research
(2) Provide a uniform system of IP management through the establishment of a national IP management office

(3) Provide a more effective protection of IP emanating from publicly funded research
(4) Give preference to small micro medium enterprise and broad based black economic empowerment entities with regards to licensing of IP derived from publicly financed research
(5) Provide incentives to inventors who are employees of publicly funded institutions who develop IP.

The South African National Research Foundation (NRF) is developing a framework that can stimulate innovative activities in publicly funded research organisations. The framework seeks to develop the research capacity in all the fields of knowledge and technology, promote value-added research, technology development and eventually commercialisation. Through the Research and Innovation Support and Advancement units (RISA), the NRF (NRF 2005) supports the following focus areas:

- Funding researchers and research students from the parliamentary core grant
- Providing service to various innovation related programmes such as:
    - Science and Technology Agreement Fund (STAF)
    - Innovation Fund
    - Technology and Human Resources for Industry Programme (THRIP)
    - Scarce Skills Development Fund
    - Biodiversity, indigenous knowledge, etc.

- Advancing the interface between science and society, coordinating science and technology advancement across the business units of the NRF, through SAASTA (South African Association for Science and Technology Advancement)

RISA allocates the parliamentary Core Grant into the focus areas that address national needs and priorities and are capable of generating strategic advantages (NRF, 2005) below:

- Strategic knowledge

- Distinct South African research opportunities
- Conservation and management of ecosystems and biodiversity
- Economic growth and international competitiveness
- Education and challenges for change
- Indigenous Knowledge System (IKS)
- Information and Communication Technology and the Information Society in South Africa
- Socio-political impact of globalization
- Sustainable livelihoods - the eradication of poverty

2.2 Overview of the patent application process at CIPRO

CIPRO, located in Pretoria, administers the South African patent system. In terms of the South African Pact Act of 1978, an inventor himself, or with the assistance of an expert (e.g. an attorney) can file a patent application. South Africa is one of the 124 countries that accept the Patent Cooperation Treaty (PCT), allowing individuals to file an application at both local and international levels. Internationally, the treaty designates the countries in which applications are feasible. CIPRO follows section 25 of the South African Patent Act No 57 of 1978. That Act defines patentable inventions as:

(i) involving inventive steps, and being applicable in trade, industry or agriculture
(ii) not being anything consisting of:

- discovery
- scientific theory
- mathematical method
- scheme, rule or method for performing a mental act or of doing business
- a programme for a computer

The registration involves the following steps:

(i) Search of existing patents; this step is not essential but is advisable to follow to avoid infringing on existing patents that the inventor or the applicant can conduct him/herself

(ii) Application for Registration. Any of the following methods is applicable:

1. Filing a provisional patent application. The cost in Rands (R) is R60 and, alone or aided by an attorney (or another expert), an inventor or an applicant can undertake the process
2. Filing a complete application. The cost is R266 and this step requires the assistance of an expert (attorney)
3. File a PCT. The process only applies when necessary

(iii) Registration. After the filing of a provisional patent application, the patents office opens a file and provides a provisional application number. The submission of the complete application can take place 12 months later. A formal examination that usually lasts six months is normally subsequent to the lodging of an application. Successful applicants send their patents for publication in the government owned Patent Journal. The issuance of a Patent Certificate happens when no objections by the public within a 3-month period take place. The lifespan of a patent can go up to 20 years, if annual renewals before the third year occur (http://www.cipro.co.za, 2006).

Copies of patent application forms are available in the registers, which are accessible to the public. Registers are in many volumes and sorted in a chronological order in a CIPRO's library. Indexes and cards available in the library facilitate the search of patent applications, grants, and other intellectual property information. An electronic database of intellectual property, like patents, copyright, etc. is still in the development phase. It does not yet cover all the information available. The core information on a patent application file appears in the following order: application number (and date), type of application (complete or provisional), title of application, name(s) of applicant(s), name(s) of inventor(s), country of priority, priority number, and priority date.

2.3 Patent decision-making in the South African universities

The model of invention disclosure and the patent-making decision process in South African universities, displayed in Figure 1, was derived from a semi-structured interview of two leading universities' senior patent officers. Most South African universities follow a very similar patenting procedure.

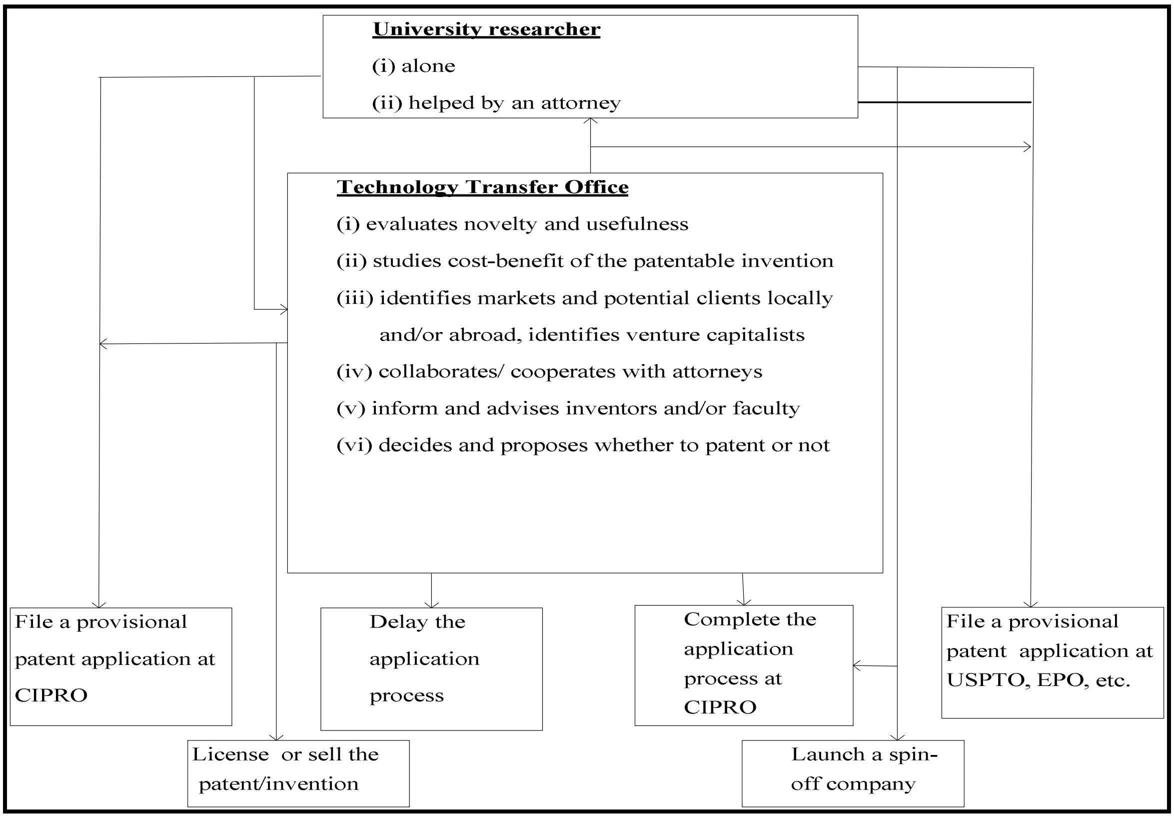

Figure 1: Patent decision-making model in South African universities

The process usually starts with a discovery by a university scientist, who works on a private or national research grant and who decides to file an invention with the help of the Technology Transfer Office (TTO). University officials decide and recommend whether patent is the appropriate mechanism for securing the developed intellectual property. Interest in the university technology expressed by an industry partner is often a strong justification for filing a patent. In other cases, TTO can opt for other best alternatives based on the commercialisation potential of the technology. The applicant is free to choose between domestic and international patent applications. The limited budget assigned to patenting is the alleged major reason that holds back universities from pursuing the very costly international patent application route. A domestic patent protection that safeguards the technology at much lower cost is a frequently followed alternative. Upon the grant of a patent, the TTO may market the technology, sometimes with the help of the faculty. Faculties may help identify potential corporate licensees. In the next stage, TTO may work with firms or entrepreneurs to negotiate a licensing agreement that might include royalties or equity stake in a start up firm. Commercialisation of the technology is feasible in the final stage.

As in many developed and some developing countries, the discovery and disclosure of a university's research results largely depend on both the TTO's capacity and faculty's policy and openness. The opposition of the latter to disclosing discoveries, indifference to licensing opportunities and poor quality of discoveries, low budget and poor administrative support are the common impediments to the speed of patenting and licensing processes. The slow pace of publication clauses imposed by most licensing agreements that goes through the evaluation of university disclosures, negotiation of licensing agreements with potential clients, and interaction with IP attorneys and university administrators also discourages faculties from co-operating with the TTO.

CHAPTER 3 LITERATURE REVIEW AND THEORETICAL BACKGROUND

The intellectual capital system comprises the human, structural, and relational capital and constitutes the intangible asset base of an organisation (Bontis 1998:63). Its components, depicted in Figure 2, build up during the course of an assortment of activities that take place in an organisation.

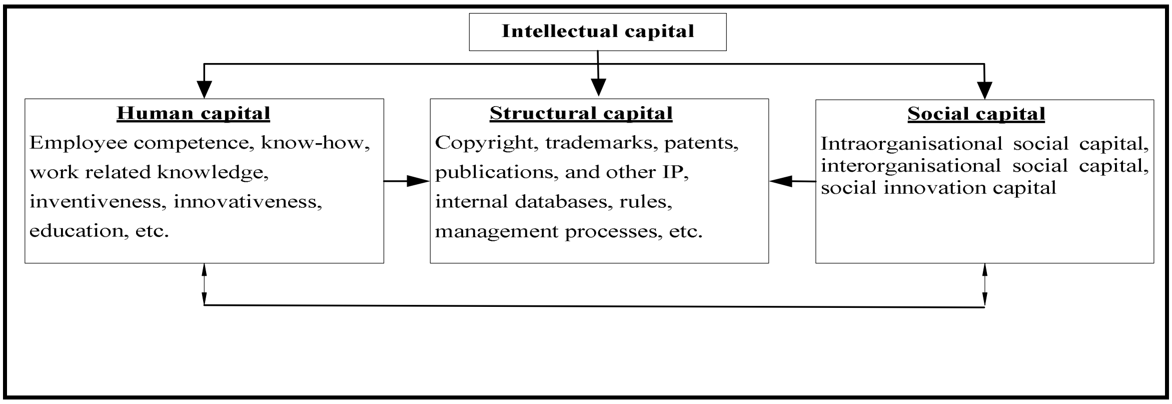

Figure 2: Components of intellectual capital

All the three components are interrelated, interdependent on each other, and act collectively to accomplish the organisational objectives, although they belong to different categories. Other arrows have been added to the models described elsewhere by McElroy (2001), Bontis (1998:63) and Buckh et al. (2001:87) to emphasise the dynamic nature, and reflect the interrelatedness of the system's parts. The following sections will briefly describe some important characteristics of the components of intellectual capital and their linkages.

3. 1 Structural capital

Structural capital mainly includes the internal enabling structures that allow an organisation to exploit its intellectual capital. They range from copyright, trademark, patents, internal database, computer system, organisation intranets, policies and procedures, knowledge, etc. The following sub-sections will describe some fundamental characteristics of knowledge, whether patented or copyrighted.

3.1.1 Knowledge creation process

The study of knowledge management emphasises the distinction between data, information and knowledge. Data are the inputs required to produce information, but information involves more than just data. Information is data put in context and is required to produce knowledge, which involves more than just information (Davenport & Prusak 1998; Nissen et al. 2000; Firestone & McElroy 2002).

Malhotra categorised the knowledge creation models in organistional learning into two broad groups. The traditional models, summarised in Figure 3, claim that knowledge is created through the processes of identifying, capturing, retrieving, sharing and evaluating enterprise information assets in an integrative way, using information technology. Those models heavily rely on the developments in information technology such as Lotus Notes, Internet and World Wide Web that organise various scattered pockets of information into organisational "knowledge repositories" (Malhotra 2001:10).

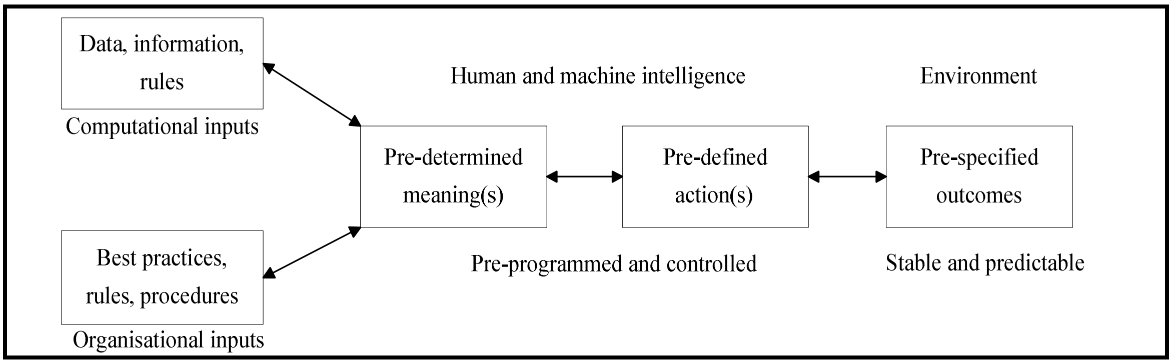

Figure 3: Knowledge management for routine and structured information processing

In these models, knowledge is viewed as a mechanistic and static information processing exercise made through a search for a consensus and compliance that minimises variance, so that pre-specified business performance outcomes result within an organisation (Malhotra 2001:10). Frequently, these models define knowledge as:

- a process of collecting, organising, classifying and disseminating information through an organisation (Albert 1998:52)
- capturing the knowledge that employees really need in a central repository and filtering out the surplus (Bair 1997:28)
- mapping knowledge and information resources both on-line and off-line, training, guiding and equipping users with knowledge access tools, monitoring outside news and information (Maglitta 1995)
- facilitation of autonomous coordinability of decentralized subsystems that can state and adapt their own objectives (Zeleny 1987:59)

These models fail to draw a clear distinction between information and knowledge. The assumption that tacit knowledge can be stored in computerised databases, software programs and institutionalised rules and practices carries a significant weight. Optimisation of organisational goals with the objective of realising greater efficiencies can only be suitable in relatively stable and predictable environments (which in reality are scarce).

The models depicted in Figure 3 are better suited to knowledge creation that is a non-routine and unstructured sense-making process. The models are suitable for uncertain environments (e.g. R&D, new product innovation, etc.) characterised by wide range of potential surprises that defy predictive logic (Malhotra 2004:87).

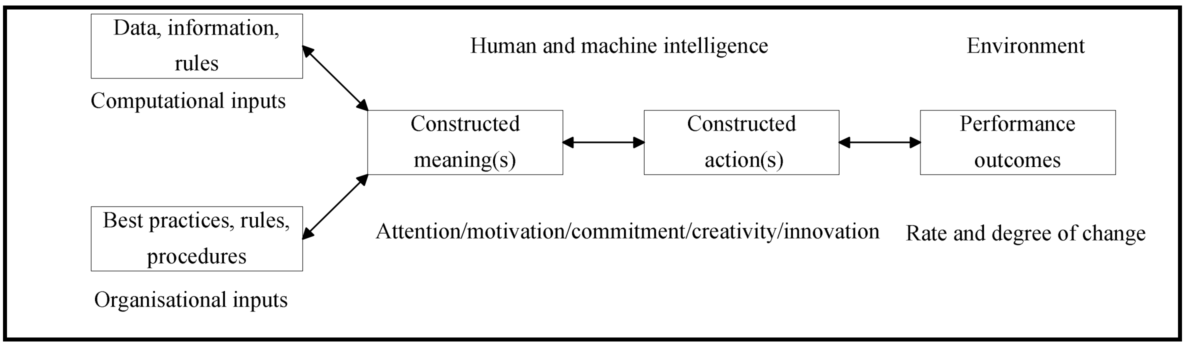

Figure 4: Knowledge management for non-routine and unstructured sense making

In such configurations, the premises of pre-determination, pre-definition, and pre-specification of meanings, actions, and outcomes become less relevant. Knowledge here is intelligence in action rather than a static computerised construct. It is an outcome of intense interactions of data and information processing, rules, procedures, best practices and traits such as attention, motivation, commitment, creativity, and innovation (Malhotra 2001:10). As active, knowledge is best understood in action. It is not the theory but the practice of the theory that differentiates it. It is effective as it takes into account the emotional, in addition to the cognitive and rational, dimensions of human decision-making. It is dynamic as it relies upon ongoing interpretation of data, information and assumption while proactively sensing how the decision-making process should adjust to future possibilities. Some examples in this category are described next.

Best practices and their underpinning assumptions are subjected to continual re-examination and modification. The models entail a synthesis of information processing capabilities with the innovative and creative capabilities of human and social elements of the organisation. Intuitions and playfulness are used. Goals are treated as hypotheses, intuitions are treated as real, organisational memory as enemy and experience as theory, which requires ongoing re-assessment. The organisation’s members define problems for themselves, generate their own solutions, evaluate and revise their solutions-generating processes. Here knowledge creation becomes a complex and an ongoing process of searching, indexing, and archival reassessment, re-framing of existing and new information, given the dynamically changing context of applications. Knowledge creation is subjective, interpretative and sense making, with a social interactive nature.

One example in this category is the Nonaka’s SECI model according to which, one of the following four triggers induces creation and dissemination of knowledge: field building, dialogue, linking explicit knowledge, and learning by doing. SECI stands for Socialisation, Externalisation, Combination and Internalisation.

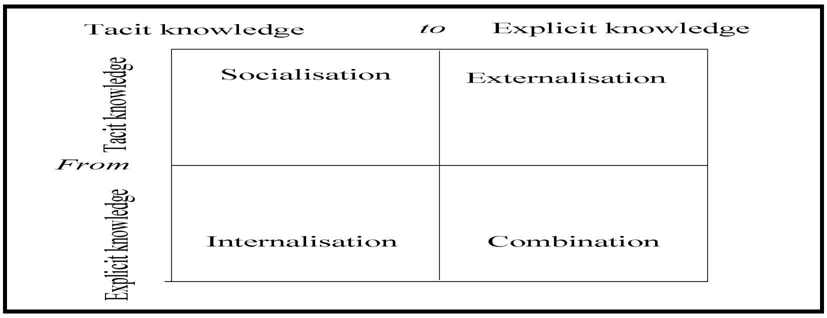

Figure 5: SECI model (Nonaka)

The model entails a continuous and dynamic mobilisation, sharing and integration of knowledge. Socialisation, combination, internalisation and externalisation convert and amplify, through a spiral of knowledge, the tacit knowledge held by individuals. The created organisational knowledge flows through an upward spiral from the individual level to the collective level, and then to the organisational level, sometimes to the interorganisational level. The spiral becomes larger in scale as it moves up through organisational levels, and can trigger new spirals of knowledge (Nonaka1994:14).

Other examples in this category are the Life Cycle models, which contend that the creation and dissemination of knowledge across an enterprise go through a continuous cycle that mainly comprises six phases: creation, organisation, formalisation, distribution, application and evolution. Progress through the various phases of the Life Cycle models is generally iterative and involves feedback loops between stages. Not all the steps need to be in order, and the flow through the Life Cycles is not necessarily unidirectional.

The Despres & Chauvel (1999), Gartner Group (1999), Davenport & Prusak (1998), Nissen (1999) and Nissen et al. (2000) models, depicted in Table 1, are some of the well- documented Life Cycle models of knowledge flow. The later model (Nissen et al., 2000) is an amalgamation of all the former. The other four Life Cycle models begin with a “create or generate” phase.

The Nissen model begins with knowledge capture, which appears in the third phase of the Gartner Group model. The second phase belongs to the organisation, mapping or building of knowledge. The Davenport and Prusak’s model imply this phase by their codify phase. Phase three addresses mechanisms for making knowledge explicit. Similar terms from other models include store and codify. The fourth phase concerns the ability to share or distribute knowledge in an enterprise. This also includes terms such as transfer and access. Knowledge use and application for problem solving or decision making in the organisation constitutes the fifth phase. A sixth phase incorporates knowledge refinement and evolution and thus reflects the organisational learning through time (Gupta & Sharma 2002).

Table 1: Some Life Cycle models of knowledge creation and dissemination

Model	PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6
Despres & Chauvel	Create	Map/bundle	Store	Share/transfer	Reuse	Evolve
Gartner Group	Create	Organise	Capture	Access	Use	-
Davenport & Prusak	Generate	-	Codify	Transfer	-	-
Nissen	Capture	Organise	Formalise	Distribute	Apply	-
Amalgamated	Create	Organise	Formalise	Distribute	Apply	Evolve

The amalgamated model of Nissen integrates the key concepts and terms from the four Life Cycle models. Whereas knowledge creation involves the discovery and development of new knowledge, knowledge capture requires only that the knowledge be new to a particular individual or organisation. Formalisation involves the conversion of existing knowledge from tacit to explicit form (Nissen et al., 2000).

3.1.2 Models of knowledge diffusion

3.1.2.1 The innovation diffusion model

Rogers (1983) and Rogers (2003) theorised that innovations would spread through society in an S-curve, as early adopters select the technology first, followed by the majority, until a technology or innovation is common.

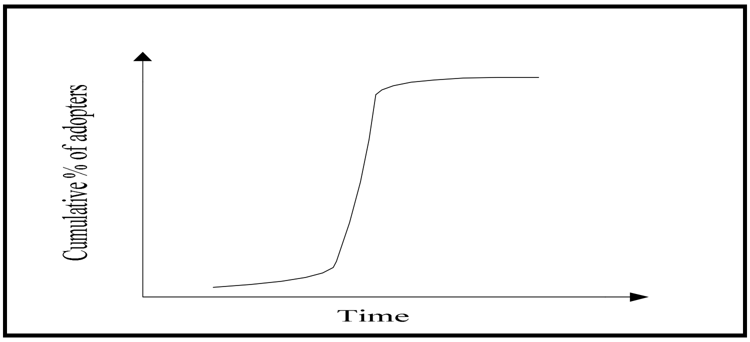

Figure 6: S-curve

The S-curve, depicted in Figure 6, essentially shows a cumulative percentage of adopters over time: slow at the start, more rapid as adoption increases, and then levelling off until only a small percentage of laggards have not adopted.

