QUANTITATIVE ASSESSMENT OF SOUTH AFRICA'S INVENTIVE OUTPUTS: INTERNATIONAL PATENT ANALYSIS

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ABSTRACT

This article aims to identify and analyse the inventive activity of South Africans as it is manifested in the form of patents. Patents are used internationally as indicators of national and corporate inventive activity, but they rarely are reported in the context of the South African reality. Inventive activity is analysed in terms of patents awarded to South African inventors by the USA patent office (USPTO). South African inventors are identified to apply and receive approximately 110 patents per year from the USPTO. Analysis of the patents according to technological classes identifies classes that indicate the country's strengths. South Africa is ranked fourth internationally in technological class "Chemistry: Fischer-Tropsch Processes; or Purification or Recovery of Products Thereof"; and twelfth in "Specialised Metallurgical Processes". It is argued that government should support further innovation in the country's strong inventive areas. Corporate patent analysis identifies the most inventive organisations in the country; co-inventive analysis identifies the countries with which South Africans cooperates; and international comparisons set South Africa in an international context. An important finding is that South Africa appears not to have participated in the international explosion of patents during the last twenty years. It is suggested that neither the policy environment nor factors determining technological fertility have changed in South Africa during the last two decades.

OPSOMMING

Hierdie artikel het ten doel om Suid-Afrika se innoverende aktiwiteite in die vorm van patente te identifiseer en te ontleed. Innoverende aktiwiteite word in terme van patente, wat aan Suid-Afrikaanse innoveerders deur die VSA se patente-kantoor ("US Patent Office – USPTO") toegeken word, ontleed. Suid-Afrikaanse uitvinders word genader om aansoek te doen en ongeveer 110 patente word jaarliks deur USPTO toegeken. 'n Ontleding van die patente identifiseer klasse wat die land se sterk punte aantoon. Suid-Afrika is op internasionale vlak vierde in die tegnologiese klas *Chemie: Fischer-Tropsch-prosesse; of Suiwering of Herstel van Produkte Daarvan* geplaas, en twaalfde in *Gespesialiseerde Metallurgiese Prosesse*. Daar word gestel dat nóg die beleidsomgewing nóg die faktore, wat tegnologiese vrugbaarheid bepaal, gedurende die afgelope twee dekades in Suid-Afrika verander het.

1. INTRODUCTION

Monitoring and evaluating the various facets of the scientific enterprise is a necessary and integral part of science policy. Rising costs of research and development, and competing disciplinary claims for financial resources, require intelligent allocation of resources, which presupposes knowledge of the activities and performance of the innovation system.

One of the most efficient and objective methods of assessing research and innovation performance is through scientometric indicators. An indicator is defined [1] as "statistics of direct normative interest which facilitate concise, comprehensive, and balanced judgments about the condition of major aspects of a society. It is in all cases a direct measure of welfare, and is subject to the interpretation that, if it changes in the 'right' direction while other things remain equal, things have got better or people have got better off". Scientometric analysis, the quantitative study of the innovation system, is based mainly on bibliometric and patent indicators. In bibliometrics the number of publications in a field is considered to be an indicator of research activity. Similarly, in patent analysis the number of patents awarded to an institution or a country is used as an indicator of technological activity. Patent indicators – within the science and technology (S&T) context – are used to measure inventive performance, diffusion of knowledge, and internationalization of innovative activities, across countries, firms, industries, technology areas, etc.

The philosophy underlying the use of bibliometric indicators as performance measures has been summarized in De Solla Price's statement that "for those who are working at the research front, publication is not just an indicator but, in a very strong sense, the end product of their creative effort". [2]

Of course, there are many trained scientists who are not required to publish. They may perform managerial or administrative functions, they may teach available knowledge, or they may apply existing knowledge in making new products and in providing services. The common characteristic of all these scientists is that they are far away from the research front. They provide the infrastructure for the producers of knowledge, and they exploit the end results of research and development. In any case, however, they cannot be considered as 'researchers'.

The same way in which scientific articles are accepted as a legitimate reflection of scientific research, patents are accepted as a reflection of technological achievements. Griliches [3] has pointed out that "patent statistics remain a unique source for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and potential industrial, organizational, and technological detail".

Patents fulfil two roles: they provide inventors with legal protection for novel products and processes, and simultaneously they ensure that the knowledge of these products and processes becomes available to society. In this way both private and public interests are served. Carr [4] describes the concept of patent as follows:

A patent is an exclusionary right granted by a government entity. The concept behind the United States patent system is that the government grants statutory protection to an inventor in the form of exclusionary rights for a period of years in return for a disclosure of the creativity of the grantee. The exclusionary rights granted by the patent are the rights to exclude others from making, using or selling the patented invention throughout the United States and its territories for a period of 17 years. In exchange for these rights, the patent discloses and teaches technical knowledge relating to the invention. During the life of the patent, scientists and other inventors benefit from the disclosure of prior art information by avoiding repeating efforts to discover that which is already known. After the patent expires, the invention belongs to the public and anyone can make, use or sell the invention without permission of the patentee.

Patent analysis possesses a number of strengths that facilitate their universal use as scientometric tools. They are highly reliable because they are well defined and unambiguous. They facilitate detailed categorisation and thus make possible the study of scientific and technological fields and sub-fields. Finally, they make possible international comparisons. The Organisation for Economic Cooperation and Development (OECD) provides guidelines for the use of patents in their relevant manual. [5]

In the United States of America the National Science Foundation [6] is using bibliometrics, patent, and trade in high technology analysis to monitor the health of American science and technology on a continuous basis; in Europe the European Commission [7] is using similar approaches in order to monitor the health of the European innovation system; and the OECD [8] is using the indicators for monitoring and comparative purposes.

In South Africa, policy researchers rarely utilize patents as a source of information [9] [10]. The purpose of this document is to identify the performance of the inventive component of the South African innovation system as it is manifested in the analysis of patents.

2. METHODOLOGY AND DATA SOURCES

Patent analysis – within the science and technology (S&T) context – is used to measure inventive performance, diffusion of knowledge, and internationalization of innovative activities, across countries, firms, industries, and technology areas. Porter *et al*. [11] argue that patent indicators are the most appropriate for defining the innovative capacity of countries, and that international patenting is strongly correlated with alternative measures of innovative output such as the number of scientific journal articles, and also with outcome measures such as a country's market share in high-technology industries.

The patents most often utilized internationally for this type of analysis are those awarded by the United States Patent Office (USPTO). Although most countries in the world have their own patent authorities, the use of the USPTO provides a number of advantages. First, in the majority of the patent offices, patents are not examined for originality, usefulness, or novelty. The South African patent office is one of these.

Consequently, counting and comparing patents awarded by different patent offices in