From the System Dynamics perspective, the adoption rate depends on the size of the population and the intensity of interactions among adopters. The wider the population is, the larger the adoption rate becomes. The net result is an exponential curve whose fashion is similar to that displayed in Figure 6.

The spread of technology adoption depends on two major characteristics: *p*, which is the speed at which adoption takes off, and *q* the speed at which later growth occurs. A cheaper technology might have a higher *p*, for example, taking off more quickly, while a technology, whose value increases as it spreads to others, such as a fax machine, may have a higher *q*. From an analysis of standard deviations of the mean of the normal curve (bell curve), Rogers later proposed that adopters of any new innovation or idea could be categorised as innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%) (Rogers 2003). Each adopter's willingness and ability to adopt an innovation would depend on their awareness, interest, evaluation, and trial.

At the macroscopic level of an organisation, the S-curve could well describe adoption over time. In early stages, few firms adopt; then there is a sudden increase that precedes a slowing in the rate of adoption. Economists suggest the S-shape of the curve is evidence of the shifting balance of supply and demand, which is a function of the investment required to adopt a technology and the profitability of that technology. The steep rise of the curve could thus be reflecting substantial drops in the price of the new technology causing a surge in demand (Attwell 1992:3).

Eveland & Tornatzky (1990:117) suggested that diffusion and adoption occur within contexts that constrain, mould choices, and are accordingly determined by the factors listed below:

1) nature of the technology
2) user characteristics
3) characteristics of the deployers
4) boundaries within and between deployers and users
5) characteristics of communication and transaction mechanisms.

Diffusing or deploying a technology would thus be more difficult if:

1) its scientific base is abstract or complex
2) the technology is fragile (i.e. it does not work consistently)
3) it requires a handholding aid and advice to adopters after the initial uptake.

The innovation diffusion model clearly shows that contacts between technology-creating organisations and potential users are central to successful flow of technological information and ideas. Diffusion is thus constrained by time and communication.

Factors that can promote the deployment of a university's technology to industry will be discussed later in this chapter.

3.1.2.2 The Nissen notional model of knowledge flow

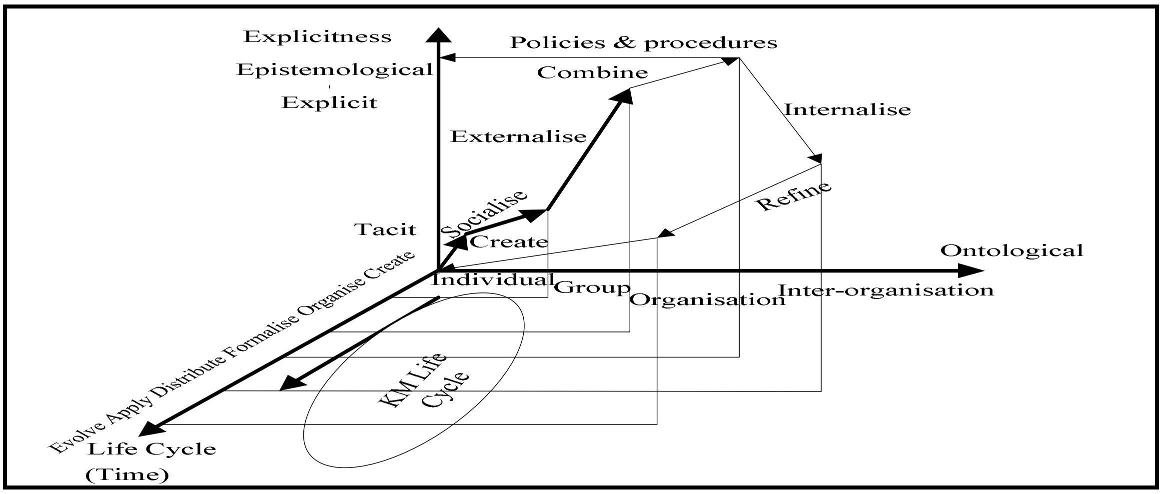

Figure 7: Notional knowledge flow trajectories

Nissen (2002:251) added two dimensions to the model of Nonaka and developed a more dynamic model of knowledge flows depicted in Figure 7. The model has four dimensions: the epistemological, ontological, knowledge, Life Cycle and time. The epistemological dimension that included binary states (i.e. tacit and explicit) is now larger. Knowledge fills the continuum between tacit and explicit endpoints. It flows through a continuous range of explicitness. The ontological dimension that supported only a few granular states (individual, group, organisation) is now larger. Knowledge might fill a continuum along the dimension characterised by the number of people it reaches.

The simple linear vector labelled Policies and Procedures depicts the way in which most enterprises inform and train employees using policies and procedures. These might include explicit documents and guidelines that individuals in the organisation have to memorise, refer to and observe. The amalgamated KM Life Cycle model shown in Figure 7 represents the cyclical flow of knowledge. The SECI model could be depicted in this space by curvilinear vector sequences corresponding to the processes labelled create, socialise, externalise, combine and internalise. The model also includes the time dimension. Life Cycles here stand for time.

3.1.2.3 The network models

The network models of knowledge flow assume that a logistic knowledge flow process takes place in a knowledge network, where the nodes are the team members, software or knowledge portals that provide services and the links are the flows of knowledge between nodes. According to these models, a knowledge flow is the passing of knowledge between nodes following specified conditions. A knowledge node is a team member or role, or a knowledge portal or process. A knowledge flow starts and ends at a node. A node can generate, learn, process, understand, synthesise; and deliver knowledge (Zhuge 2006:573, Zhuge 2002:23, Zhuge 2004).

Knowledge usually flows by means of communication facilities, especially the Internet. Knowledge flows from one node to another across a network, helping people to solve problems and work in cooperation (Zhuge 2002:23). Knowledge can flow through spirals or other ways that will be described later. A node can deliver knowledge to its successors either by forwarding knowledge it received from a predecessor, or by passing on its own knowledge.

Figure 8 shows a knowledge spiral, which consists of nodes and two types of flow: external knowledge passing between nodes, and internal knowledge creation in nodes (for example through abstraction, analogy, synthesis or reasoning).

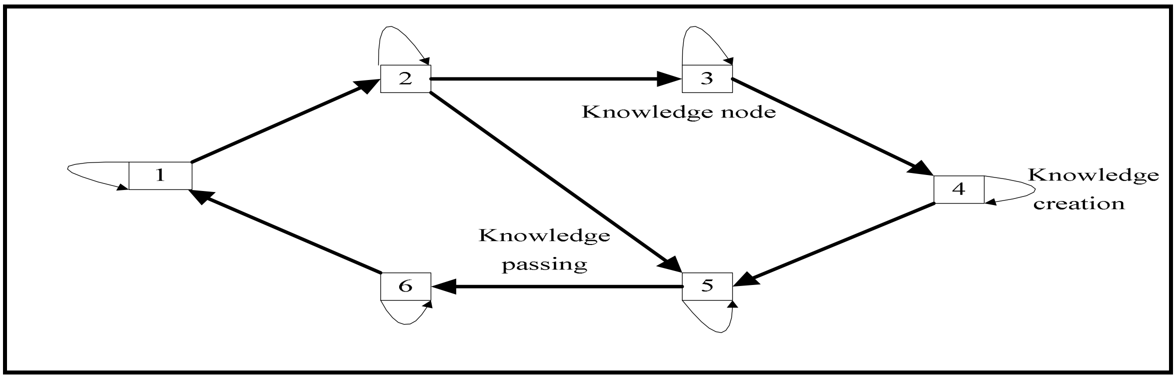

Figure 8: Spiral patterns

The self-replication arc and the catalytic-support arc of the hypercycle correspond to the knowledge-passing link and the knowledge-processing link, respectively. The self-replication in the hypercycle occurs within a node. Knowledge passing takes place between the nodes. The catalytic-support in the hypercycle happens between nodes and the knowledge processing appears within a node.

According to Zhuge (2006:573), the following principles facilitate knowledge flows:

(i) The composition of knowledge flow networks should guarantee the effectiveness of the composed network. This requires that:

- knowledge flows in the same flow chain share the same knowledge space, subspace or appropriate in a way that knowledge can be delivered to the right person, and the contents of the flow can be stored in the right location in the space
- knowledge energy differences exist between nodes

(ii) The composition of knowledge flow networks will not be effective unless the corresponding results obey the regulations and meet the targets of the organisation (for example, the profit, the security and copyright, etc.)

(iii) Knowledge gained by a team should help it complete its tasks

(iv) The composed knowledge flow networks should be the smallest network that includes all the nodes and flows of the original networks (i.e. there must not be redundant flows of nodes)

(vi) Effective cooperation and trust between team members.

The network model views a knowledge flow pattern as an abstraction of a category of knowledge flow networks that can follow:

(i) An authority, peer-to-peer and hybrid patterns

(ii) A resource mediated pattern

(iii) A split-join pattern.

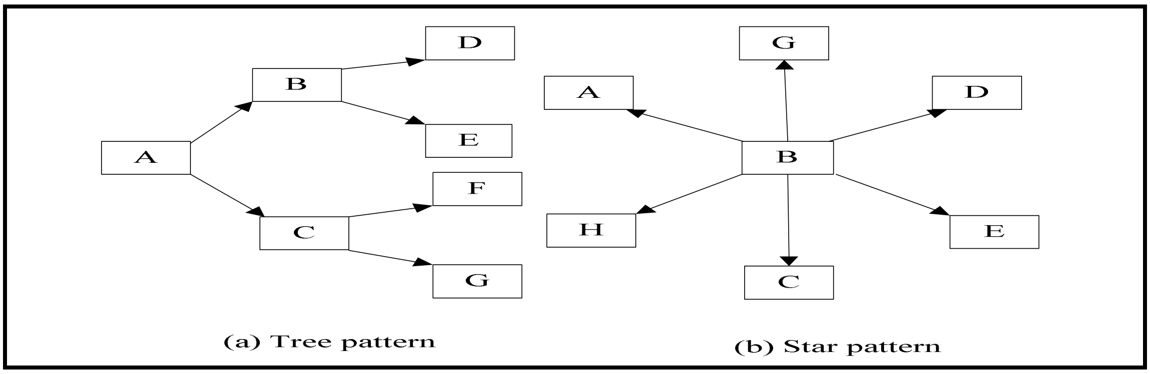

Figure 9: Authority patterns

An authority pattern can be a tree or a star as illustrated in Figure 9. The root node of a tree and the core node of a star pattern act as the leader of all the other nodes. The root and core nodes constitute the knowledge authority of the team.

In a peer-to-peer pattern, every node can be reached from any other node via a path consisting of nodes and links under certain constraints.

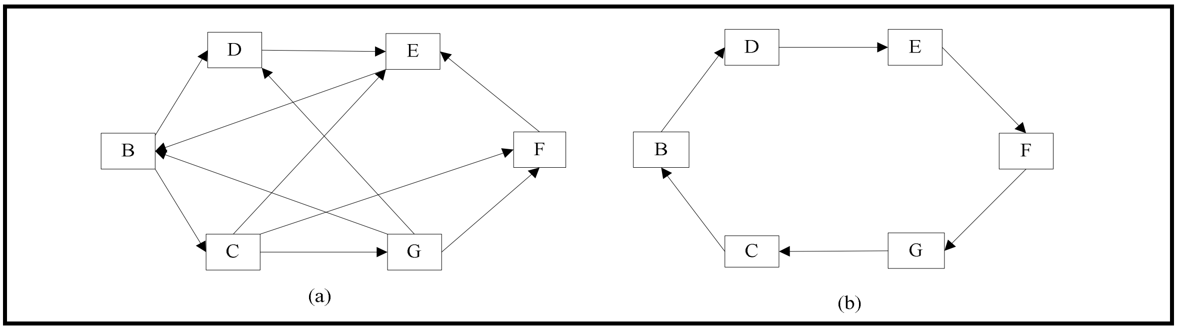

Figure 10: Peer-to-peer patterns

A hybrid pattern is made of an authority and a peer-to-peer pattern. The authority node in the peer-to-peer pattern (a) does not emit. It flows to all the other nodes**.** Each node can connect with a tree pattern to form a new hybrid pattern as shown in Figure 11 (b).

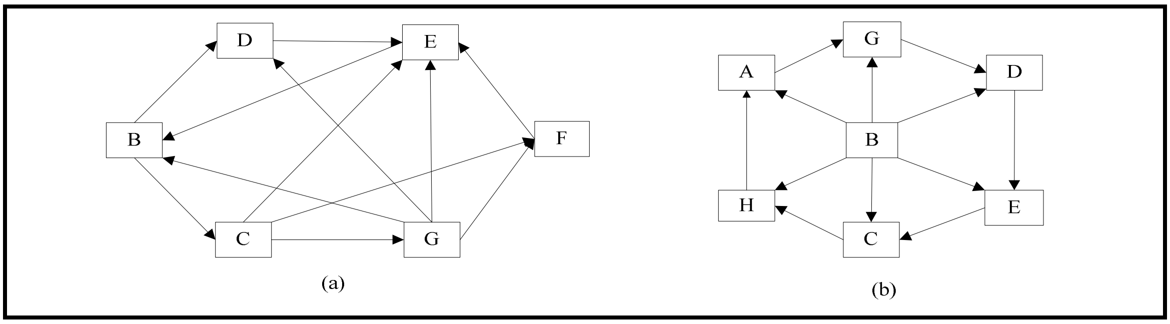

Figure 11: Hybrid patterns

In a resource-mediated pattern, there are no direct flows between knowledge nodes. Any knowledge flow takes place between a knowledge node and a resource node. Here, resources are blackboards, knowledge bases, knowledge portals, data tables, files of any form, and even soft-devices (Zhuge 2002:60).

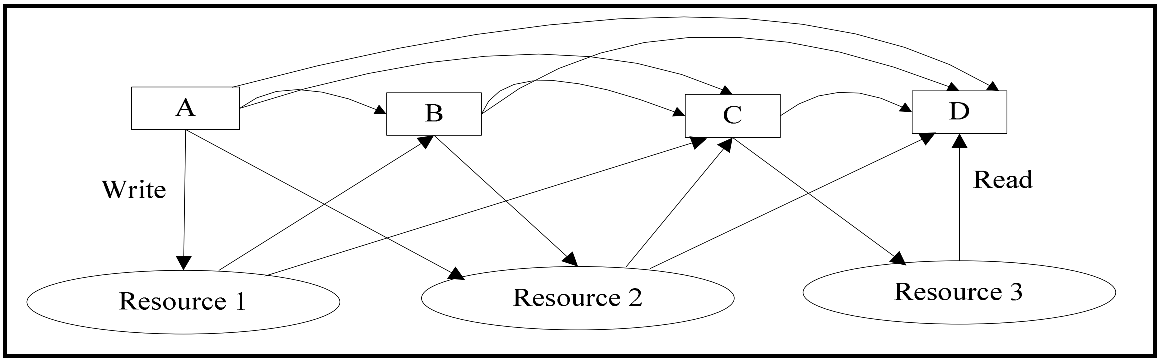

Figure 12: Resource mediated patterns

Figure 12 shows an example of this pattern. The elliptical nodes denote the resources, the rectangular nodes denote the knowledge nodes, the downward arrows denote the knowledge flows of the writing kind (i.e. expression) and the upward arrows denote the knowledge flows of the reading kind (i.e. acquisition). The flows between the knowledge nodes (i.e. curved arrows) can derive from the flows between the knowledge nodes and resource nodes. Here, topic relevance, cooperation, and access privilege (i.e. where only qualified consumers can use certain resources) can constrain the flow.

A split-join pattern has an initial node N with N *(N ≥ 1)* output flows under the condition denoted CON1, a final node M with M (*M ≥ 1*) input flows under the condition denoted CON2, and a black box that receives the flows from the initial node and sends its own output flows to the final node as illustrated in Figure 13.

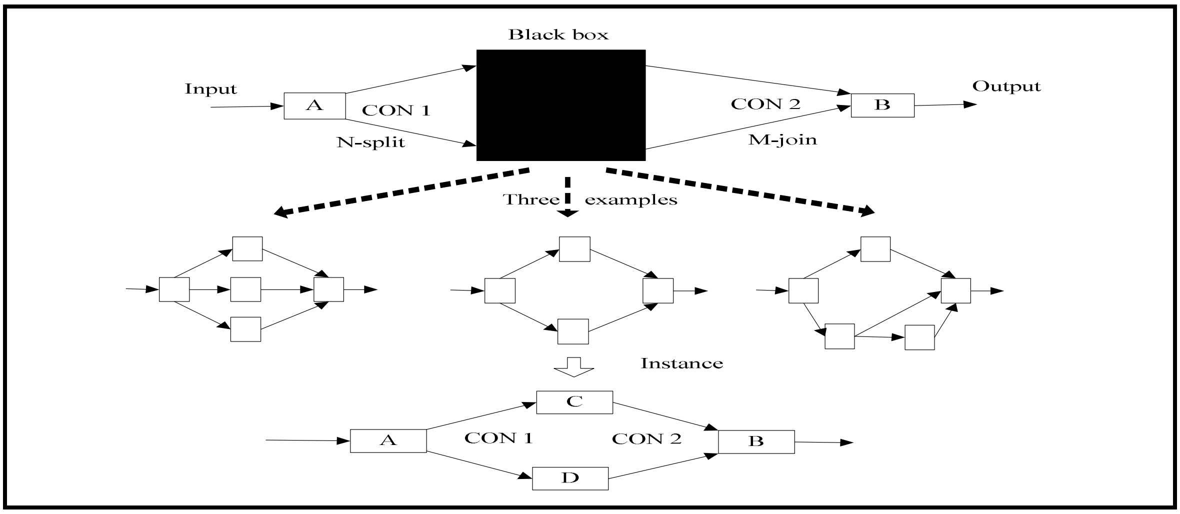

Figure 13: Split-join patterns

If:

1. CON1 = “and-split” then CON2 =“and-join or CON2=“or-join”;
2. CON1=“or-split” then CON2=“or-join”;
3. CON1= “x or-split then CON=“x or-join” or CON2=“or-join”;
4. CON2=“and-join” then CON1=“and-split”

The knowledge flow pattern of a team may change as work proceeds, as the team adapts to change and the efficiency of the knowledge is increased.

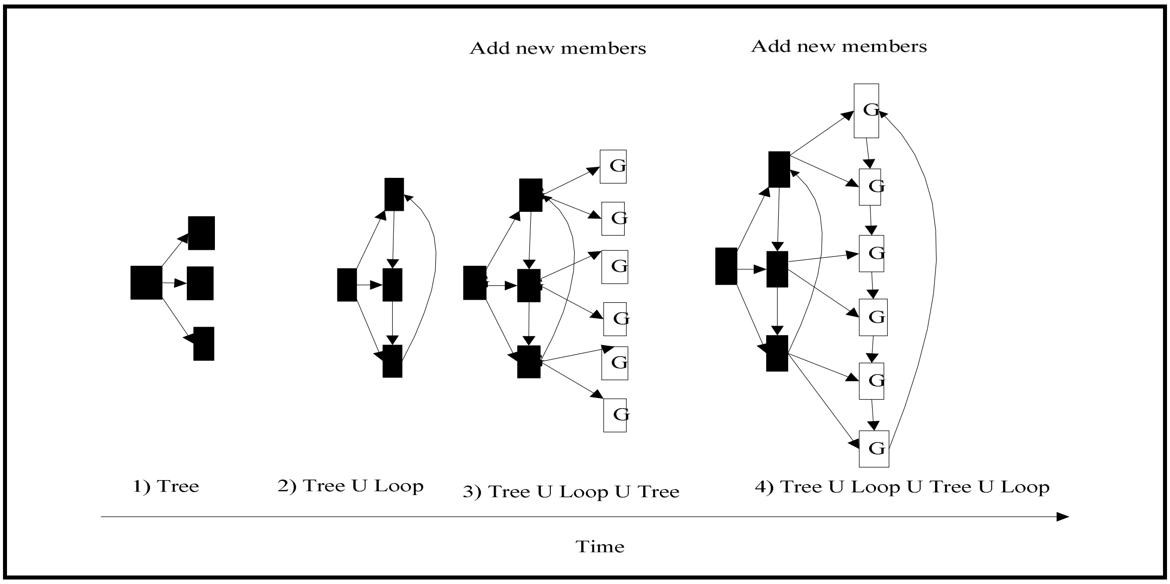

Figure 14: Evolution of knowledge flow of a research team

Figure 14 illustrates how a research team's knowledge flow can evolve. In the first stage, the team follows a tree-like pattern with a leader and three members working in separate areas. These three members learn from the leader at this stage and only communicate with him. In the second stage, team members learn from each other. In the third stage, new members join the team to work on the three areas. In the fourth stage, these new members learn from each other (Zhuge 2006:573).

This work contends that the creation and diffusion of technological or scientific knowledge are embedded in a network of researchers or knowledge creators and users. The size of a network and the intensity of interactions that take place among its members can considerably influence the phenomenon.

3.1.3 Comparison between a patent and an article

Patent specifications are generally made of three main components:

(i) The subject and object of the invention or discovery, and a discussion of earlier works

(ii) A solution, including specific examples

(iii) The unique advantages and applications of the invention.

The structure of patent specification generally includes:

- The field of the invention which corresponds to the subject
- The background of the invention that indicates the problems to be solved, and the prior art
- The object of the invention that lists the benefits to be accrued
- The summary of the invention that defines the invention and the solution to the problem it provides
- A detailed description of the invention that includes the drawings, experimental data, method and apparatus or instruments used. This section is similar to that of an article, although it may be given with more detail in patents to permit the replication by the skilled artisan. This section might also describe the structure, the usefulness and the operation of the invention.

From this perspective, to any component of a patent specification there exists a parallel component in the journal article (Meyer 2000:97).

One of the most significant differences between the two documents is the source of the cited references. Whereas in articles, the authors mostly cite other authors who have contributed to the subject of the article, in patents, it is rather the examiner who recommends what is to be cited. Furthermore, professionals review a patent, while papers are peer-reviewed.

On one hand, the author assumes a very substantial familiarity with the subject matter of the article. On the other hand, the inventor only assumes the ability to understand the specific application for which patent protection is sought. In either case, the range of erudition may be great, but it is usually different.

A patent application, and a granted patent, further describe and include a solution to a problem as well as opportunities for applications. A patent puts much emphasis on the deficiencies in prior arts, something that does not appear in articles, in neither frequency nor intensity.

The novelty hunt is a common characteristic of both patent and article. This feature is detectable in the citations of both documents. Examiners check and assess prior documents to find out if they have the same or almost similar features as the patent application and only accept the application as novel when no other relevant documents question the claimed novelty. The following types of citations are commonly encountered in most patent applications:

(i) Documents of particular relevance and
(ii) References concerning the general background.

The documents of particular relevance restrict the claims of an invention. One example of those documents is individual documents that when alone may question the novelty or inventive step of a patent claim (marked with the letter X in most European countries' search reports). Another example is documents considered to question the inventive step of a patent claim, if taken in combination with another document usually marked with the letter Y. The second type of reference, documenting the technical background of the invention, is marked A.

Different interpretations of the patent document can mirror the social context of the patent. Patents could mean, for example, a strategic component of the economic exploitation of and development of technology and indeed as an important feature of social dynamics of technical invention. A patent document addressing different readers with different interests could also reflect a compromise of various strategies. The readership structure can influence the writing style of patents and the selection of citations. On the one hand, one has to fence off, while on the other hand, however, one must point out an interesting area (Meyer 2000:105).

The difference in citation frequencies in the same fields between countries shows how the legal and social contexts can influence a patent. If compared to those filed at EPO or those originating from Europe, patents at the USPTO or US patents cite more patents than articles, probably due to the emphasis on applicability that carries a higher weight at USPTO than at EPO.

The examinations of claims can also differ from one country to another. At USPTO, for example, all claims are examined equally and thoroughly. The German system examines first and largely the main claim. The second examination of the dependent claims is brief and searches one or two related prior arts. Most practitioners try to have one single claim that functions as an umbrella of both the main and the dependent claims at the EPO.

Furthermore, the patent system is designed as an incentive mechanism for the creation of new, economically valuable knowledge and at the same time as a mechanism for disseminating this information to the public (Thumm & Blind 2004:1586). Open literature generally aims at advancing the understanding and development of the science and the disseminating of that knowledge to the public. In a patent, there is thus a trade-off between the disclosures of detailed information by the inventor against the guarantee of a limited monopoly awarded by the state. The inventor discloses enough information to make a legal claim on a similar technology, but not enough information to make easy derivatives.

The core traditional motive to patent is the protection of one’s own inventions from imitation. The strategic motive is to block competitors from using protected inventions. Whereas an offensive blockage erects walls around an own invention, in a defensive blockage, an organisation prevents the infringement of lawsuits by third parties by possessing own patents (Blind, Edler, Frietsch & Schmoch 2006:657). Other motives such as licensing income, accessing foreign markets and the internal evaluation of R&D productivity play smaller roles.

Unlike with articles, one can protect an invention through patent in a number of jurisdictions and nations: a number that usually defines a patent's family size. Patents can further be subject to legal oppositions, which may result in rejection of the objection; restriction; full-upheld revocation and withdrawal or lapse of the patent (Harhoff et al. 2003:1352).

3.1.4 Overview of the innovation process and science-technology linkages

Innovation was first described as a linear process that starts with basic research and then goes through applied research and development, and ends with production and diffusion (Schumpeter, 1939, Schumpeter, 1934; Bush, 1945). The subsequent chain models, which emphasised the non-linear character and the forces outside the firms that shape innovation, were a major progress in describing the process.

The Kline and Rosenberg model depicted in Figure 6 (Kline and Rosenberg (Landau, Rosenberg, 1996)), for example, showed that two major distinct but interrelated forces control innovation.

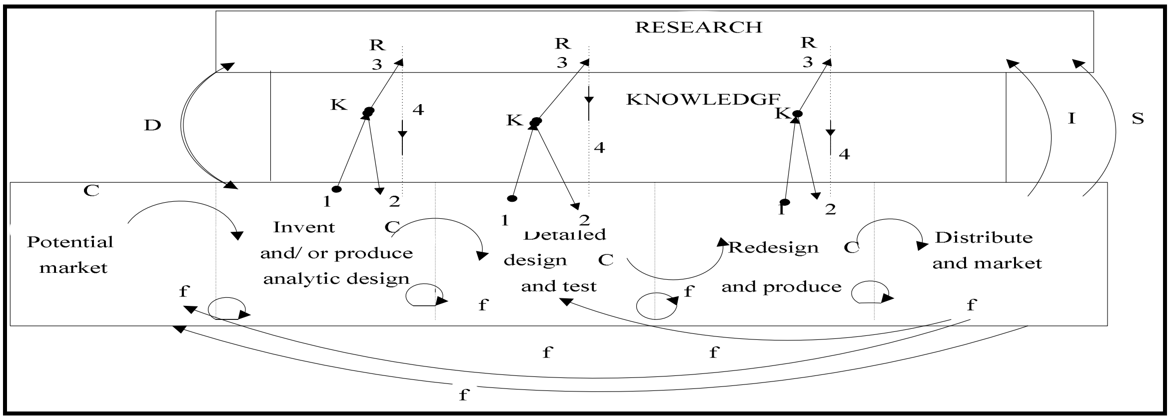

Figure 15: Kline and Rosenberg chain-linked model of innovation

The first are the market forces that include factors such as changes in income, relative prices, and underlying demographics that combine to produce continual changes in commercial opportunities for specific categories of innovation. The second are factors such as technological and scientific frontiers that often suggest possibilities for fashioning new products, or improving the performance of old ones, or producing those products at lower cost. A successful outcome in innovation thus requires the running of two cohorts: the commercial and the technological aspects. It requires a design that balances the requirements of the new product and its manufacturing processes, the market need and the need to maintain an organisation that can continue to support all those activities effectively.

Symbols on arrow C = central chain of innovation; f = feedback loops. K-R = links through knowledge to research and return paths. If problems are solved at node K, the links 3 to R are not activated. Return from research (link 4) is problematic – therefore, dashed lines. D = direct link to and from problems in invention and design. I = support of scientific research by instruments, machines, tools, and procedures of technology. S = support of research in sciences underlying product area to gain information directly and by monitoring outside work. The information obtained may apply anywhere along the chain.

Briefly, the first path of the innovation process labeled C constitutes the central chain of innovation. The path begins with a design and continues through the development and production to marketing. The second path, a series of feedback links marked f, starts immediately. The foregoing feedback path iterates the steps and connects back directly from perceived market needs and users, to potentials for improvement of product and service performance in the next round of design. A feedback is thus part of the cooperation between the product specification, product development, product processes, marketing, and service components of a product line.

A perceived market need will be satisfied only if the technical problem can be solved, and a perceived performance gain will be put into use only if there is a realisable market use. Each market need entering the innovation cycle leads in time to a new design and every successful new design, in time, leads to new market conditions. Innovation is thus often impossible without the accumulated knowledge of science and the explicit development work often highlights the need for research that is new science.

According to this model, innovation nearly always deals with the optimisation of many demands and desiderata simultaneously. If a technological improvement is to have a significant economic impact, it must combine design characteristics that will closely match the needs and tastes of eventual users, and it must accomplish these things subject to basic constraints and cost (and frequently the legally mandated requirements). Commercial success turns on the attainment either of cost levels that are below available substitutes or creation of a superior product at a cost that is at least not prohibitively expensive in comparison with lower-performance substitutes. Higher performance is commonly attainable at higher price.

The model implies that strong linkages to science lie alongside development processes. The use of the first part of science, i.e. known science or stored knowledge, is imminent at the first occurrence of a problem. The second part of science, i.e., research, is crucial and justified when all stages of the first part of science fail to supply the needed information. The use of the accumulated knowledge, also called modern science, is essential to modern innovation. It is also necessary and is often a crucial part of technical innovation, but it is not usually the initiating step. It is applicable at all stages along the central chain of innovation, as needed. It is only when the knowledge fails, from all known sources, that the much more costly and time-consuming process of mission-oriented research is justified to solve the development problems.

Innovation is, of course, an oscillatory, non-linear process or rather a closed circle of innovation, which consists of problem setting and problem solving. It is a self-mobilised process emerging as a discrete wholeness. In total, it is in a constant interaction with its functional environment, causing changes and suffering forced adaptation, and at the same time striving for autonomy, self-preservation and stability. The innovation activity and process of qualitative change implies uncertainty and disequilibrium, fluctuation, minimisation of disturbing factors, pressure of decision-making, result oriented motivation and independence of organisational constraints. The whole system of innovation works as a generator of information and knowledge (Szanto 1996:411, Firestone & McElroy 2002). One could thus argue that successful innovation would require the awareness of the market needs, the skills related to applied and basic research and development, manufacturing, prototype development, etc.

3.1.5 Overlaps between patents and articles and knowledge flows

A patent contains comprehensive information on the technical properties of an invention and its linkages to other technologies and to science. The current bibliometric models of knowledge flows argue that citations from one patent to another can proxy how an invention builds on prior inventions, i.e., flows of knowledge from previous to the actual invention. In the same manner, references to scientific papers in patents can indicate the flow of knowledge from science to technology (Jaffe 1998:957; Podolny et al 1995:659, Murray 2002:1394, Tijssen 2001:35, Braam 1991:233, Egghe & Rousseau 2002:349, Van Raan & Van Leeuwen 2002:611).

This work expands the concept of patent citation network. The indirect and direct, as well as the forward and backward citations for a given patent are investigated to get perspective on the knowledge flows in and out of the universities.

A direct citation link usually exists between two patent families if a patent family cites or receives a citation by another (Von Wartburg et al 2005:1592). If a cited patent family in turn cites another family, an indirect citation chain is established between the first and the last patent family. A co-citation link occurs if two or more families are cited together by another patent family. Indirect citations differ from scholarly publication citations as references are strictly limited to the nearest, i.e. most recent, prior arts. A forward citation for a patent x is a reference made by another patent y to patent *x*. A backward citation by a patent *x* is a reference that patent x makes on another patent *z*. The forward citation will encompass both the direct and the indirect citations (i.e. second generation, etc.).

The technological foundation of the citing patents should, therefore, include both the most recent development cited and the basic principles from earlier patents (Lubango, 2008b). The indirect linkages captured by the citation chains could thus reveal the existing ties to a basic patent. Given that a patent A cites exclusively patent B, which in turn solely cites another patent C, it is possible to assume a unique development path that could stem from C and leads to A. A and B could be the technological improvements of C. It then appears reasonable that A could not only build on B, but also in the same way on C. Accordingly, the identical proximities of A and B, B and C and A and C could thus be established.

For a given set of patents, both the forward and backward citations to (or by) other patents and non-patent documents should count in the citation network. The non-patent documents are generally references to scientific input in patents. They mainly include the ISI articles and other sources, e.g. hard and/or electronic copies of books of abstracts or proceedings of scientific or technical conferences that do not appear on ISI data. They may also include scientific or technical journals in university or government libraries, non-scientific publications, product specifications, technological disclosure, bulletins and trade journals, articles in company journals, local scientific journals, or international academic periodicals. They can serve as measures of the industrial relevance of research. They can also reveal the trends of the various linkages between science and technology and the differences in international as well as domestic utilisation of industrial research produced by the science base (Tijssen 2001:35).

The scientific and technological networks are distinct systems whose knowledge flows are bi-directional, capable of overlapping and thus reinforcing each other (Murray 2002:1394). Each flow can shape another during the spillover of ideas. The processes that shape those overlaps and co-evolution range from the continued involvement of key scientists in further patenting and technology development to firm founding, consulting, mentoring and informal scientific advising, etc.

During the period when scientific and technical constructs overlap, scientific ideas represent not only new insights but also new technical solutions. The same idea can be different in the patent and the paper, and thus constitutes a patent-paper pair. The two documents might thus transcribe the same idea in texts that might be very distinct in nature; a paper explaining the experimental results and a patent defining the utility and making claims (Murray 2002:1395).

Pairs can thus make a considerable contribution to distinguishing between institutions' performances though they represent inscriptions of one underlying idea. They also perfectly constitute an instant when science and technology overlap. They epitomise the intertwined and co-evolutionary nature of scientific and technical ideas in communities.

This work assumes that the context, outlined below, in which the South African universities currently produce their proprietary and public knowledge, is very likely to encourage scientist entrepreneurs to produce patent-paper pairs as a way of maximising the returns over their intellectual properties:

- Heavy R&D reliance on business enterprise funding (about 50%), that is over five-times the average of that of the OECD countries. This situation is likely to constrain researchers to carry out more applied than basic research in order to access industry's grants
- High incentives bestowed by faculties and the NRF to researchers who are academically excellent, particularly those who publish papers
- High incentives bestowed by the NRF to researchers who innovate, i.e. patent, license, create spin-off companies
- IP regime which gives part of royalties to inventors.

This assumption will be tested by examining pairs.

3.2 Human capital

3.2.1 The concept of human capital

Human capital has been described variably as:

- People-embodied know-how (Perez & De Pablo 203:92), embracing the acquired knowledge, skills, and capabilities that enable persons to act in new ways (Coleman 1988:995)

- Implicit knowledge (Lynn 1998:163)
- Human centered assets, like expertise, creativity, problem-solving, capability, leadership, entrepreneurial and managerial skills (Roos & Roos 1997:413)
- Innovativeness, talents, values, culture, philosophy, ability (Litschka 2006:162)
- Individual competencies, experience, and attitude (Edvinsson 1997:366)
- Motivation, agility and ability to be a technology broker (Brooking 1996)
- Changing capability (Bontis 2000:391)
- Specialised (*tacit)* human skills that are:

    - Know-how and know-what (Winter 2006:246) which vary with the degree of tacitness: a function of the extent to which knowledge is or can be codified and abstracted
    - Communicable and includes theoretical and practical knowledge of people and the performance of different kinds of artistic, aesthetic or technical skills

- Generic (*explicit*) human skills that include "conscious knowledge" that is typically available to an individual in the form of facts, concepts, and frameworks that can be stored and retrieved from memory or personal records
- The scientific and technical human capital (Bozeman 2000:627) that includes:

    - Individual human capital endowments normally included in labour economics model (Becker 1992:9)
    - The sum of total researcher's tacit knowledge, craft knowledge, and know how, individual scientist's tacit knowledge, craft knowledge and know-how.

Not all organizations' human capital or skills carry the same weight nor are they always evenly distributed among employees. This could rationalise the move in many organisations to adjust their human capital structures in order to meet their strategic goals through in-service training, use of consultants, joint ventures, etc. This work investigates whether invention related skills that are idiosyncratic to universities, but core to industries, could be transferred to a university that employs researchers who have previously been exposed to industry through their careers.

3.2.2 Previous industry working experience, human capital and inventive capacity of university researchers

Experience usually builds up through the "learning ropes" from previous to current employment. Such experience may lead to skills that are useful across a wide range of occupations (Madsen et al. 2003:428). The extant studies on the effect of career on productivity focus on the impact of the number of years, the path or the nature of such career in a narrow way, i.e. within the same organisation. Accordingly, experience increases with age and vary with gender (as men and women are not likely to make the same educational and vocational choices).

Successes, productive and non-productive failures are usually linked to experience. A productive failure could lead, for example, to insight, understanding, and thus addition to the commonly held wisdom of the organisation. Processes aimed at learning from previous experience can thus be valuable in knowledge acquisition, accumulation and improvement. Such processes can convert internal stimuli into new knowledge and firm-specific competencies, which are central to the enhancement of the firm's competitive advantages (Daghfous 2004:943).

Many authors associated success in innovation with entrepreneurs' career age. Younger firms' fragility and higher failure rate of their business start-ups were ascribed to lack of experience (Van de Ven et al. 1984:89, Cooper & Dunkelberg 1981, Pena 2002:180). Bontis et al. (2000:85) suggested that there is a significant positive relationship between the intellectual capital that accrues over time and business performance, regardless of industry sector.

Other scholars found that firms were more likely to succeed when entrepreneurs have previously occupied decision-making positions (Cooper et al. 1989:317, Dutriaux & Simyar 1987). Entrepreneurs, whose parents, relatives or friends had business start-up experience, were also familiar with the endeavors of building a firm (Duchesneau & Gartner 1990:297, Dunkelberg et al. 1987; Cooper et al. 1989:317).

Further studies investigating teamwork performance in the food industry found strong positive relationships between the stated goals and productivity only for employees who have had at least a year of experience in a similar job (Dachler & Mobley 1973:397; Allen et al. 1988:295). Weisberg & Israel (1996:24) suggested that longer tenure represents more firm-specific human capital. He argued that workers with longer tenure had invested their human capital in the firm and presented, on the one hand, more efficiency during the years they worked with the same employer. On the other hand, they tended to be more motivated and emotionally involved in the firm.

The pioneering work of Diets & Bozeman (2005:350) which analysed the differences in performances of university scientists and engineers, based on their career paths is worth mentioning. The authors suggested that the scientific and technical human capital developed through work experience translated into long-term productivity. Higher publication productivity was associated with careers that were more academic. Patenting was associated with more industry-oriented careers, even though a substantial fraction of those with industry working experience continued to patent while working in academia.

Undoubtedly researchers change jobs between academia, industry and governments, sometimes changing sectors many times or working in multiple settings simultaneously. The foregoing movement can induce knowledge spillovers from one firm to another (Jaffe et al. 1993:577). A human capital that a researcher transfers while moving from one job to another and principally from one sector to another may provide critical and ongoing knowledge input into new problems (Lubango & Pouris 2007:788).

Colombo & Grilli (2005:799) also supported a positive impact of career heterogeneity on the production of academic entrepreneurs. The human capital of founders affected positively the post-entry performances of new technology-based firms. Accordingly, founders with previous industry working experience had greater human capital wealth, which allowed them to survive and grow in the new ventures. Furthermore, they used their relational capital to access external grants usually needed to fund their operations as they were in a better position to resort to outside collaterals.

This work contends that employing scientists with previous industry working experience would broaden the following skills that are typical to mainstream universities:

- lecturing and training graduate students
- proof of concept research design and methodology
- writing articles
- use of instruments for demonstration purposes
- developing scientific disciplines.

The following skills, which are mainly available in various divisions of the mainstream industries (marketing and sales, R&D, manufacturing/engineering, IP, etc.) are likely be transferred to universities that employ researchers who previously worked in industry:

- industrial design and testing
- prototype development
- manufacturing
- plant design, commissioning and operation
- marketing and sales
- patenting, licensing, project management
- business development
- etc.

These skills are likely to inform researchers on how to develop inventions that are patentable and, particularly, inventions that meet industry's needs and are thus transferable to industry (Lubango 2009).

3.3 Social capital

3.3.1 The concept of social capital

Social capital arises from a broader cosmopolitan network with colleagues and collaborators from various academic institutions and builds up through practices and the social structure of science through an inventor's career (Murray 2005:645). It is the actual and potential resources embedded within, and derived from a network of relationships possessed by an individual or social unit. It encompasses both the network and the assets that may be obtained through that network (Nahapiet & Goshal 1996:243) and could reflect the over-all patterns of connections between actors. Those networks of relationships are likely to facilitate the conduct of social affairs among members to whom the collectively owned capital is available, and on whom important credentials are bestowed.

The social capital construct has many interrelated dimensions including the structural, relational and cognitive (Nahapiet & Goshal 1996:243). The structural embeddings concerns the properties of the social system and of the network of relations as a whole. It refers to the impersonal configuration of linkages between people or units, e.g., friendship, respect, etc., that can influence their behaviour, and fulfill social motives like sociability, approval and prestige. The cognitive dimension of social capital refers to resources that provide shared representations, interpretations and systems of meaning among parties that can facilitate the achievement of ends that would be impossible without it or that would only be achievable at an extra cost (Nahapiet & Goshal 1996:244).

Social capital also includes social innovation capital, which refers to the innovation capital of a social kind (held by a collective) as opposed to the innovation capital held by an individual (McElroy 2001). It refers to the structural manner in which the whole social systems (firms) organise themselves around and carry out the production and integration of new knowledge. It is thus a particular archetypical social capital pattern, which has as its aim the production, diffusion and application of new knowledge by, and for the organisation. It should also be regarded as a self-organised community of independent learners who co-attract one another because of their shared interests and positions, and who collaborate with one another to develop and validate new knowledge (McElroy 2001).

3.3.2 Previous industry working experience and academics' performances

Change in career between academia and industry can broaden a researcher's social capital and facilitate the transfer of knowledge between academia and industry (Bozeman et al 2001: 717; Dietz & Bozeman 2005:349). Scientists with strong and diverse social capital have thus been differently labelled as:

- *Brokers* (Murray 2004:645)
- *Boundary spanners* (Allen 1984; Tushman 1977:588; Tushman & Scanlan 1981:289), etc.

These are agile individuals capable of creating bridges, either for themselves or for their organisations, into other domains and functional areas such as in industry.

The present work assumes that employing researchers with previous industry working experience would help a university access industry's social capital, which is likely to facilitate collaborations and knowledge spillovers between the two institutions. A university might thus deploy its technologies to a potential market, aided by its social linkages with prominent referrals, decision-makers, engineers and scientists in industry (Lubango 2009).

The above assumptions could well explain the finding of Gulbrandsen & Smeby (2005:934) that professors with external industry funding generally collaborate more compared to their colleagues without such external financial support. Through these intense collaborations, the capacity for shared problem solving and for developing technological knowledge that can potentially satisfy demand expectations and meet market requirements can build up.

An important example that could illustrate the effects of a broad and heterogeneous network of collaborators on a researcher's capacity is the peer-review/quality control-like mechanism among researchers who collaborate/co-author. Prior to a submission in a journal, a co-authored paper normally undergoes a first peer-review, evaluation, or audition by co-authors, co-workers or peers from industry or academia. If intensified, this practice could subject a researcher's outcomes to frequent evaluations by co-authors who are peers or experts in the field, on the different facets of research and its impacts. When the co-authors or collaborators are the leading international scientists, the researcher's capacity is likely to increase considerably. This work proposes that the larger the network of collaborators, the higher the foregoing capacity is likely to be (Lubango & Pouris 2009:315) due to the subsequent intense knowledge flow, as previously outlined in various network flow models.

A researcher who has intense collaborations with industry is further likely to raise enough funds which can sponsor various research projects, employ many PhD and post-doctoral researchers, invite leading international scientists as fellows or visitors, attend and lead conferences and thus broaden his/her network of collaborators that can increase his/her research capacity, as described previously.

CHAPTER 4 RESEARCH DESIGN AND METHODOLOGY

4.1 Hypotheses

The following hypotheses build on previous discussions about the dynamics and the enablers of knowledge creation and flows:

1. Previous industry working experience is likely to promote the inventive capacity of universities' researchers
2. Patenting technical inventions and publishing scientific developments in journal articles are not likely to be in conflict; particularly in universities that employs researchers with previous industry working experience
3. Concurrent patenting of technical inventions and publication of scientific discoveries in journal articles are likely to be associated with dual disclosures of the same piece of an underlying knowledge in patent and journal articles.

The questions and the hypotheses set out in this work will be addressed as follows:

1. Analysing the South African universities' patent activities at CIPRO, USPTO, WIPO and EPO from 1996 to 2006
2. Investigation of the career histories of South African scientists and engineers who engage in high levels of patenting and commercial activities in universities
3. Comparing research capacity and the inventive capacity of South African universities' researchers
4. Investigating the existence of pairs
5. Analysing the flow of knowledge disclosed in pairs
6. Analysing whether:

    - A patent built on a knowledge disclosed in a journal article could effectively be cited by other patents

- An article built on technical knowledge disclosed in a patent could effectively be cited by other articles.

4.2 Rationale for using patent data

Patent databases from most national and international patent offices are generally readily accessible to the public electronically or manually. They can provide important information on patentable invention, e.g., the geographic distribution of particular inventions, citation characteristics, patenting companies, etc.

The importance of patents in the whole technological innovation process, including knowledge creation and flows between private markets and unrelated parties (public sector, academia, etc.), could justify its frequent use as an indicator of inventive and/or innovative activities (Archibugi & Coco 2005:175, Motohashi 2005:583; Pouris 2005:221; Miyata 2000:413; Maskus 2003:3). Patent and patent applications can further indicate the level of technological development in specific sectors, as well as the relationship between technological development and economic growth (Abraham & Moitra 2001:245; Coombs et al. 1996:403; Gans & Hayes 2005; Grupp & Mogee 2004:1373; Pouris 2006).

The following limitations on the use of patent as an indicator of innovation activities are worth noting. First, patent assets are without doubt disproportionately valuable in the drug, computer hardware and software, motor vehicles, telecommunications equipment and services, electronic components, food, chemicals, molecular biology, microbiology and instrument industries. Second, the newness, usefulness and non-obviousness criteria for patent grants limit the weight of patent as an indicator of innovation, the later being more the successful commercialisation of the former. Patents should thus serve as intermediate indicators of innovation. Third, patents cannot reflect some other technological developments that, for strategic or other reasons, are protected by other means (e.g. trade secret, etc.). Fourth, patents cannot reflect all the linkages between scientific and industrial laboratories in some countries, e.g. in Germany, where university professors generally do not personally apply, own, or sell their intellectual property rights readily. The use of patent as a measure of industry-university links thus ought to consider the national framework policy on the ownership of intellectual property rights.

This work will first count national patents as proxies of inventive activities in South African universities where researchers have much freedom to patent. Some international patent databases including the USPTO, the EPO and the WIPO will also be explored. The latter exploration will help recover important data needed in the last part of this work, which were not accessible locally for technical reasons. The research design is more useful in the technological sectors considered (i.e. chemicals, polymers, materials, electronics, microbiology, pharmacy, biotechnology) where patent is among the most important means of protecting and disseminating knowledge.

4.3 Rationale for using ISI bibliometric data

The assumption that scientific progress results from the work of researchers with local, national, but primarily international impact that build on the results of other scientists and continuously improve the quality of their research output, significantly drives the use of bibliometric data as an evaluation tool of scientific research performance. References in a publication can thus indicate how a researcher builds on previous work and the number of times a body of literature receives citations worldwide can indicate the impact or the international visibility of the research.

This work uses the SCI, produced by the Institute for Scientific Information (ISI), which covers the core, i.e., most journals with international scope in the natural and life sciences.

SCI journals are among the most important communication media for most science-based activities. They largely cover most technological sectors investigated in this work, i.e. chemicals, polymers, materials, electronics, microbiology, pharmacy, biotechnology. SCI is increasingly publishing a large number of non-journal materials such as conference books, published proceedings, multi-authored books, monographs and thematic collections of papers, etc. as special issues.

Bibliometric indicators are not intended to replace the evaluation of experts, but they can offer crucial information about research performance. They could thus be balancing the peer's opinion (the latter also having its serious draw back) (Horrobin 1990:1438; Wenneras & Wold 1997:341; Van Raan & Van Leeuwen 2002:614). This can justify the combination of the bibliometric analysis with peer review for an effective evaluation of researcher performance, as undertaken in this work. The interpretation of bibliometric results notably at the aggregate level of a department will take into account the background knowledge of the departments and fields, as they may be reflecting specific habits within a department (e.g. publication habits) or the internal characteristics of a research field in which the department is active.

4.4 Rationale for using NRF evaluation and rating data

The NRF evaluation and rating system, developed in South Africa, has been in operation since 1984. The approach yields ratings from an extensive, deep, and long-term evaluation led by peers. This approach goes beyond the traditional quantitative bibliometric counts and integrates various researchers' inputs. National and international peers/reviewers lead the whole process of evaluating and rating researchers that focuses primarily on the quality of the research outputs during the past seven years. Research outputs could include publications in peer-reviewed journals, books or chapters in books, peer-reviewed published conference proceedings, other significant conference proceedings including published abstracts, keynotes or plenary addresses, patents, artifacts and products, technical and other reports. Other important output include annotated bibliographies, CD-ROMS, development and production of software, electronic publications, plant breeding rights, research guides, vaccines, web sites, etc.

The assessment considers research outputs that happened within a seven-year period. The closing date on 28 February 2007, for example, is from 1 January 2000 to 31 December 2006. Further research outputs amounting to a maximum of the 10 best research outputs of the period preceding the last 10 years could also be included. The assessment panels include members of respective specialist committees, an independent assessor, and a chairperson who is either a member of the NRF executive or a researcher of international repute. The specialist committees assess and rate applicants based on the reviewers' comments, and the standing of applicants among their peers. The objectivity of the foregoing reports also undergoes an assessment. The key research areas include:

- Animal and Veterinary Sciences
- Anthropology
- Development Studies
- Geography
- Sociology and Social Work
- Biochemistry
- Chemistry
- Communication, Media Studies, Library and Information Sciences
- Earth Sciences
- Economics, Management, Administration and Accounting
- Education
- Engineering
- Health Sciences
- Historical Studies
- Law
- Literary Studies, Languages and Linguistics
- Mathematical Sciences
- Microbiology and Plant Pathology
- Performing and Creative Arts
- Physics
- Plant Sciences
- Political Sciences, Policy Studies and Philosophy
- Psychology and Religious Studies.

Applicants choose freely their assessment panels. The latter make recommendations to the NRF based on the assessments of the reviewers' report. Assessments are purely based on:

(i) The quality of the research outputs of the last seven years as well as the impact of the applicant's work on his/her and on adjacent fields

(ii) An assessment of the applicants' standing as a researcher in terms of both South African and international perspectives

(iii) The quality and appropriateness of the journals, books, conference proceedings, etc. in which the applicants' work is published

(iv) Other research contributions.

The NRF-rating categories include:

A-rated: leading internationally acclaimed researchers. Their peers unequivocally recognise them as leading international scholars. Their recent research outputs have a high quality and impact. Category A includes two sub-categories A1 and A2. A1 are internationally leading scholars in their field who have high quality and wide impact beyond a narrow field of specialisation of their recent research outputs. A2 are internationally leading scholars in their field who have high quality research outputs.

B-rated: internationally acclaimed researchers. They enjoy considerable international recognition by their peers for the high quality of their recent research outputs. These applicants are independent researchers with considerable international recognition for the high quality and impact of their recent research outputs. This work does not describe other sub-categories of B, i.e., B1, B2, and B3.

C-rated: established researchers. They have a sustained recent record of productivity in the field and are recognised by their peers as having: (i) produced a body of quality work, the core of which has coherence and attests to ongoing engagement with the field, (ii) demonstrated the ability to conceptualise problems and apply research methods to investigating them. This work does not describe the three sub-categories of C, i.e., C1, C2, and C3.

P-rated: promising young researchers. They are normally younger than 35 years of age and have held the doctorate or equivalent qualifications for less than five years at the time of application. Based on the exceptional potential demonstrated in their published doctoral work and of their research outputs in their early postdoctoral careers, these researchers are likely to become future leaders in their field.

Y-rated: young researchers. They are normally younger than 35 years and had the doctoral or equivalent qualification for less than five years at the time of applications. They have the potential to establish themselves as researchers within a five-year period after evaluation, based on their performance and productivity as researchers during their doctoral studies and/or early post-doctoral careers.

L-rated: late entrant researchers. They are normally younger than 55 years and were previously researchers or demonstrated their potential through their own research products. They are capable of fully re-establishing themselves as researchers within a five-year period after evaluation. Candidates in this category are South African citizens or foreign nationals who have been residents in South Africa for five years during which time they have been unable, for practical reasons, to realise their potential as researchers. Candidates eligible in this group are: black researchers, female researchers, researchers employed in a higher education institution that lacked a research environment, or researchers who were previously established as researchers and who have returned to a research environment.

4.5 Data collection process

The domestic patents data from 1996 to 2006 were obtained from CIPRO using patent index cards and Registries as well as the South African Journal of Patent. The collection process covered patent data from all the South African universities and tertiary institutions, including the University of Cape Town, Stellenbosch University, University of Pretoria, University of the Witwatersrand, University of the NorthWest, University of Johannesburg, University of Kwa-Zulu Natal, University of the Free State, Tswane University of Technology. Patents co-owned by university and industry or other public specialised research centres were also covered.

The CIPRO electronic database was still in the development phase. It did not always cover all the patent data (i.e. claims, classes, addresses, etc.), had many duplicates, and was thus not always easy to exploit. The main patents data investigated were the application number, including the year of application, the type of application (i.e. provisional or complete), the assignees, the title and the inventors' names and details.

The inventors' details included names, affiliation (university, school or department), gender, title, education and professional experience. They were accessible from the university and department or school's web pages and archives, short or detailed CVs, national or international journal articles, industry databases, archives and directories. E-mails, telephone calls to inventors themselves or the secretaries of schools, university research centres, companies, etc. were also used when possible.

Almost all the patents collected described process and/or product innovation. They were grouped in the following broad sectors in accordance with the claims, descriptions, abstracts and/or subject matters:

- Optoelectronics and related arts/technology
- Chemistry and related arts/technology
- Separation technology
- Metals, metal products
- Biotechnology/genetics
- Drug design/pharmacology
- Immunoassay/pathology
- Machine and related arts/technology
- Optics
- Medical equipments, methods and related arts
- Water and environment
- Food technology
- Sea transportation
- Diagnostics and related arts

- Construction/building materials
- Nuclear technologies
- Acoustics
- Wood processing.

These categories/sectors have been created in this work to facilitate a discussion on the technical orientations of inventions undertaken in South African universities.

4.6 Patent data from EPO, USPTO and WIPO

Not all the patents' details were available in the CIPRO registers. Nevertheless, 244 copies of patents applications that included the title of the invention, the priority date, and the names of the inventor, the abstracts, the application numbers and IPC were manually gathered. The data that were missing in CIPRO patents were electronically accessible from the USPTO or EPO databases where all the patent details normally appear in the complete applications.

4.7 Construction of patent-paper pair dataset

Patents contents (abstracts, claims, applications, examples, etc.) and biobliographic data were compared with those of the papers (authors' name, address affiliation, abstracts, methods, results and discussion) from the journals in order to establish a pair. The articles' citation data were accessible electronically from the Science Citation Index Expanded (SCI-EXPANDED) using the inventors' names, affiliation and the period of publication/citation. Citations where an author or an inventor cited him Know-how self did not count. Names, addresses, and affiliation of the authors and co-authors were accessible from the corresponding journal articles' front pages. The inventors' names and initials, authors and the affiliations given in patents had to match those given in a corresponding article. The period investigated was from 1996 to 2006.

The information that corresponded to patents' forward and backward citations listed below were analysed:

1. Inventors or authors' names
2. Assignees or affiliations details
3. Years of citation and
4. Number of citing patents or papers.

The citation analysis focused on:

1. Forward patent citations
2. Forward non-patent citations
3. Backward patent citations
4. Backward non-patent citations
5. The number of articles (excluding meeting and abstracts) covered
6. The number of times those articles have been cited by other journal articles during the period 1996-2006.

The ISI citation analysis included:

- Count of the number of articles (excluding meetings and abstracts)
- Count of the number of times those articles have been cited in the period 1980-2006 by other journal articles

Only the citations that revealed article-article links were counted. A reference by an article to another article several times, counted as one citation. Citation practices within fields can change during a decade. Analysing the SCI database in the period 1970-1980, e.g., Moed et al. (1985:132) showed that a journal article contains on average an increasing number of citations. Citation practices can also differ from field to field, even within disciplines, or sub-fields. They can also change over time. Comparing performance of disciplines based on citations data is thus difficult. The aim of this work was not to compare citation profiles of disciplines, so changes in SCI source journal books (which may happen during a decade) should not be regarded as a major threat to the validity of the results of this work.

4.8 NRFrating data

The NRF-rating data set included the ratings of both inventive and non-inventive professors (particularly of the control and the experimental group). The ratings were electronically accessible from the NRF-rating database using the names, titles, affiliations and research fields of the professors.

4.9 Construction of control groups for testing hypotheses

4.9.1 Control group 1

The control group was set out to test the importance of previous industry work experience on the determination of inventive capacity of university researchers. The control group consisted of 30 professors from the same departments (including Botany, Electrical, Electronic and Computer Engineering, Chemical Engineering, Mechanical Engineering, Microbiology, Biochemistry, Civil Engineering, Metallurgical Engineering and Veterinary Science) and from the institutions studied, i.e. SUN, WITS, UP, UNNW and UCT.

The selection of the control group used a matched sampling approach. None of the professors of the control group belonged to the initial population of inventors of the 280 patent applications investigated in this study. Names of these professors were accessible from the web pages of their departments and, if necessary, professors provided their CV by e-mails. All members of this group were professors, mainly male, and aged between 35 and 60 years. Members of this group had similar background characteristics, belonged to similar institutions and similar departments and thus faced the same labour market conditions that could affect performance. An analysis of the CVs identified two sub-groups. The first sub-group included 10 professors who all had previous industry working experience. Seven of them had patent applications before 1996, and the remaining three professors had no applications. The second sub-group included 20 professors who had no previous industry work experience. None of them had a patent application.

The selection approach clearly made the two sub-groups of the control group significantly homogeneous and thus suitable for the comparison of their inventiveness, based on the sole effect of previous industry working experience. Previous industry working experience that was zero in the second sub-group of the control group, consisting of 20 professors was the sole criterion of comparison that carried considerable weight. This approach significantly minimised possible threats to the validity of comparison of the two sub-groups. The large magnitude of the difference in inventiveness of the two sub-groups of the control group made other statistical tests unnecessary.

4.9.2 Control group 2 and experimental group

A comparison of the publication profiles of the two groups of professors in peer-reviewed journal articles (covered by the ISI) over the past 10 years was set out to find whether patenting of inventions impeded or was in conflict with publication of articles. The two groups of professors were from the departments with the highest inventive activities. Each group contained 30 professors from the five South African universities with the highest patent activities including Stellenbosch University (SUN), the University of Cape Town (UCT), the University of Pretoria (UP), the University of the NorthWest (UNNW) and the University of the Witwatersrand (WITS).

All professors were predominantly male and were aged between 45 and 65 years. All professors worked at least in one of the five universities and were randomly selected from the departments with more inventive activities including Botany, Biochemistry, Chemistry, Chemical Engineering, Civil Engineering, Electrical, Electronic and Computer Engineering, Mechanical Engineering, Metallurgical Engineering, Microbiology, Molecular and Cell Biology, Physics and Nutrition. Professors who belonged to the control group had no patent applications and all professors who belonged to the experimental group have been patenting technical inventions for the past 10 years.

4.10 Evaluation of the publication performances of inventive and non-inventive professors

(i) Variable specification

1. Inventiveness (Inv). Inv = 1 for professor(s) who had at least a patent application. Inv = 0 for professors with 0 patent applications. Inventiveness was measured through patent application counts
2. Publication capacity (Y) was measured through the number of publication counts
3. Collaborative capacity (L) was measured through the counts of the number of co-authors that appeared on a journal article. Professors (inventors or non-inventors) whose collaborative capacities were being investigated were not counted as co-authors
4. Faculty orientation (F) = 1 for professors from the faculty of natural science, pharmacy or medical fields. F = 0 for the professors from the faculty of engineering or technology
5. Activity (A) = 0 for professors who were aged over 65 years. A = 1 for professors who were below 65 years. (A) was introduced in the model to investigate whether being above 65 years (i.e. being a retiree according to the South African employment Act) has an impact on the publication activity

(ii) Modeling the publication profiles of innovative and non-innovative professors

The Poisson regression model was used to investigate the effect of patenting technical inventions on the academics' performance in publishing papers. The regression assumes that the investigated data follow a Poisson probability distribution: a distribution frequently encountered when counting the number of events, like the number of publications, co-publications, patents, encountered in the present work. The following features distinguish the Poisson regression from the traditional (i.e. least squares):

1. The Poisson distribution is skewed, whereas traditional regressions assume a symmetric distribution of errors

2. The Poisson distribution is non-negative, whereas the traditional regressions might sometimes produce predicted values that are negative
3. For the Poisson distribution, the variance increases as the mean increases whereas traditional regressions assume a constant variance.

The Poisson regression model uses implicitly a log transformation, which adjusts the skewness and avoids negative predicted values. The regression also models the variance as a function of the mean.

The Poisson probability distribution displayed below:

$$P(y/\mu) = \frac{\exp(-\mu)\mu^{y}}{y!}$$

has the same mean and variance (equidispersion) (Park 2005):

$$Var(y) = E(y) = \mu .$$

As the mean increases the probability of zeros decreases and the distribution approximates a normal distribution. The distribution also makes a strong assumption that events are independent. The regression model incorporates all the observed heterogeneities into the Poisson distribution function:

$$Var(yi/xi) = E(yi/xi) = \exp(xi\beta).$$

As μ increases, the conditional variance of y increases, the proportion of predicted zeros decreases, and the distribution around the expected value becomes approximately normal. The conditional mean of errors is zero, but the variance of the errors is a function of independent variables:

$$Var(\varepsilon/x) = \exp(x\beta).$$

The Poisson mean in the generalized linear models (GLM) is commonly modeled using a log-link function:

$$\log(\mu) = \alpha + x\beta$$

$$\mu = \exp(\alpha + \beta x) = \exp(\alpha)\exp(\beta)^{x}$$

or an identity link:

$$\mu = \alpha + \beta x.$$

This work used SAS (SAS's GENMOD) to model publication profiles (Y) of inventive and non-inventive professors, as dependent variable and inventiveness and non-inventiveness as independent variables. The model also considered the confounding effects of other independent variables, including collaboration (L), activity of professor (A) and research orientation of a professor (F).

CHAPTER 5 RESULTS AND DISCUSSION

5.1 CIPRO patent datasets

Table 2 (a): Distribution of patent applications by sector from 1996 to 2006, SUN

Patent No	Inventor(s)	Title	Sector
2002/08876	Burger J.T., Robson J.	Expression vector - provisional	Biotechnology/genetics
2003/06703	Aggenbach J. H.	Bach (barrow)	-
9801153	Milne G.W.	Voice activable protector- provisional	Acoustics
9906230	Du Toit M.H, Enslin J.H.R., Visser A.J.	Transformerless Dip sag compensation device-provisional	Acoustics
9906231	Du Toit M.H, Enslin J.H.R, Frederik Wilhelm C.	Active resonant turn of snubber - provisional	Acoustics
2001/02258	Cloete J.H., De Villiers W.	Ampacity and sag monitoring of overhead power transmission lines - provisional	Acoustics
2002/04048	Stander M.A., Steyn P., Smith M.S.	Metabolic degradation of ochratoxin A by certain yeasts	Biotechnology/genetics
2003/05367	Pretorius I.S., Vivier M.A., Lambrecht M.G, Du Toit M.	Recombinant yeast cells for increasing the synthesis of resveratrol during fermentation - provisional	Biotechnology/genetics
2004/05628	Burger B.V.	Sample enrichment device - complete	Biotechnology/genetics
2004/09060	Swiegers J.H., Bauer F.F.	A caritine producing saccharomyces cerevisiae strain - provisional	Biotechnology/genetics
2005/09973	Light M.E., Van Staden J., Burger B.V.	Method for producing germination stimulants-provisional/complete	Biotechnology/genetics
2006/03738	Van Zyl W. H., De Haan R.	Method for fermenting celluloses - provisional /complete	Biotechnology/genetics
2001/01657	Cross P., Perold W.J.	CCR2 isoforms – provisional	Optoelectronics and related arts
2003/08959	Milne G.W.	Terrestrial communication system – provisional	Optoelectronics and related arts

96/06449	Weerdenburg J.W.	Road surface barrier device	Construction materials
2005/06779	Rautenbach M.W., Manya U.I., Hoppe H.C.	Pharmaceutical composition for treating malaria - provisional	Drug design/pharmacology
96/05096	Van Vuuren J.H.J., Pretorius I.S., Mulder L., Dicks T.	A method of destroying or inhibiting the growth of microbe, and a microbiocidal or microbiostatic agent for use in the method - provisional	Food technology
2003/08796	Van Zyl W.H., Shaunita H.R., Setati. M.E., Jorgens J.F.	Method for producing soluble coffee extracts-provisional	Food technology
9639/71	Subden R.E, Van Vuuren J.J, Aldis K. Chuanpit O-E.	A method and nucleotide sequence for transforming microorganisms	Biotechnology/genetics
9703448	Pretorius I. S.	Genetically engineered yeast strain	Biotechnology/genetics
2001/07768	Van Rensburg J.E., Hayes V.M., Petersen D..	CCR2 isoforms - provisional	Biotechnology/genetics
2002/06062	Van Zyl W.H., De Haan Riaan	Method of enhancing xylan degrading ability of pichia stipitis - provisional	Biotechnology/genetics
2002/02017	Van Zyl W.H., Shaunita R.H.	A recombinant fungus strain	Biotechnology/genetics
2002/08336	Van Zyl W.H. Linsay R.R.	Method for providing a recombinant fungus strain - complete	Biotechnology/genetics
2004/00793	Ying L., Megede J.Z, Van Rensburg E.J., Scriba T., Engelbrecht S. Barner S.W.	Polynucleotides encoding antigenic HIV type C polypeptides, polypeptides and uses thereof - complete	Biotechnology/genetics
2004/01537	Warren R.M., Van Helden P.D., Bourn W., Jansen Y.	High copy number plasmid replicon - provisional	Biotechnology/genetics
2004/01648	Van Zyl W.H., Pluddemann A.	A fungus strain for producing viral coat proteins and a method of producing the fungus strain - complete	Biotechnology/genetics
2004/06714	Cordero O.R.R., Pretorius I.S., Van Rensburg P.	Recombinant saccharomycess cerevisiae strain	Biotechnology/genetics

		expressing alpha-amylase and glucoamylase genes and the use of such strains - complete	
2004/04219	Warren R.M., Van Helden P.D., Van Pittius N.C.G.	Bacterial secretion system and uses therefore - provisional	Biotechnology/genetics
2004/05100	Van Zyl W.H., Botha A., Cruywagen C.W., Prior B.A.	Fungus strain and use thereof	Biotechnology/genetics
2005/03063	Conradie E.C.	Gene regulation - provisional/complete	Biotechnology/genetics
2006/00683	Van Pittius N.G., Van Helden P.D., Warren R.M.	Method of identifying species of tuberculosis - provisional	Biotechnology/genetics
2003/05138	Dimitrov D.M.	Rapid conformal tooling - provisional.	Machine and related arts
2002/07909	Van Rooyen G.J., Laurens J.G.	Baseband digital signal processing system with digital spur compensation - provisional/complete	Optoelectronics and related arts
2004/08735	Cloete J.H., De Villiers W.	Impedance monitoring system and method - provisional	Optoelectronics and related arts
2005/06457	Smith F., Mostert S.	Radiation hardened electronic circuit - provisional/complete	Optoelectronics and related arts
9900634	Detlev G.K.	Solar chimney power plant – provisional	Metal and metal product
96/02517	Sanderson R.D., Opperman W.J.	-	Chemistry and related arts
9806151	Sanderson R.D, Charles Frederick F.	Microstructure of organic materials	Chemistry and related arts
9801078	Sanderson R.D, Charles Frederick F.	Process for forming polymerized microstructures of organic materials	Chemistry and related arts
2002/03238	Sanderson R.D.	Synthetic wine closure - provisional	Chemistry and related arts
2002/03237	Sanderson R.D.	Membrane cleaning toll - provisional	Chemistry and related arts
2002/02583	Sanderson R.D., De Wet R.D.	Raft emulsion dispersion techniques - provisional	Chemistry and related arts
2003/08902	Sanderson R.D., Naidoo V.B., Rautenbach M.	Bola amphiphilic peptides - provisional	Chemistry and related arts
2004/00021	Sanderson R.D., Opperman W.J.	Preservative gas generating device - complete	Chemistry and related arts

2004/08983	Sanderson R.D., Naidoo V.B., Rautenbach M.	Bola amphiphilic peptides - provisional	Chemistry and related arts
96/9195	Ysbrandy R., Gerischer F.R.	Processing of mill sludge	Chemistry and related arts
2000/01832	Meets M., Hall B.M., Boucher C.	Method of grading smoke water - provisional	Chemistry and related arts
2002/07826	Potgieter H.J.	A central assessment and evaluation system and method	Chemistry and related arts
2003/03673	Pelser M. Eksteen J.J., Lorenzen L, Swart A.	Process for the control of calcium and magnesium in a base metal sulphate leach solution	Chemistry and related arts
9703436	Hoppe K.G.W.	Hydrofoil supported water craft	Sea transportation
9707291	Hoppe K.G.W	Boat	Sea transportation
9810632	Laurens J.G, Van Rooyen J.G.	Baseband FM exciter - provisional	Optoelectronics and related arts
2004/01619	Dimitrov D.M., Bester A.G.J., Humphrey P.	Integrated product and tool design system - provisional	Machine and related arts
2000/00330	Gerischer G.F.R.	Fungal pretreatment of wood chips with a consortium of fungal cultures to enhance alkaline pulping - provisional	Wood processing
2000/00329	Gerischer G.F.R., Ebbe J.D	Hot water extraction of wood chip - provisional	Wood processing

Table 2 (b): Distribution of patent applications by sector from 1996 to 2006, UP

Patent No	Inventor(s)	Title	Sector
9708319	Landauer L.J., Preez J.G	Treatment of PTK or CDK Modulational disease or injury states	Diagnostics and related arts
99/04254	Snyman L.W.. Ahoni H., Bogalecki A., Du Plessis M., Seevinck E..	Communication system including integrated silicon light emitting devices and detectors - provisional	Optoelectronics and related arts
99/03392	Van Wygnaraard C.J., Malan W.R.	Telephone line monitoring and control unit - provisional	Optoelectronics and related arts
2002/03239	Coetzee P.C.	Communication arrangement - provisional	Optoelectronics and related arts
2000/03159	Van Rensburg J.A.	Radiation modulation - provisional	Nuclear technology
9904526	Bouwer A.C., Du Toit L.D.	Identification of a disability in learner or a barrier to his/ her learning - provisional	Diagnostics and related arts
2000/02465	Heydenrych M.D, Stone A.K., Morgan D.L.	Fluidization - complete	Chemistry and related arts
2000/05591	Retief P.M., Geldenhuis J.M.A.	Metallurgical process - provisional	Chemistry and related arts
2000/03158	Verbeek C.J.R.	Method of making a structural material - provisional	Chemistry and related arts
2002/04106	Morgan D.L., Kgobane B.L., Mthembi P.M.	Method of extraction of a carbonaceous material for the subsequent production of graphite - provisional	Chemistry and related arts
9810672	Snyman L.W., Berhrens B.A.	Automatic Chlorination for swimming pools - provisional	Chemistry and related arts
9904892	Visser J.A	Flow control valve - provisional	Machine and related arts
2000/02513	Focke W.W.	Flame retardant with carboxylic acid or precursor or derivative thereof - complete	Chemistry and related arts
2001/02272	Focke W.W. Mentz J.C., Labuschagne F.J.W.J.	Intumescent flame retardants - provisional	Chemistry and related arts
9906682	Focke W.W., Rolfes H.	Odd carbon x olefin copolymers	Chemistry and related arts

2001/03872	Scheffler T.B.	Multiple line welding of polymer film - provisional	Chemistry and related arts
2002/07384	Focke W.W., Ricco I.M., Safanyetso S.O.	An alternative oxidant for a delay composition	Chemistry and related arts
2003/07155	Focke W.W., Ricco I.M.., Sefanyetso S.O.	An alternate oxidant for a delay composition - provisional	Chemistry and related arts
2004/05594	Focke W.W., Kalombo L., Del Fabbro O., Du Plooy C.C.	An alternate oxidant for a delay composition - provisional	Chemistry and related arts
2005/02785	Landman E.P., Focke W.W.	Carboxylic acid intercalated layered double hydroxides - provisional	Chemistry and related arts
9802366	Matthews E.H., Kleingeld M.	Solar Water Heater- provisional	Machine and related arts
2000/05670	Lane James Robert Timothy	Camera installation - provisional	Optics
96/1741	Snyman L.W., Aharoni H., Du Plessis M.	Improvements and additions to optoelectronic device	Optoelectronics and related arts
96/2478	Snyman L.M., Aharoni H., Du Plessis M.	Indirect band gap semi-conductor optoelectronic device	Optoelectronics and related arts
96/0355	Linde L.P., Lotter M.P.	Spread spectrum modulator and method	Optoelectronics and related arts
96/0570	Seekola D.L., Leuschner F.W.	Liquid crystal wavelength multiplexer	Optoelectronics and related arts
9703744	Seekola D.L.	Electronic game based on time ordered pattern sequencing	Optoelectronics and related arts
9810919	Lyndsay M.C., Snyman L.W.	CMOS optocoupler - provisional	Optoelectronics and related arts
9802273	Seekola D.L.	Light modulator for use in electronic and light projections - complete	Optoelectronics and related arts
9902315	Schoeman J.F., Joubert T-H.	Memory circuitry - provisional	Optoelectronics and related arts
9802352	Pretorius G.	Zirconia beneficiation - provisional	Chemistry and related arts
9802351	Pretorius G.	Zirconia production - provisional	Chemistry and related arts
9903815	De Wet J.W.	Beneficiation of zircon - provisional	Chemistry and related arts
2000/02797	De Wet J.W.	Method of treating zircon	Chemistry and related arts
96/8900	Solomon A., Hanekon J.J.	Apparatus for measuring a force exertable a group of muscles in the human body	Medical equipment, method and related arts

9900732	Visser C., Eksteen C.A.	Therapeutic seat cushion - provisional	Medical equipment and related arts
9801655	Scheffler T.B.	Water milk pasteurization indicator - complete	Machine and related arts
96/2568	Huyssen R.J.	Maudling of an article	Machine and related arts
9903725	Van Wyk S. L., Matthews E.H.	Method of making insulating material	Machine and related arts
2000/01349	Theron J., Venter S.N., Brozel V.S., Du Preez M.	Oligonucleotide primer a pcrex for the amplification of Vibrio cholerae in sample and a kit for use in the test	Biotechnology/genetics
2006/04517	Myburg A.A., Creux N.M., Ranik M.	Plant promoters	Biotechnology/genetics
2006/04012	Cloete T.E. Ramaite R.A.A., Mvhungu J.	Starter culture for foodstuff production	Food technology
2001/05583	Crewe R., Moritz R.F. A	Device and method for solid phase micro extraction and analysis - provisional	Machine and related arts
2003/07906	Stoffberg G.H., Van Rooyen M.W., Van der Linde M.J. Groenewald H.T.	Ecological management	Water, environment and related arts
2000/07167	Swarts J.C., Medlen C.E.	Substance or composition for the treatment of cancer – provisional	Drug design/pharmacology
2001/05357	Apostolides Z., Selematsela M.	Substance or composition for the treatment of viral infections - provisional	Drug design/pharmacology
2001/10527	Meyer J.J.M., Namrita L.	Naphtoquinone derivatives and their use in the treatment and control of tuberculosis – complete	Drug design/pharmacology
2002/08081	Medlen C.E., Albrecht C.	Substance or composition for use in a method of preventing diseases – provisional	Drug design/pharmacology
2004/06953	Eloff J.N.	Antimicrobial composition - provisional	Drug design/pharmacology
2005/08983	Henk H., Maree F.	Chimeric antigen and vaccines - provisional	Drug design/pharmacology
2005/09681	Eloff J.N., Havanokwavo C.	Antioxidant - provisional	Drug design/pharmacology
9704484	Medlen C.E., Anderson R., Huygens F.	Antimicrobial activity	Drug design/pharmacology
9904176	Meyer J.J.M., Nam rita L.	Treatment and control	Drug design/pharmacology

9906242	Meyer, Abbey J.J.M. Mathegka D.M.	Phloroglucinol compounds – provisional	Drug design/pharmacology
2002/03662	Neuse E.W., Medlen Constance Elizabeth	A substance or composition for the treatment of cancer – provisional	Drug design/pharmacology
2004/01220	Nothling J.O.	Diagnostic procedures – provisional	Diagnostic and related arts
9808787	Focke W.W.	Corrosion inhibitor – provisional	Chemistry and related arts
9704800	Van Vuuren J.S.	Combating cavitations in liquid flow system	Construction materials
2000/03521	Kearsley E.P., Mostert H.F.	Structural panel – provisional	Construction materials
2002/04586	Heyns P.S., Du Plooy F.N.	Vibration isolator – provisional	Construction materials
9902998	Bisschoff J., Focke W.W.	Flame retardant- provisional	Chemistry and related arts
2000/01834	Heydenrynch M.Dichael David.	Recovery of carbon values – provisional	Chemistry and related arts
2002/03002	Rohwer E.R., Venter A.	Chemical analysis of samples – provisional	Chemistry and related arts
9905408	Zdyb L., Coetser S.E.	Bioreactor – complete	Biotechnology/genetics
2003/09462	Van Vuuren S.J., Cloete T.E.	Method and apparatus for monitoring biofilm formation – provisional	Biotechnology/genetics
2004/03678	Verschoor J.A., Ramathudi S.D.G., Van Wygnaardt S.	Method for detecting mycobacterium infection - provisional	Chemistry and related arts

Table 2 (c): Distribution of patent applications by sector from 1996 to 2006, UCT

Patent No	Inventor(s)	Title	Sector
9705195	Millar R., Conkhin D. Hapgood J.C., Rumback E., Tooskie B., Illing N.	Human type II Gonadotrophin releasing hormone receptor	Biotechnology/genetics
9810988	Miller D.E., Towle N.R., Lang I.C.	Hardening low solute platinum alloys - provisional	Metals an metal products
9906265	Vicatos G., McCulley S.J., Aaron S.	Joint mobilization device – provision	Medical equipment, method and related arts
9906649	Sweet, Craig G., Wright B.A., Bradshaw D.J., Jonathan F.J., Cilliers Le Roux J.J., de Jager G.	Extraction of valuable minerals from mined ores - provisional	Separation technology
9907603	Chibale K.	Substance for treating African trypanosomiasis, chagas disease, leishmanisis and malaria	Drug design/pharmacology
2000/04924	Williamson C., Swanstrom R.I., Lynn M., Abdool K.S., Johnston R.E.	Process for the selection of HIV subtype C isolates selected HIV 1 subtype isolates their gene and-provisional	Biotechnology/genetics
2000/05937	Govindasamy M.S., Thomson J.A., Walford S.A., Parakattil K.P	Nucleic acid encoding polypeptide for conferring stress resistance - provisional	Biotechnology/genetics
2001/03874	Williamson A.L., Kate A.	Recombinant vaccine - provisional	Drug design/pharmacology
2001/03640	Lowenthal R.E., Ori L., Barak E.M.	Treatment of water - provisional	Water and environment
2001/03242	Vicatos G.	Fixation of an endoprostetic stem to a long bone - provisional	Medical equipment, method and related arts
2001/07675	Matsabisa M.G., Campbell W.E., Folb P.I.	Treatment of parasitic infections in humans and animals - provisional	Drug design/pharmacology

2001/09083	Vicatos G.	Total proximal femoral prosthesis – provisional	Medical equipment, method and related arts
2001/05981	Shepherd D.N., Mangwende T., Rybicki E.P., Thomson J.A.	Transgenic organism and method of producing same - provisional	Biotechnology/genetics
2001/07226	Varsani A., Williamson A.L., Rybicki E.P.	Vectors and/or constructs and transgenic organisms - provisional	Biotechnology/genetics
2001/07228	Varsani A., Williamson A.L., Rybicki E.P.	Pharmaceutical compositions a method of preparing and isolating said pharmaceutical composition - provisional	Drug design/pharmacology
2002/03957	Versani A., Rybicki E.P.	Chimaeric human papillomavirus16 L1 virus like particles and method for preparing the particles	Biotechnology/genetics
2002/04007	Vernon E.C., Doeschate K.I.T., Macey B.M.	Production of abalone - provisional	-
2002/01702	Steenkamp D.J..	A method of isolating thiol - provisional	Chemistry and related arts
2003/06966	Purdie N., Krouse J., Studer J., Marais A.	Direct serum lipids assays for the evaluation of disease states - complete	Immunology/pathology
2003/02508	Steenkam D.J., Gammon D.W., Hunter R., Mudzunga T.T.	Composition for the inhibition of actinomycetes - provisional	Biotechnology/genetics
2003/08774	Matsabisa M.G., Folb P.S., Smith P.J., Cambell W.E.	The treatment of parasitic infections in human and animals – provisional	Drug design/pharmacology
2004/01266	Rybicki E.P., Williamson A.L., Livio H.	Brak and feather disease virus sequences compositions and vaccines and the use thereof in therapy diagnosis and assays	Biotechnology/genetics
2004/02504	Williamson A.L., Rybicki E.P., Varsani A.	Vectors constructs and transgenic plants for HPV-11 and HPV-16 L1 capsid proteins - complete	Biotechnology/genetics
2004/02505	Rybicki E.P., Williamson A.L. Varsani A.	Pharmaceutical composition and a method of preparing and isolating said pharmaceutical compositions, and	Biotechnology/genetics

		use -complete	
2004/06157	Jonathan F.J., De Jager G., Hatfield D.P., Bradshaw D.J., Rapacz B.	The extraction of valuable minerals from mined ore - provisional	Separation technology
2004/04205	Williamson C., Abdool K.S., Bourn W., Van Harmelen J.H., Gray C.M.	HIV-1 subtype isolate regulatory/accessory genes and modifications and derivatives thereof - provisional	Biotechnology/genetics
2005/02088	Acharya R., Sturrock E.	Crystal structure of an angiotensin-converting enzyme (Ace) and uses thereof - provisional	Chemistry and related arts
2005/05300	Britton D.T., Harting M.	Semiconducting nanoparticles with surface modification - provisional	Optoelectronics and related arts
2005/05346	Williamson A.L., Halsey R.J., Tanzer F.L., Rybicki E.P.	Method for the production of HIV-1 gas virus-like particles – provisional	Biotechnology/genetics
2005/06779	Rautenbach M.W. Manya U.I., Hoppe H.C.	Pharmaceutical composition for treating malaria – provisional	Drug design/pharmacology
2005/03454	Williamson A.L. Malcolm M.L.J., Rybicki E.P.	A floatable facility - provisional	-
2005/04364	Chibale K., Sturrock E., Nchinda A.	Angiotensin-I-converting enzyme (Ace) inhibitors	Biotechnology/genetics
2005/09021	Kelleher J.M.	A traceability framework and process - provisional	-
2005/09035	Williamson A.L., Halsey R.J., Tanzer F.L., Rybicki E.P.	Chimaeric HIV-1 subtype c gas virus-like particles – provisional	Biotechnology/genetics
2006/01124	Tapson J.G.	-	Separation technology
2006/01520	De Jager G., Forbes G.	A Method of determining the size distribution of bubbles in the froth in a froth flotation process - provisional	Separation technology

Table 2 (d): Distribution of patent applications by sector from 1996 to 2006, WITS

Patent No	Inventor(s)	Title	Sector
2002/03842	Indness P.	Electronic placard – provisional	Machine and related arts
2005/02558	Rodolph M.J.	Mobile facility – provisional	Machine and related arts
2005/02593	Laquet B.M.	Remote operated rain shield – provisional	-
2005/08270	Van Breda S.M., Damir L., Weseela M.	Improvements in the scrubbing of fumes - provisional	-
2005/09619	Gohnert M.	Improvement in block floor slabs	Construction materials
2005/10427	Mendelow B.V., Capovilla A., Napier G.B.	Peptide – provisional	Chemistry and related arts
2006/02532	Gray M.V	Process and bioreactor for the simultaneous conversion of primary hydrocarbons into biohydrogen, bioethanol and bioplastics - provisional	Biotechnology/genetics
2006/02959	Gray M.V., Straker C., Nainisha M.B.	A bioreactor system for the continuous production of conical spores – provisional	Biotechnology/genetics
2004/08571	Ripamoti U.	Composition for stimulating de novo bone induction - complete	Medical equipment, method and related arts
2005/06651	Kemp A.R., Dundu M.	Building structure – provisional	Construction equipment
9704872	Indrasen M., Danckwerts P., Salima E., Waller D.D.	Pharmaceutical product	Drug design/pharmacology
2001/03997	Medlen C.E., Neuse E.W.	Substance or composition for the treatment of cancer – provisional	Drug design/pharmacology
2005/07545	Patel R., Viness P., Danckwerts M.P.	Oramucosal pharmaceutical dosage form - provisional /complete	Drug design/pharmacology
2005/09618	Gray M.V.	Treatment of waste water - provisional/complete	Water and environment
2004/05108	Pole S., Cukroska E.	The removal of coatings from bones - provisional	Chemistry and related arts
2004/07676	Glasser D., Hildebrandt D., Hausberger B.	Production of synthesis gas and derived products	Chemistry and related arts
2005/07818	Keller M., Miller A., Natori Y., Carmona S., Arbuthnot P.	Composition for modulating gene expression in a liver cell – provisional	Biotechnology/genetics

2005/03784	Kabamba Bankoledi A.	A method of inhibiting HIV replication - provisional	Biotechnology/genetics
2005/06275	Jandell I.R., Hove M.	Surge protection devices – provisional/complete	Machine and related arts
2005/07376	Jandell I.R., Michalopoulos A., Van Coller J.M., Beutel A.A.	Improvements in spark gap switching devices - provisional	Machine and related arts
2004/08357	Sideras-Haddad E.	A method of dating biological material - complete	Nuclear technology
2000/00148	Luyks S., Leu S.T.	Embrittlement control in hard metals	Metals and metal products
2005/05200	Campbell I., Reid R.G.	A novel submarine hull - provisional	Construction materials
2005/09325	Meyer L.C.R., Salter G.D.	Portable intra-artificial blood-pressure monitor and logger - provisional	Medical equipment, method and related arts
2005/09323	Meyer L.C.R.	Enhancement of blood and tissue oxygenation - provisional	Medical equipment, method and related arts
2005/06233	Makokha A.B., Moys M.H.	Replaceable lifter for a mill liner - provisional	Separation technology
2003/09066	Maaza M.	A novel method of preparing nano particles - provisional	Chemistry and related arts
2004/02010	Sellschop J.P.F., Connel S.H.	Detection of diamonds - provisional	Nuclear technology
2004/02449	Sellschop J.P.F., Connel S.H.	Athermal resonant annealing of selected defects in diamond - provisional	Nuclear technology
2005/09324	Tshilidzi M., Milton R.D., Starfield D.M.	Improvements in coded aperture nuclear medicine - provisional	Medical equipment, method and related arts
2005/07594	Bower G.	Pesticide	Chemistry and related arts
2003/09067	Maaza Malik	Improvements in solar cells - provisional	Machine tools
2005/07377	Meyer L.C.R., Duncan M.	Animal immobilization - provisional	Medical equipment, method and related arts
2005/03438	Esayegbemu I.S.	Swirled fluidized bed chemical vapor deposition reactor	Chemistry and related arts
2004/07676	Nam T., Keddy R., Assiamah M.	Improvement in radiation detectors - provisional	Nuclear technology
2005/10110	Nam T., Keddy R., Assiamah M.	Ionizing radiation detector - provisional	Nuclear technology

2004/04983	Geyer J.A, Nam T., Candy G.P.	Improvements in the measurement of radioactive carbon isotope in carbon dioxide - provisional	Nuclear technology

Table 2 (e): Distribution of patent applications by sector from 1996 to 2006, TFS

Patent No	Inventors	Title	Sector
9707175	Prinsloo G., Snader, R., Pieterse, P, Britton, T.	-	-
2001/06869	Hertzog P.E.	Intersection control system - complete	Optoelectronics and related arts
2001/07053	Olivier J.H., Greyling C.D.W.		-
2003/07191	De Beer D.J., Diegaardt D.M., Ludrick J.B., Booysen G.J.	A container - provisional	Machine and related arts
2004/03106	De Beer D.J., McGregor O.J., Strauss J.A.	Cutting system - provisional	Machine and related arts
2004/03105	Van Der Walt J.G., De Beer D.J.	A treatment system	Machine and related arts
2005/06738	Van Der Walt J.G., De Beer D.J.	A method of radiating an object - provisional	Nuclear technology
2005/06739	McGregor O.J., Strauss J.A., De Beer D.J.	Prototype manufacturing system - provisional	Machine and related arts

Table 2 (f): Distribution of patent applications by sector from 1996-2006, UFS

Patent No	Inventors	Title	Sector
2002/08176	Swarts J.C.	Crown ether derivatives - provisional	Chemistry and related arts
2005/04041	Du Preez J.C., Van Rensburg E.	Microorganism and its uses	Biotechnology/genetics

Table 2 (g): Distribution of patent applications by sector from 1996 to 2006, UNNW

Patent No	Inventor(s)	Title	Sector
9904175	-	-	-
2004/03699	Lemmer N.T., Roberts J.G., Kasaini H.	Fluorescent lamp disposer - provisional	-
2006/01725	Grobler A.F.	Plant support formulation, vehicle for the delivery and translocation of physlocation of phytologically provisional	-
2006/0417	Visser B., Kruger P.P.	Ignition system - provisional	Chemistry and related arts
2005/10346	Jonker A.S., Bosman J.J.	Controlling the boundary layer of an airfoil - provisional	Construction materials
2002/02314	Vorster S.W., Waaders F.B., Geldenhuys A.J.	Corrosion inhibitor - complete	Chemistry and related arts
2006/01441	Northwest university	The treatment of halitosis	Drug design/pharmacology
2003/03496	Visser B., De Klerk M.A., De Jager O..	Oxygen Meter - provisional	Machine and related arts
2004/07575	Kasaini H.	Recovery of one or more platinum group metals from a source of one or more platinum group metals - provisional	Separation technology
2004/02219	Van Rensburg L.	Medium and method for treating tailings of mining activities - complete	Separation technology
2001/04418	Vorster H.H., Tomlinson A.W.	Anorexic composition - provisional	Food technology
9905930	Visser B., De Jager O.C.	Low noise amplifier arrangement - provisional	Optoelectronics and related arts
2000/00361	Visser B., De Jager O.C.	Air moving apparatus - provisional	Optoelectronics and related arts
2000/00887	Visser B.	Drive circuit and method for mosfet	Optoelectronics and related arts

2002/02059	Visser B., De Jager O.C.	Low noise amplifier arrangement - provisional	Optoelectronics and related arts
2001/07013	Visser B.	Method and apparatus for producing ozone	Chemistry and related arts
2005/07156	Van Rensburg L., Du Plessis T.A., Seute H.	Plant protective cover - provisional	-
2004/01867	Breytenbach J.C., Maritz J., Yeates C.A., Krieg H.M.	Purification of chemical compounds - complete	Separation technology

Table 2 (h): Distribution of patent applications by sector from 1996 to 2006, TUT

Patent No	Inventor(s)	Title	Sector
9906868	Gordon F.Z.	Method of detecting incisal and occlusal height in a patient's jaws	Diagnostics and related arts
2002/02819	Botha B.M.	Method of monitoring a supercritical fluid extraction process - provisional	Chemistry and related arts
2003/01730	Du Plessis M., Snyman L.W., Aharoni H.	Chargement of light emission from silicon avalanding functions by means of current density confluerement techniques - provisional	Optoelectronics and related arts
2003/08363	Snyman L.W.	High definition modulatable Si Led matrix - provisional	Optoelectronics and related arts
2005/03254	Fay T.H., Allanson H.K., Joubert S.V.	Wheel - provisional	Machine and related arts

Table 2 (i): Distribution of patent applications by sector from 1996 to 2006, UJ

Patent No	Inventor(s)	Title	Sector
9905561	Meyer J.P., Coetzee H.	Tube in tube heat transfer with enhanced heat transfer – provisional	Machine and related arts
2001/05170	Moreno A., Bronwyn M.	Control system for level crossing- provisional	Machine and related arts
2001/08715		Training equipment – complete	-
2001/09477	Swart P.L., Laquet B.M., Chtcherbakov A.	Optical fibre pressure sensor – provisional	Optoelectronics and related arts
2002/04958	Moreno A., Bronwyn M., Berman K., Sihlahli D., Sihlahli L.	Pulp beater – complete	Machine and related arts
2003/06316	Albert V.	A method for preparing a semiconductor film of a group I-III-IV quaternary or higher alloy -provisional	Chemistry and related arts
2003/02585	Chtcherbakov A..A., Swart P.L., Kruger L., Van Wyk A.J.	Optical system and method for monitoring variable rotating member – provisional	Optoelectronics and related arts
2004/02497	Alberts V.	Group I-III-IV quartenary or higher alloys - provisional	Chemistry and related arts
2005/06497	Vermeulen M.	Accessory fro drill	Machine and related arts
2005/08065	Swart P.L.	A fibre optic sensor for measurement of refractive index – provisional	Optoelectronics and related arts
2005/08066	Swart P.L., Van Brakel A., Chtcherbakov A.A., Gavriilovich S.M.	Optical device for measuring fluid pressure – provisional	Optoelectronics and related arts
2005/03824	Thompson A.L.T.	Anthropometry apparatus method and system – provisional	Machine and related arts
2006/02100	Van Wyk J.E.	Water supply terminal point – provisional	Hydraulics

Table 3: Distribution of patent applications by sector

Sector	Number of patent applications			
	Product development		Process development	
	CIPRO	Foreign	CIPRO	Foreign
Optoelectronics and related arts	7	4	16	2
Chemistry and related arts	8	5	20	13
Separation technology	1	-	18	5
Metal and metals products	8	-	9	-
Biotechnology/genetics	20	4	26	5
Drug/pharmacology	24	6	2	1
Immunoassays and/or pathology	1	-	3	3
Machine and related arts	7	-	10	-
Optics	-	-	1	1
Medical equipment, methods and related arts	5	-	6	-
Water and environment	-	-	4	-
Food technology	-	-	4	2
Sea transportation	3	1	-	-
Diagnostics and related arts	-	-	7	-
Nuclear technology	1	-	5	2
Construction/building	5	-	1	-
Acoustics	5	-	-	-
Others	11	-	3	

Table 3 summarises the distribution of domestic and foreign patent applications by technical sectors. Data on foreign applications (i.e. patent filed abroad) obtained from Table 15 were inserted in this table to create a perspective on the South African universities' patent practice. The sector of biotechnology/genetics had the highest number of applications. This might be one outcome of the integration of the departments of biochemistry, microbiology, genetics, and biotechnology, which happened in most South African universities after the year 2000. It might also be another outcome of vast physical and financial resources devoted to this field by the government in its efforts to address the issues of AIDS and related diseases. Only nine out of the 50 domestic applications were filed abroad.

The sectors of chemistry and related arts had 28 domestic applications and 18 of those were filed abroad. The sector of drug/pharmacology had 24 domestic applications and only seven of those were filed abroad. The optoelectronics and related arts had 23 domestic applications but only six were filed abroad. The machine and related arts sector had 17 domestic applications and none was filed abroad. The separation technology sector had 19 domestic applications and only five were filed abroad. The sector of metals and metal products had 17 domestic applications but none was filed abroad. The medical equipment, method and related arts sector had 11 applications but none was filed abroad. The sector of nuclear technology had six domestic applications but only two were filed abroad. Other sectors had small number of applications. The over-all number of patents filed abroad was small, probably due to limited financial resources allocated to TTO.

Table 4: Distribution of number of patent applications by 5 South African universities from 1996 to 2006

University	UP	SUN	UCT	WITS	UNNW	UJ	TUT	UFS	UKZN	TFS
Total number of applications	66	56	36	37	18	15	5	3	3	8

Table 4 summarises the distribution of patent applications by all the universities actively involved in the patenting activity for the last 10 years. The University of Pretoria had the highest number of applications and was followed by Stellenbosch University. The performances of the University of Cape Town and the University of Witwatersrand were very close and preceded that of the University of the NorthWest.

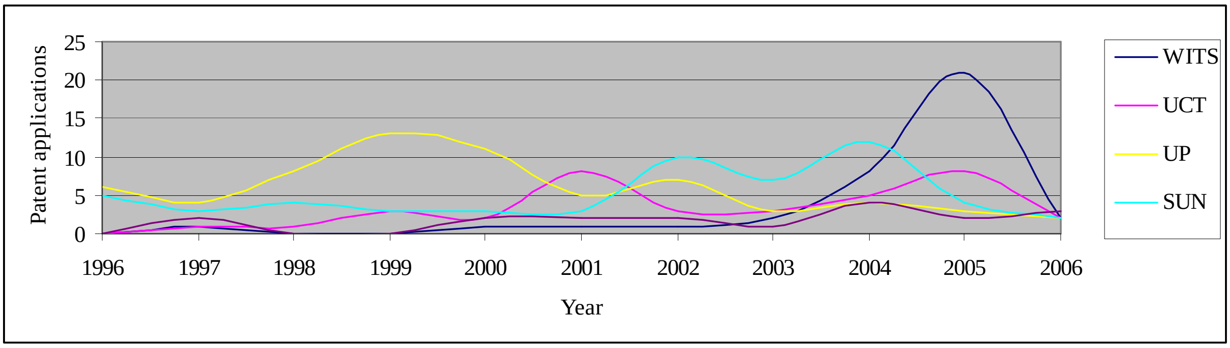

Figure 16: Patent application profiles at CIPRO of five South African universities, the most active in patent activity, from 1996 to 2006

Figure 16 shows the trends of the inventive activity for five South African universities - the most active in patent activities (i.e. those having more than 16 patents over the past 10 years). From 1996 to 2001 the number of applications of UP was the highest (with about 13 in 2000) and dropped thereafter. The other universities with less than five applications started increasing from 2002 onwards. WITS had the highest number of applications (about 20) in 2005 and was followed by UCT (with about eight applications), SUN (with about four applications), UP (with three applications), and UNNW (with two application). In 2004, SUN led with (with about 12 applications) and was followed by Wits (with eight application), UCT (with five applications), UP and UNNW with four applications each. UNNW inventive capacity did not increase enough during that period.

Table 5: Distribution of patent applications by department and inventor's industry work experience, UP

Department	Number of applications	Inventor worked in industry		No responses
		Yes = 1	No = 0	
Biochemistry	3	2	0	1
Botany	4	4	0	0
Chemical Engineering	10	8	-	2
Chemistry	1	1	0	0
Civil Engineering	2	2	0	0
EEC* Engineering	11	11	0	0
Educational Psychology	1	1	-	0
Entomology	1	1	0	0
Mechanical Engineering	5	5	0	0
Metallurgical Engineering	7	3	-	4
Microbiology	5	4	0	1
Pharmacology	4	4	0	0
Physics	2	2	2	0
Radiation Oncology	1	-	0	1
Veterinary Science	3	3	0	0
Others	6	-	-	6
Total	66	51	0	15

*(EEC Engineering) denotes Electrical, Electronic and Computer Engineering

Table 5 summarises the distribution of patent applications by departments and the inventors' work history for the University of Pretoria. The over-all number of applications was 66. The faculties and names of inventors for six patent applications (termed others) were not accessible. The CVs of nine inventors were not available. For the remaining 60 patent applications, 51 inventors had previous industry work experience. Only one inventor without previous industry work experience had an application. The department of Chemical Engineering had 10 applications and preceded the department of Electrical, Electronic and Computer Engineering, which had 11 applications. The departments of Metallurgical and Mechanical Engineering had each seven applications. The departments of Microbiology had five applications, and Pharmacology had four. The departments of Veterinary Science and Biochemistry had three applications each and the departments of Physics and Radiation Oncology had two each. The departments of Chemistry and Educational Psychology were the last with only one application each.

Table 6: Distribution of patent applications by department and inventor's industry work experience, UCT

Department	Number of applications	Inventor worked in industry		No response
		Yes = 1	No = 0	
Biochemistry	1	1	0	0
Biomedical Engineering	3	3	0	0
Chemical Engineering	5	3	-	2
Chemical Pathology	3	3	0	0
Chemistry	1	1	0	0
Civil Engineering	1	1	0	0
Electrical Engineering	1	1	0	0
Internal medicine	3	3	0	0
Molecular and Cell Biology	11	9	-	2
Pharmacy	4	4	0	1
Physics	2	-	1	1
Others	1	-	-	1
Total	36	27	1	7

Table 6 summarises the distribution of patent applications by departments and the inventors' work history for the University of Cape Town. The over-all number of applications was 36. The faculty and name of an inventor for one patent application (termed others) were not accessible. The CVs of five inventors were not obtained. For the remaining 35 applications, 27 inventors had previous industry work experience. Only one inventor without industry work experience had an application. The department of Molecular and Cell Biology displayed the highest performance with 11 applications and preceded the department of Chemical Engineering, which had five applications. The departments of Biomedical Engineering (Biomechanical Engineering) had three applications and Pharmacy had four. The departments of Chemical Pathology and Internal Medicine had three applications each. The department of Physics had two applications. The departments of Biochemistry, Civil Engineering and Electrical Engineering had one application each.

Table 7: Distribution of patent applications by department and inventor's industry work experience, SUN

Department	Number of applications	Inventor worked in industry		No responses
		Yes = 1	No = 0	
Biochemistry	4	4	0	0
Chemical Engineering	2	2	0	0
Chemistry	10	10	0	0
Civil Engineering	1	1	0	0
EE* Engineering	10	7	-	3
Forestry and Wood Science	3	-	-	3
Mechanical Engineering	3	1	-	2
Medical Virology	2	2	0	0
Microbiology	14	13	-	1
Others	7	-	-	7
Total	56	40	0	16

*(EE Engineering) denotes Electrical and Electronic Engineering

Table 7 summarises the distribution of patent applications and the inventors' work history for Stellenbosch University. The over-all number of patent applications was 56. The faculties and names of inventors of seven patents applications (termed others) were not accessible. The CVs of 16 inventors were not accessible. For the remaining 40 patent applications, all inventors with previous industry work experience had patent applications. No inventors without previous industry work experience had a patent application. The department of Microbiology showed the highest inventive capacity with 14 applications and preceded the department of Electrical and Electronic Engineering that had 10 applications. The departments of Chemistry had 10 applications and Biochemistry had four. The departments of Forestry, Wood Science and Mechanical Engineering had three applications each. The departments of Chemical engineering and Medical Virology had each two applications. The department of Civil Engineering had only one application.

Table 8: Distribution of patent applications by department and inventor's industry work experience, WITS

Department	Number of applications	Inventor worked in industry		No response
		Yes = 1	No = 0	
Chemical Engineering	5	5	0	0
Chemistry	1	-	-	1
Civil Engineering	2	2	0	0
EI* Engineering	2	2	0	0
Mechanical Engineering	2	-	-	2
Pathology	1	1	0	0
Medical Genetics	2	2	0	0
Molecular and Cell Biology	4	1	1	2
Pharmacy	2	2	0	0
Physics	9	8	-	1
Physiology	1	-	-	1
Others	6	-	-	6
Total	37	23	1	13

Table 8 summarises the distribution of patent applications and the career history of inventors for the University of the Witwatersrand. The over-all number of applications was 37. The faculties and names of inventors of six patent applications (termed others) were not accessible. The CVs of 13 inventors were not accessible. For the remaining 24 patent applications, 23 inventors had previous industry work experience. Only one inventor with no previous industry work experience had an application. The department of Physics displayed the highest inventive capacity with nine patent applications and preceded the department of Chemical Engineering, which had five. The department of Molecular and cell Biology had four applications. Chemistry, Pathology and Physiology had one application each. The departments of Pharmacy, Mechanical Engineering, Civil Engineering, Medical genetics and Electrical and Information engineering had two patent applications each. The departments of Orthopedics and Physiology had one application each.

Table 9: Distribution of patent applications by department and inventor's industry work experience, UNNW

Department	Number of applications	Inventor worked in industry		No response
		Yes = 1	No = 0	
Chemical Engineering	5	3	-	2
Chemistry	2	1	-	1
Civil Engineering	1	1	0	0
Electrical Engineering	7	7	0	0
Nutrition	1	1	0	0
Others	2	-	-	-
Total	18	13	0	3

Table 9 summarises the distribution of patent applications and the career history of the inventors for the University of the NorthWest. The total number of application was18. The faculties' details and names of inventors for two patents (termed others) were not accessible. The CVs of three inventors were not accessible. Inventors of the three remaining applications had previous industry work experience. No inventor without work experience had an application. The department of Electrical Engineering had the highest inventive capacity with seven patent applications and preceded the department of Chemical Engineering, which had five applications. The department of Chemistry had two applications and was followed by the departments of Civil Engineering and Nutrition, which had one each.

Table 10: Distribution of patent applications by faculties (Engineering, Science and Health), by university

Faculty	Number of applications				
	SUN	UP	UCT	WITS	UNNW
Science	28	16	15	15	3
Engineering	16	34	11	11	13
Health	2	6	10	6	1
Total	46	56	36	32	17

Table 10 summarises the inventive performance of faculties of Science, Engineering and Health of the five universities under investigation on the inventive capacity. In the faculties of Science, Stellenbosch University had the highest inventive capacity with 28 patents applications and preceded the University of Pretoria which had 16. The University of the Witwatersrand and the University of Cape Towh had 16 applications each. The University of the North West had three applications. The University of Pretoria led in the faculties of Engineering with 34 applications and preceded Stellenbosch University, which had 16 applications. The University of the North West had 13 and preceded the University of Cape Town and the University of the Witwatersrand had 11 applications each. The University of Cape Town, which had 11 applications, dominated the faculty of Health. The University of the Witwatersrand had seven applications, the University of Pretoria six, Stellenbosch University two and the University of the North West had one.

Table 11: Control group 1

Number of professors	Inventor worked in industry		Number of applications
	Yes = 1	No = 0	
20	0	20	0
10	7	3	7

Table 11 summarises the inventive performance of the control group. The findings support strongly the hypothesis that previous working experience in the private sector affects inventive activity. This work first investigated the inventive activity of five South African Universities through patent applications to the South African patent office. CIPRO provided a more detailed picture of South African inventive activities than USPTO. The University of Pretoria had the highest over-all number of patent applications and preceded the University of Stellenbosch, the University of Cape Town, the University of the Witwatersrand and the University of the North West.

The University of Pretoria's over-all performance of 56 patent applications with regard to the faculties of Science, Engineering and Health, was dominant and preceded that of Stellenbosch University, which had 46. The University of Cape Town had 36 applications, the University of the Witwatersrand 32 and the University of the NorthWest 17. The faculty of Science of the Stellenbosch University had the highest inventive capacity with 31 patents among the institutions considered. Two departments, including Microbiology with 14 applications, and Chemistry with 10 displayed the highest performances in this faculty.

The University of Cape Town followed Stellenbosch University in Science with 20 applications. Most of those applications came from the departments of Molecular and Cell Biology, which had 11 applications, and Chemistry had four.

The University of the Witwatersrand fell below the University of Cape Town with 18 applications. The major portion of the University of the Witwatersrand's applications was from

the departments of Physics, which had nine applications, and Molecular and Cell Biology, which had four.
The University of Pretoria had 16 applications, which were mainly from Microbiology with five, Botany with four and Biochemistry with three. Lastly, the University of the NorthWest had two applications, both from Chemistry. The University of Pretoria led in the faculty of Engineering with 34 applications. The major part of these applications was from the departments of Chemical Engineering, which had 10 and Electrical Engineering with 11. The department of Mechanical Engineering had five applications and the department of Metallurgical Engineering had seven. Stellenbosch University followed the University of Pretoria with 18 applications, most of these originated from the departments of Electrical and Electronic Engineering, which had 10, and Mechanical Engineering had three.

The University of Cape Town came after Stellenbosch University with 13 applications. The major part of these applications was from the departments of Chemical Engineering, which had five applications and Biomedical Engineering (Biomechanical Engineering) with three.

The University of the North West had 13 applications, the major part of them originated from the departments of Electrical Engineering (seven), and Chemical Engineering (five). The University of the Witwatersrand had 12 applications, the major part of them originating from the departments of Chemical Engineering (five), and Mechanical Engineering (two). The faculty of Health was dominated by the University of Cape Town with 11 applications, the major portion of them coming from the departments of Pharmacy (two) and Chemical Pathology (one). The University of the Witwatersrand followed the University of Cape Town, which had seven applications, mostly from the departments of Pharmacy (two), and Genetics (two). The University of Pretoria came after the University of the Witwatersrand with six mainly from the departments of Pharmacology (four) and Radiation Oncology (one). Stellenbosch University had two applications originating from the departments of Medical Virology and the University of the North West had one application.

The dramatic increase in inventive activities at WITS in 2005 and the decrease of such activities at UP from 2002 as well as the big differences in inventive activities amongst institutions and departments are subject for further research.

A preliminary analysis of inventive activities of the five South African institutions considered in this study at the USPTO portrayed an extremely low coverage of patenting activities. This suggests that CIPRO provided a more detailed picture of South African inventive activities compared to that of USPTO. Patent applications at national level can provide a broader picture of innovative or inventive activities within countries.

The over-all performance of South Africa, however, over the period of 10 years, which included fewer than 300 patents, is far below that of other countries. Italian universities' patent applications totalled 1 475 from 1978 to 1999 (Balconi et al. 2004:127) and Taiwanese 1 009 from 1997 to 2001 (Chang et al. 2006:199). The South African higher education authorities and the universities' administrations should consider the enactment of appropriate incentives in order to improve the inventive outputs of the country's universities. Important mechanisms that should receive considerable attentions would include, for example:

- Building a strong entrepreneurial capacity by, for example:

    1. Employing CEOs, former CEOs or people with business mindset in faculties, departments and technology transfer offices
    2. Raising the awareness of the market needs and dynamics, promoting business and managerial cultures and skills amongst researchers through workshops, etc.

- Strengthening the management capabilities of TTOs, promoting effective links with the private sector, setting up research joint ventures, collaborating with technology incubators, adopting royalty and equity policies that stimulate researchers to invent and innovate are some examples in this direction.

In the second leg of the investigation, it appeared that industrial work experience enhanced inventive capacity as measured by patent applications. Inventive capacity of professors endowed with industry experience typically differed from that of professors whose entire career was in academia. Prior industry working experience of scientists working at university appeared to be an effective mechanism (through which knowledge can be transferred from industry to university) to increase the university's inventive activities**.** The evidence displayed by the test of the control group seems to be in line with the general observations of the strong association between industry work experience and patent applications. These findings strongly support the hypothesis that previous working experience in the private sector positively affects inventive activity.

The South African patent applications from 1996 to 2006 at CIPRO for all the institutions of higher learning amounted to 244. The University of Pretoria had the highest patenting activities with 66 applications (27%) and preceded the University of Stellenbosch, which had 56 (23%). The University of Cape Town had 36 (15%); the University of the Witwatersrand, 37 applications (15.2%) and the University of the NorthWest was the last with eighteen applications (7.4%). From the above mentioned sample of domestic patents, seventy patents filed at USPTO, EPO and/or WIPO listed South African professors as inventor(s) or co-inventor(s).

Table 12: Distribution of patent applications by departments from 1996 to 2006 and the NRFratings

Department	Number of applications and NRFratings (in brackets - Yes = 1, No = 0)				
	UP	UCT	WITS	SUN	UNNW
Biochemistry	3 (3)	1 (1)	-	4 (4)	-
Biomedical Engineering	-	3 (3)	-	-	-
Botany	4 (4)	-	-	-	-
Chemical Engineering	10 (10)	5 (5)	5 (5)	2 (2)	5 (5)
Chemical Pathology	-	3 (3)	-	-	-
Chemistry	1 (1)	1 (1)	1 (1)	10 (10)	2 (2)
Civil Engineering	2 (2)	1 (1)	2 (2)	1 (1)	1 (1)
EEC* Engineering	11 (11)	1 (1)	2 (2)	10 (10)	7 (7)
Educational Psychology	1 (1)	-	-	-	-
Entomology	1 (1)	-	-	-	-
Forestry and Wood Science	-	-	-	3 (3)	-
Internal Medicine	-	3 (3)	-	-	-
Mechanical Engineering	5 (5)	-	2 (2)	3 (3)	-
Medical Genetics	-	-	2 (2)	-	-
Medical Virology	-	-	-	2 (2)	-
Metallurgical Engineering	7 (7)	-	-	-	-
Microbiology	5 (5)	-	-	14 (14)	-
Molecular and Cell Biology	-	11 (11)	4 (4)	-	-
Pharmacology	4 (4)	4 (4)	2 (2)	-	-
Physics	2 (2)	2 (2)	9 (9)	-	-
Physiology	-	-	1 (1)	-	-
Nutrition	-	-	-	-	-
Radiation Oncology	1 (1)	-	-	-	1 (1)
Veterinary Science	3 (3)	-	-	-	-
Others [a]	6	1	6	7	2
Total	66 (60)	36 (35)	37 (31)	56 (49)	18 (16)

[1] *(EEC Engineering) denotes Electrical, Electronic and Computer Engineering. a indicates that the details of inventors have not been obtained. Figure in brackets denotes the NRFrating.

Table 12 summarises the distribution of patent applications by department and the academic performances of inventors as measured by their visibility on the NRFrating database, for the five universities under investigation. The NRFrating/evaluation process is led by national and international peers/reviewers and is based primarily on the quality of the research outputs during the past seven years. Publications considered in this study were those covered by the ISI.

Inventors and non-inventors published in the journals that had the same impacts. All inventors were NRF-rated. This means that peer reviewers collectively acknowledged the contribution of the inventors to academic progress (Lubango & Pouris 2008a). This contribution includes the publications of scientific articles, technical reports, patents, books, teaching materials, training graduate students, collaboration with other scholars from academia, government, etc. A similar conclusion could be drawn from Table 13, which outlines the NRFratings, or scores, of an experimental group made of inventive professors.

Table 13: NRFrating of inventive professors

Rank	**Number of professors**
A-rated	3
B-rated	17
C-rated	10
P-rated	-
Y-rated	-
L-rated	-
Total	30

These ratings reveal that the inventive professors were also established researchers and internationally recognized as being independent, leading scholars.

The publication and co-publication profiles for the two groups of professors from 1996 to 2006 (in peer-reviewed journals of the same impacts) were also compared.

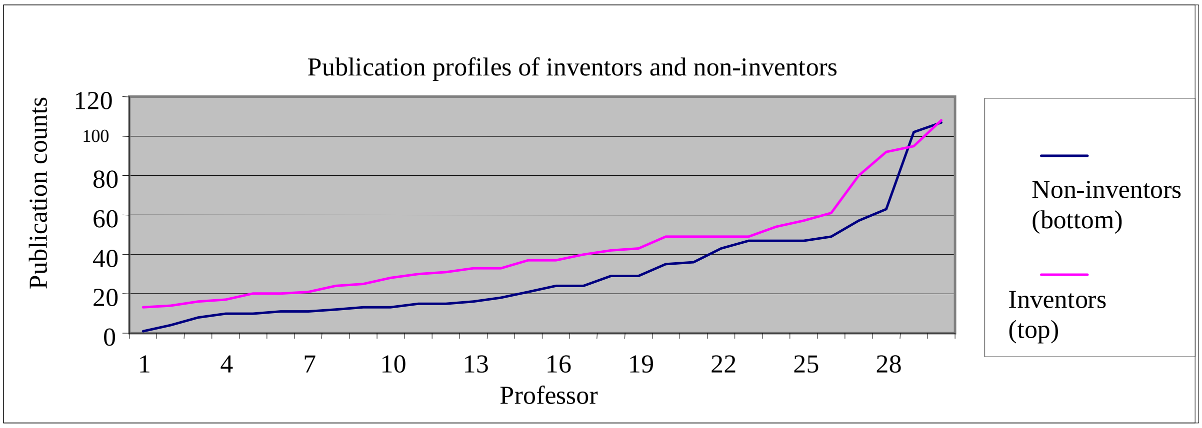

Figure 17: Publication profiles of inventive and non-inventive professors

Figure 17 summarises the publication profiles of inventive and non-inventive professors.

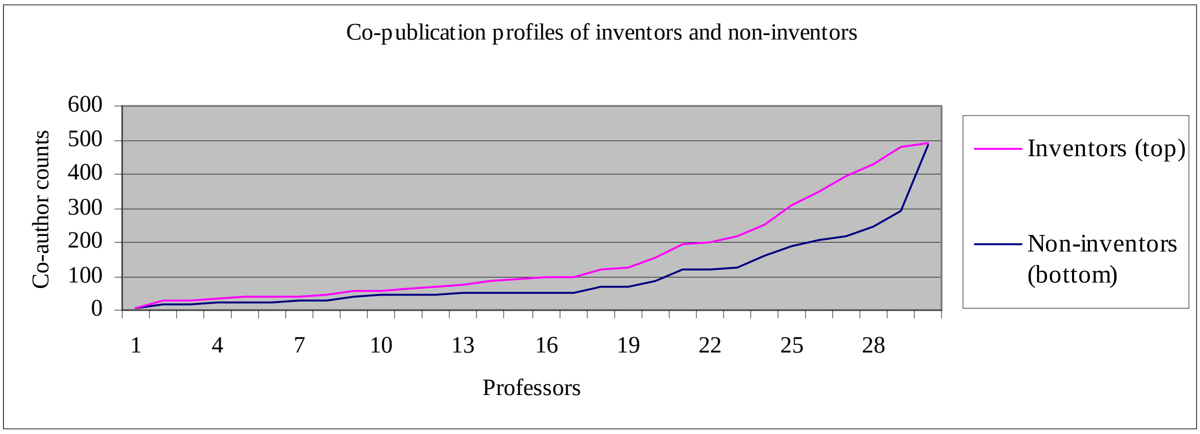

Figure 18: Co-publication profiles of inventive and non-inventive professors

Figure 18 summarises the co-publication/co-authorship profiles of inventive and non-inventive professors. The publications and co-publication profiles outlined in Figures 17 and 18 had very similar trends, though the performances of inventors were higher than the non-inventors.

The publication performances of inventive and non-inventive professors were then modelled using Poisson regression model, with the Log as a link function.

Table 14: Parameters estimates for the model

PARAMETERS	ESTIMATES	P-VALUE
Intercept	3.1166	< 0.001
Inv	0.1460	0.0029
F	0.1447	0.0128
A	0.0029	0.9721
L	0.0027	0.001

Table 14 summarises the parameter estimates for the model and their levels of significance (p-values). The group of inventors comprised 15 professors from the faculties of engineering and 15 from the faculties of science. The group of non-inventors comprised 21 professors from the faculties of science and nine from the faculties of engineering. All the results point to: (i) a strong positive effect of the inventiveness on the publication performance (p-value: 0.0029) (ii) a strong positive effect of faculty orientation on the publication performance (p-value: 0.0128) (iii) a very weak effect of activity on the publication performance (p-value: 0.97721) and (iv) a strong positive effect of collaboration on publication performance (p-value: <0.0001).

5.2 USPTO, WIPO and EPO based patent-paper pair data set

A population of about 70 patents was collected from the USPTO and WIPO databases from 1996 to 2006. Fifty-eight of those patents formed pairs, i.e. the same knowledge disclosed in a patent also appeared in a paper and thus formed patent-paper pairs (see Appandix A). The knowledge disclosed in pairs was generally cited in patents and open literature suggesting that far from being in conflict, patent and paper cross-fertilised and supported each other.

All those patents listed one or more South African university professors as inventors/co-inventors, or assignees or co-assignees. The bibliographic data revealed that: (1) most patents were assigned to South African universities (2) some patents were licensed by South African universities to local and/or to foreign industries (3) some other patents were applied by South African professors individually.

Only the contents of 53 pairs were accessible and analysed.

Table 15: Citation characteristics of USPTO patent-based pairs: backward and first generation

Focal patent				Focal journal article			
Total number 30				Total number 30			
Backward citation		Forward citation		Backward citation		Forward citation	
Article	Patent	Article	Patent	Article	Patent	Article	Patent
0	219	0	41	511	0	251	0

Table 16: Citation characteristics of WIPO patent-based pairs: backward and first generation forward citation profiles

Focal patent				Focal journal article			
Total number 23				Total number 22			
Backward citation		Forward citation		Backward citation		Forward citation	
Article	Patent	Article	Patent	Article	Patent	Article	Patent
226	64	0	0	472	0	183	0

Table 15 and table 16 summarise the citation characteristics of pairs obtained from the USPTO and WIPO databases, respectively. Generally, the USPTO patents cited patents heavily and were mostly cited by patents from industry. The corresponding articles only cited articles and received citations mostly from other articles. These patents scarcely cited articles. The focal patents published at WIPO and/or EPO cited more articles than patents. The corresponding focal articles cited articles exclusively and were mostly cited by articles. It could reasonably be argued that the industrial applicability requirement for granting a patent, which carries more weight at the USPTO than at EPO, constrained inventors and attorneys to citing more patents than articles. The following analysis focuses on patents applied at USPTO.

5.3 Extended case studies: polymer membranes, signal processing, genetics, and mineral separation pairs

An in-depth investigation of four pairs out of the 58 pertaining to polymer membrane (for water purification), circuit for generating minimum supply voltage, genetics and mineral processing was carried out.

5.3.1 Pair 1: polymer membrane for water purification device

The knowledge disclosed from this pair detailed the composition and the use of a polymer membrane in a water purification device. The focal patent filed at the USPTO in 1995 was owned in 1997 by the Water Research Commission that usually outsources research in South African universities. The focal article was published in 1996 in the Journal of Membrane Science 113 (2), pp. 275-284.

Table 17: Over-all citation profiles (first generation)

Frequency	Focal patent	Focal article
B. citation of articles	0	42
B. citation of patents	9	0
F. citation by articles	0	4
F. citation by patents	5	0

Table 17 summarises the backward and forward direct citations of both the focal patent and article.

Table 18: Over-all forward citation profiles (second generation)

Frequency	Focal patent	Focal article
F. citation by articles	0	11
F. citation by patents	8	0

Table 18 summarises the indirect forward citations of both the focal patent and focal article. A professor from a South African university (SUN) was the inventor. In the first generation, the focal patent cited nine patents and was directly cited by five patents (all from foreign industries). In the second generation, only foreign industries' patents cited (eight times) the focal patent. No non-patent sources were cited nor did they cite this patent. This suggests that the patented technology originated from industry, was developed in university, and then finally was absorbed by industry.

The focal paper was co-authored by four individuals: two of them were employed by SUN, one of whom invented the focal patent. The third co-author was a professor in a Canadian university and the fourth was a professor in a Russian university. The focal article cited 42 articles and was cited by four articles. The article did not cite any patents nor was it cited by any patents. In the second generation (i.e. indirect citations), the knowledge from the focal article was cited 11-times by articles with authors from academia (none from South Africa) and did not receive any citations by a patent. This suggests that the knowledge disclosed in the public science domain flowed via the focal article.

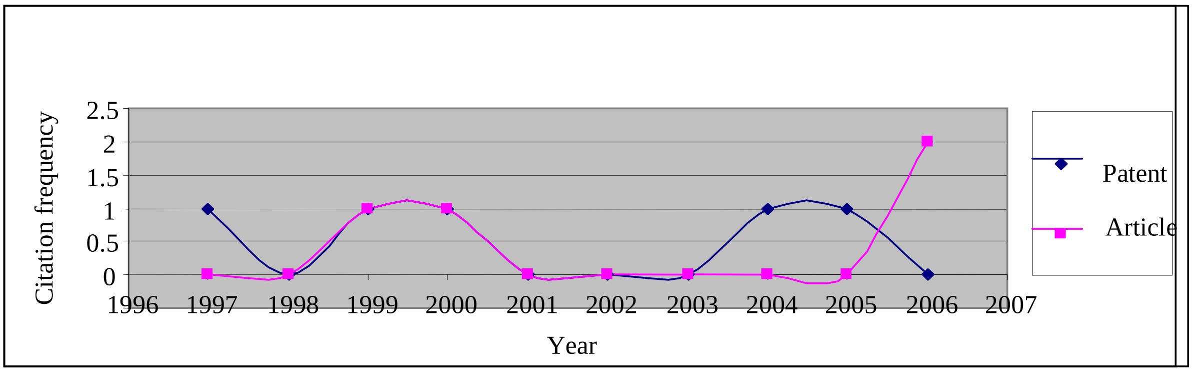

Figure 19: Diffusion of knowledge of disclosed in pair 1 (first generation)

Figure 19 shows the diffusion patterns of both the focal patent and article in the first generation. The patent was cited once in 1997 but the article was not cited. From 1998 to 2003, the diffusion pattern of the knowledge disclosed in both the focal patent and paper looked similar. Both the patent and the article were cited once in 1999 and 2000. From 2003 to 2006, the diffusion patterns differed. The patent was cited once in 2004 and in 2005, and the article was only cited twice in 2006.

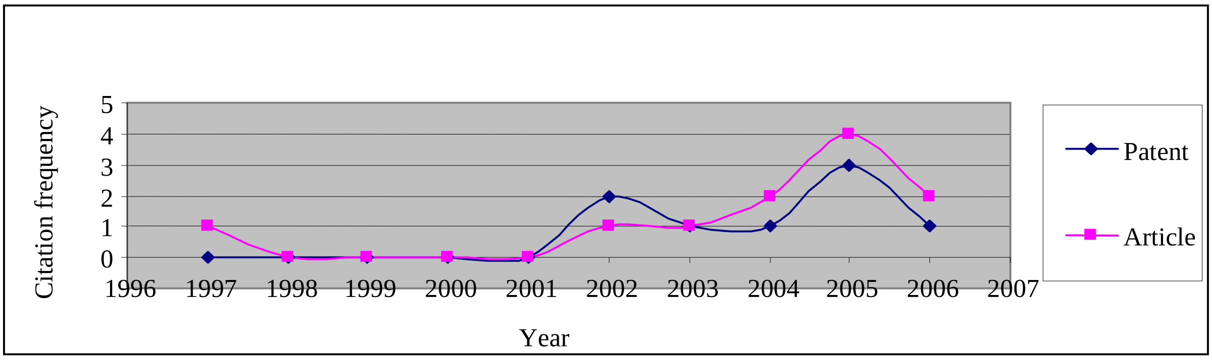

Figure 20: Diffusion of knowledge disclosed in pair 1 (second generation)

Figure 20 shows the diffusion patterns of both the focal patent and article in the second generation. The knowledge disclosed in the focal patent was not cited from 1997 to 2001. However, it was cited once twice in 2002 by patents, once in 2003 and 2004; three times in 2005 and once again in 2006 by patents. The knowledge disclosed in the focal article was cited once in 1997 by an article, but not cited at all from 1998 to 2001. Again, it was cited once in 2003, twice in 2004, four times in 2005 and twice again in 2006 by articles. The flow of the corresponding knowledge through patent and article differed in both generations. The flow was slower through the patent and faster through the article.

5.3.2 Pair 2: CMOS circuit for minimum supply voltage

The knowledge disclosed in the pair 2 described some modifications to translinear circuit topologies through a constructive use of non-saturated MOS transistors operating in weak inversion. The focal patent claimed that the configuration that was being disclosed was suitable for static and dynamic analog signal processing circuits in mixed-signal chips fabricated in digital CMOS technology and operating at the minimum possible supply voltage. The focal patent filed in 1997 was assigned to Philips Corporation by the USPTO in 1998. The focal article was published in 2000 in an IEEE Transaction on circuit and systems II - Analogue and Digital Signal Processing, Vol. 47 (12), pp. 1560-1564.

Table 19 summarises the backward and forward citations of both the focal patent and article and Table 20; the forward citations of both the focal patent and article.

Table 19: Over-all citation profile of pair 2 (first generation)

Frequency	Focal patent	Focal article
B. citation of articles	0	9
B. citation of patents	1	0
F. citation by articles	0	10
F. citation by patents	5	0

Table 20: Forward citation profile of pair 2 (second generation)

Frequency	Focal patent	Focal article
F. citation by articles	0	9
F. citation by patents	7	0

Three professors from a South African university (UP) made the invention. The complete application filed to USPTO and assigned to Philips corporation was an improved version of a provisional patent application filed to CIPRO by UP. This suggests that the provisional patent application filed at CIPRO was licensed or sold to industry by the university and/or by the inventor to Philips. This could also suggest a linkage between industry and university and the inventors. In the first generation, the patent cited only one foreign industry's patent and was cited by five foreign industries' patents.

The focal patent did not cite any non-patent and no non-patent sources cited it. This suggests that the knowledge disclosed in this focal patent flowed from industry to industry via university. Five researchers co-authored the focal article. Three of those were professors employed at UP, two of them being the co-inventors of the focal patent. The remaining two co-authors of the focal article were researchers from Circuit Research Institute in Eersel, Netherland. Another author was employed by the Swiss Electric & Microtech SA, Neuchatel. The focal article cited nine articles and other articles cited it 10 times in the first generation. The article did not cite any patents and no patents cited it.

This suggests the knowledge disclosed in the focal article flowed within the public science via the university. In the second generation, the focal patent was cited seven times by patents from industry and was not cited by any articles. This suggests the knowledge flowed within industry via the university. The focal article was cited nine times by articles and was not cited by any patents. This suggests this knowledge flowed into the public science via the university.

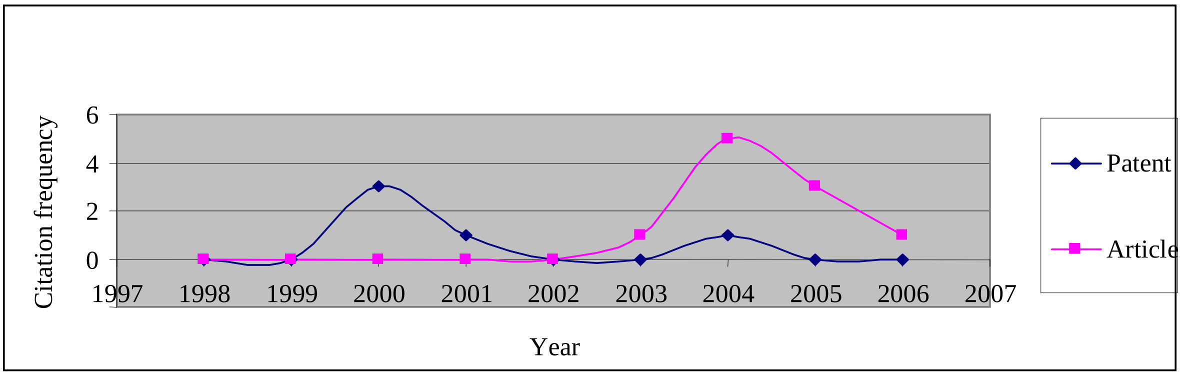

Figure 21: Diffusion of knowledge disclosed in pair 2 (first generation)

Figure 21 shows the diffusion patterns of the knowledge disclosed in the focal patent and focal article in the first generation. The pair was not cited from 1996 to 1999. The patent was cited three times in 2000, once in 2001 and again in 2004. The article was not cited until 2003 when it was cited once, and five times in 2004, three times in 2005 and once in 2006.

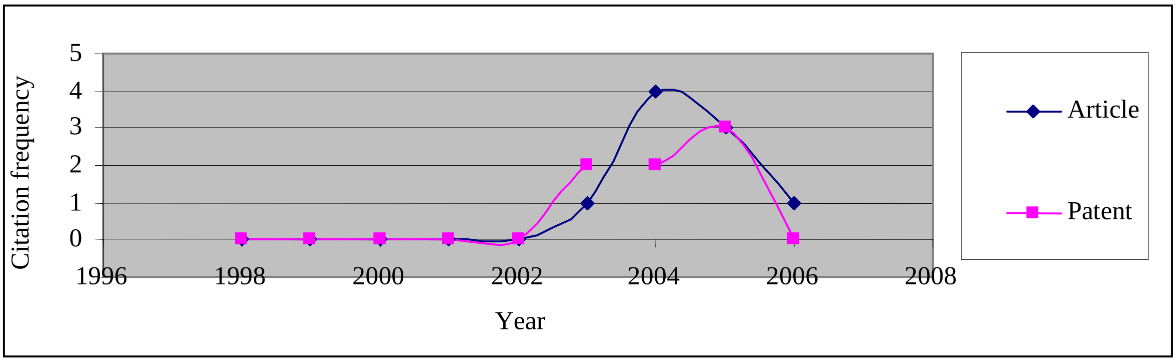

Figure 22: Diffusion of knowledge disclosed in pair 2 (second generation)

Figure 22 shows the diffusion patterns of the knowledge disclosed in the focal patent and article in the second generation. The pair was not cited from 1998 to 2002. In 2003 the article was cited once and the patent twice, in 2004 the article was cited four times and the patent twice. In 2005 the patent was cited three times, the article was not cited at all, and in 2006 the article was cited once but the patent was not cited.

5.3.3 Pair 3: genetics/biotechnology

The knowledge disclosed in the pair described an isolated nucleotide comprising a sequence, which encodes eukaryotic malate permease from *Schizosaccharomyces pombe*, which mediates the uptake of L-malate succinate and malonate. The focal patent filed in 1998 was assigned by the USPTO to SUN in 2001. The focal article was published in 1998 in Food Research International, Vol. 31 (1), pp. 37-42.

Table 21: Over-all citation profiles of pair 3 (first generation)

Frequency	Focal patent	Focal article
B. citation of articles	0	37
B. citation of patents	3	0
F. citation by articles	0	1
F. citation by patents	0	0

Table 21 summarises the backward and forward citations of both the focal patent and article.

Table 22: Forward citation profiles of pair 3 (second generation)

Frequency	Focal patent	Focal article
F. citation by articles	0	1
F. citation by patents	0	0

Table 22 summarises the forward citations of both the focal patent and article in the second generation. Six professors made the invention, three of whom were foreign visitors or collaborators at SUN. One of the three worked as a director in a Canadian Wine corporation. This suggests a linkage between the inventors and industry. One of the six was from a Thailand university, and the others worked at SUN. The provisional application filed at CIPRO was assigned to SUN and the complete application made at the USPTO was assigned to SUN. This patent was not licensed nor sold to industry. The focal patent cited three patents (all from foreign industries) but was not cited. The focal article listed five co-authors. Four of these were co-inventors of the focal patent. One of the five co-authors worked at SUN. The focal article cited 37 articles and was cited three times by articles. Two of those citing articles were self-citations and thus did not count. The article was only cited once by an article and did not cite any patent.

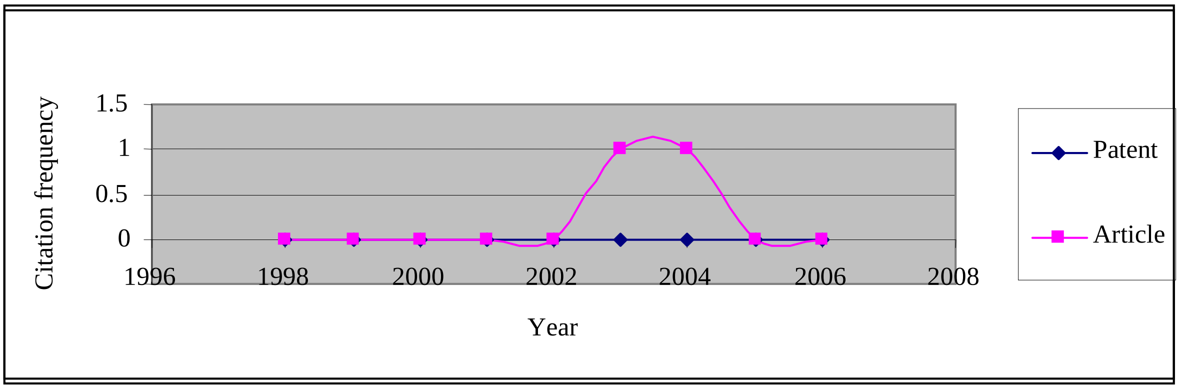

Figure 23: Diffusion of knowledge disclosed in pair 3 (first generation)

Figure 23 shows the diffusion patterns of the knowledge disclosed in the focal patent and article in the first generation. The diffusion patterns were significantly different. The focal patent was not cited at all and the focal article was only cited once in 2003 and in 2004. The diffusion of the knowledge in the second generation was very negligible and thus has not been reported.

5.3.4 Pair 4: flotation column

The knowledge disclosed in this pair described a new configuration of the flotation column that improves the quality of mixing and the resulting efficiency in recovering minerals. The focal patent filed at the USPTO in 1992 was assigned in 1994 to a mineral processing industry operating in South Africa: the Multotec Cyclones (Pty) Limited. The focal article was published in 1993 in the Bulletin of the Canadian Institute of Mining, Metallurgy and Petroleum, CIM Bulletin, Vol. 86 (968), pp. 138-143.

Table 23: Over-all citation profiles of pair 4 (first generation)

Frequency	Focal patent	Focal article
B. citation of articles	0	11
B. citation of patents	25	0
F. citation by articles	0	1
F. citation by patents	5	0

Table 23 summarises the backward and forward citations of both the focal patent and article.

Table 24: Forward citation profiles of pair 4 (second generation)

Frequency	Focal patent	Focal article
F. citation by articles	0	1
F. citation by patents	11	0

Table 24 summarises the forward citations of both the focal patent and article in the second generation. A professor employed at a South African university (WITS) invented the focal patent.

In the first generation, the focal patent cited 25 patents (all from industry) and was cited five times by other patents (all from industry). The focal patent was not cited in the second generation. The patent did not cite any non-patent sources and was not cited by any non-patent sources. This suggests the knowledge disclosed in the focal patent flowed within industry via university.

The focal article was co-authored by three individuals, one being the inventor of the focal patent and the remaining two were employed by industry. The article cited 11 articles and was only cited once by one article. This suggests that the knowledge disclosed in the focal article flowed within the public science via the university. In the second generation, the knowledge disclosed in the focal article was not cited at all, while the knowledge disclosed in the focal patent was cited 11 times.

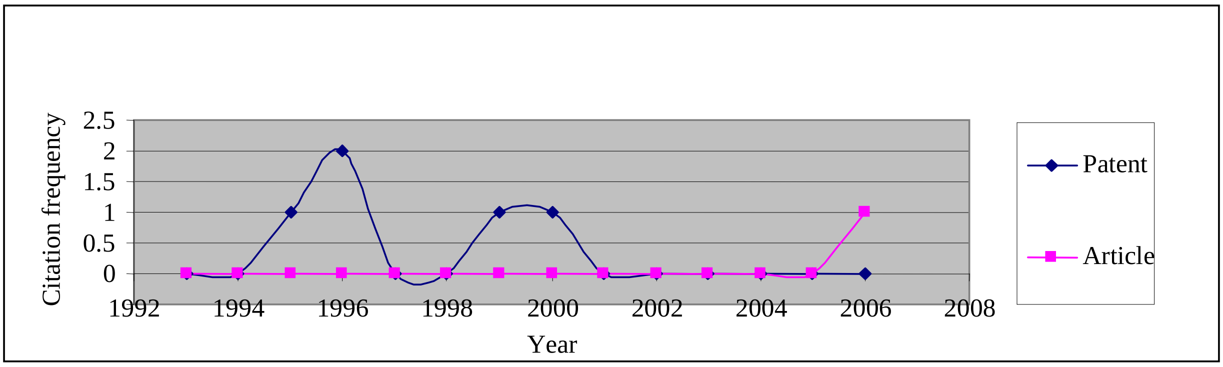

Figure 24: Diffusion of knowledge disclosed in pair 4 (first generation)

Figure 24 shows the diffusion patterns of the knowledge disclosed in the focal patent and article in the first generation. The diffusion patterns were significantly different. The focal patent was cited once in 1995, twice in 1996, and once in 1999, 2000 and 2006.

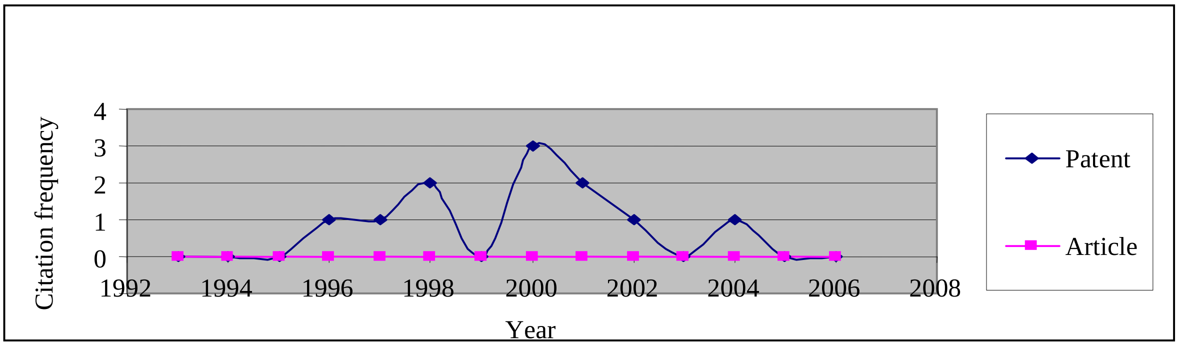

Figure 25: Diffusion of knowledge disclosed in pair 4 (second generation)

Figure 25 shows the diffusion patterns of the knowledge disclosed in the focal patent and article in the second generation. The focal article was not cited at all. The focal patent was cited once in 1996 and 1997, twice in 1998, three times in 2000, twice in 2001, and once in 2002 and 2004.

5.4 Overview of patents ownership history and transfer to industries

Most patents were first applied locally (where application fees were significantly lower and thus readily affordable) and then, abroad (where application fees were much more costly than domestic ones). Many patents owned abroad by local or foreign industries were improvements upon inventions initially applied at CIPRO. These improvements could be attributed to foreign industries, which, for their own interests, might have financially supported the development and filing of patents abroad. Other patents found abroad might have resulted from the outsourced inventions initiated in South Africa, as pointed out in semi-structured interviews by two senior South African university patent officers.

Figure 26 summarises the results outlined in Table 15. The patents referred to here were filed at the USPTO and WIPO and listed South African university professors as inventors, co inventors or assignees.

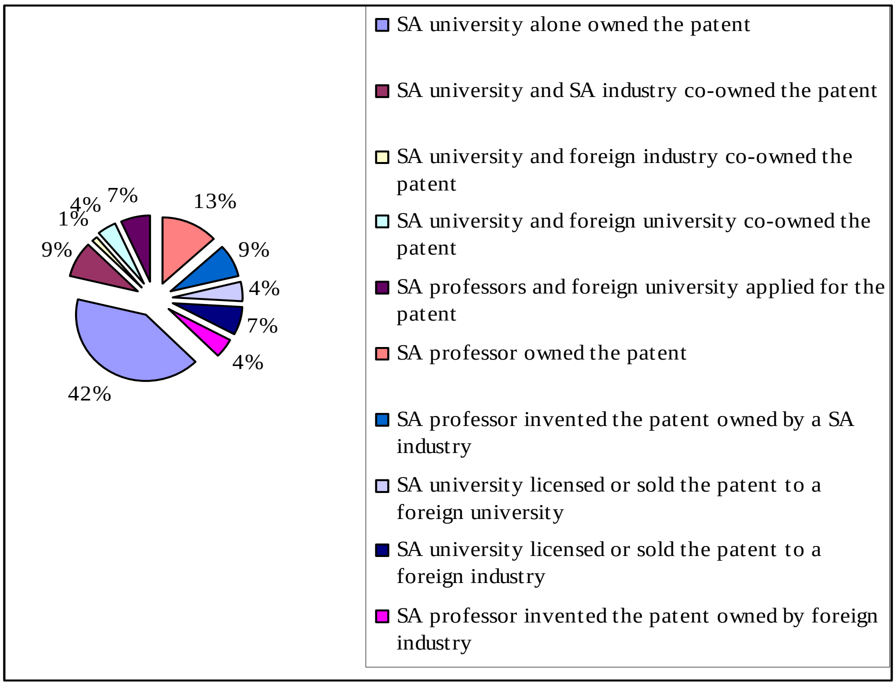

Figure 26: Distribution of patent ownership (%) by university, industry and inventor

Forty-two percent of those patents belonged to South African universities. Nine percent was jointly applied and/or co-owned by South African universities and South African industries. This suggests that those patents resulted from collaborative research between those institutions, as also pointed out by two senior South African university patent officers.

A South African university and a foreign industry only co-owned 1% of the patents, suggesting weak linkages between those institutions. Four percent was co-owned by South African and foreign universities. This suggests that these patents resulted from collaborative research between South African and foreign universities. Seven percent was applied and/or co-owned by South African professors and foreign universities. This suggests that these patents resulted from collaborative research between South African university professors individually and foreign universities.

South African university professors owned 13% of the applications alone. South African industries owned 9% of patents that listed South African university professors as inventors. This suggests that those patents resulted from work outsourced by South African industries to South African professors. Only 4% of all the patent applications were licensed or sold to foreign universities and 7% to foreign industries. Foreign industries owned 4% of patents that listed South African university professors as inventors. This suggests that those patents resulted from work outsourced by foreign industries to South African professors.

A sample of 28 patents initially developed in domestic universities and subsequently deployed in local or foreign industries through licences, sales or joint-R&D was identified and analysed. These patents listed a South African university researcher as an inventor/co-inventor, applicant or co-applicant. The contents of the patents were matched to the research fields and previous publications of the inventors to gain an insight into the development of the subject matter disclosed in the patent.

Table 25 shows the distribution of some patents deployed to industry by sector or discipline.

Table 25 Number of patents deployed to industry by sector

Sector	Number of patents
Separation technology	5
Genetics/biotechnology	6
Optoelectronics and related arts	5
Chemistry and related arts	8
Immunology	1
Drug design/pharmacology	2
Total	28

The chemistry sector and related arts had eight inventions deployed in industry and was followed by the genetics sector which had six, the separation technology and optoelectronics sectors had five each and the drug design and pharmacy sector had three patents.

The over-all number of patents transferred for the period under investigation is very small, compared to that of sister universities from developed and many developing countries. The inventors of all the patents transferred to domestic and foreign industries had previously worked in industry. This suggests that (i) previous industry working experience would better inform university scientists on how to develop inventions that meet industry's needs, (ii) scientists with previous industry exposure are likely to have stronger social/network in industry which facilitates dialogue with industry's partners and smoothes the deploying of technological innovations therein as shown elsewhere by Lubango (2009).

CHAPTER 6 CONCLUSION AND RECOMMENDATIONS

The analysis of inventive activities of South African institutions considered in this study reveals that a domestic patent office CIPRO provides a more detailed picture of local (i.e. South African) inventive activities than foreign patent offices such as USPTO and EPO. One could reasonably argue that indicators based on local patent offices can provide valuable information that is not always available or accessible through foreign patent offices. A related issue that could provide a subject for future research is why South African academics patent more locally and very little abroad? Is it an issue of costs, market considerations or do they find it easier to apply in a patent office that grants patents based on criteria that differ from those available at USPTO?

The over-all inventive performance of South African universities over the period of 10 years falls far below that of other countries. South Africa's relevant policy authorities and the universities' administrations should consider the enactment of appropriate incentives to improve the inventive outputs of the country's universities. Some examples in this direction would include:

- Employing researchers with prior industry experience
- Building a strong entrepreneurial capacity
- Strengthening the management capabilities of technology transfer offices
- Promoting effective links with the private sector
- Setting up research joint ventures
- Collaborating with technology incubators
- Adopting royalty and equity policies that stimulate researchers to invent and innovate

The dramatic increase in inventive activities at WITS in 2005 and the decrease of such activities at UP from 2002, as well as the big differences in inventive activities amongst institutions and departments, are also subjects for further research.

The study found that prior industry working experience of scientists working at universities was an effective mechanism for increasing the universities' inventive capacity. These findings are in line with those of Dietz & Bozeman (2005:349), which supports the view that the intersectoral job change by researchers from industry to university is associated with the spillover of industry-specific human capital to university. This is an effective mechanism that can support new knowledge generation capacity required in invention. This work suggests that the foregoing view is universal. It holds even in South Africa where the patenting culture and the supporting mechanisms for innovation are not present, but are in developed economies. While it will be important to verify this linkage between prior industrial experience and academic inventiveness in other countries, it is suggested that universities wishing to improve their entrepreneurial character should aim to employ academics with prior industrial experience.

The second aim of this study was to investigate whether patenting activity is an impediment to the capacity of South African university researchers to produce public knowledge. An assessment was undertaken of the NRFratings and the publication counts of professors. No convincing evidence supports the pessimistic idea that patenting impedes the academic performance of the university researchers. Most inventors were NRF-rated. The NRFrating data were used as qualitative (pilot) indicators of the academic capacity of a researcher to support the quantitative bibliometric findings.

The quantitative evidence suggests that the two activities, i.e., patenting and academic performance, particularly publication activity, can co-exist and may even reinforce each other. Professors who were active in patenting activities were also performing academically in the role of those whose entire careers were dedicated to the production of public knowledge and teaching. Research orientation, in the present context, had a significant effect on the publication performance. Professors from the faculty of engineering published less than professors from the faculty of science did.

The results of publication counts showed that inventors published slightly more than non-inventors did. Furthermore, inventors collaborated and co-published slightly more than non-inventors did although the trends of the publication profiles of the two groups were very similar.

Inventiveness might have the effect of increasing the network of collaborators and this could promote and facilitate the spillover or transfer of knowledge that could be leveraging the publication capacity. As recently reported by Lubango & Pouris (2007:788) professors with previous industry working experience were more inventive than those who did not have such experience in South African higher education institutions. This observation was in line with those of Bozeman & Corley (2004:599); Dietz & Bozeman (2005:349), and Bozeman & Mangematin (2004:565), who showed that professors who had previous industry working experience had broader social networks, broader social capital, and stronger ties with industry and funding bodies than those whose entire career had been spent in academia.

This work also suggests that previous industry working experience not only increases technical capital but also increases social networks and social capital of a researcher, which can be translated into research outputs of higher national and international standards. The career trajectories of inventive professors could be exposing them to industry in public or private sectors in addition to academia. Career heterogeneity could facilitate the building of large networks and strong ties with many researchers across various areas of their fields, through which knowledge can readily flow.

Publication and patenting are not in conflict, although evidence of some confounding effects of collaboration/co-publication activity of professors occurred. In the context of research in South African institutions of higher learning, where there are more incentives to publish than to patent or innovate, could further stimulate inventors to publish. In this context, inventive activities strengthen, and do not reduce, the publication capacity of university professors.

The study finally investigated the mechanisms of linkages between patents and articles and whether through these linkages the two constructs can support each other. All the evidence revealed that far from being in conflict, patents and articles in South African universities overlapped and cross-fertilised. A population of 70 patents, invented and/or co-invented by South African university professors was collected from the USPTO, EPO and WIPO. Fifty-eight patents from the foregoing population formed pairs with papers or articles. The same piece of knowledge disclosed in each patent was also published in an article forming patent-paper pairs.

Focal patents from the USPTO mostly cited patents from industry and only patents from industry cited the patent, in the first generation. All the focal articles cited articles and were cited by articles. Patents from the EPO cited more patents than articles and patents cited none of them. All the corresponding focal articles cited articles and were only cited by articles. The difference in citation frequencies in the two groups could be ascribed to the difference in the examination procedures at USPTO and EPO.

The analysis of forward and backward citation patterns of pairs pertaining to polymer membrane, signal processing, genetic engineering and mineral processing sectors points to two important conclusions. Technical knowledge flowing from industry to university can successfully flow through articles or through patents. Scientific knowledge disclosed through an article or a paper can successfully de diffused through an article or a patent.

The study also revealed through the analysis of the patent application ownership history, that in addition to the formation of pairs, inventors interacted with industry through other means, viz., licensing, contract and collaborative research. The citation profiles of all pairs investigated showed that the focal patent produced in South African universities, strongly built on prior arts from foreign industry. There is here enough evidence to support the view that knowledge does not have a rigid nature but can be transformed, accumulated, stored and transferred. Foreign industries absorbed most of the knowledge from South African universities. There were very few patents co-owned and/or developed jointly by universities and local industries. The latter interactions could have strengthened the linkages between industry and universities and might have influenced the interaction of science and technology network and the associated overlap. The observed difference in flow of knowledge disclosed in pairs is attributable to the different social networks to which patent and paper pertain (the technical and the scientific networks respective to patent and paper). The driving forces of the diffusion in the two networks are different.

The findings could be used to promote knowledge transfer and diffusion between university and industry within the South African National Innovation System and elsewhere.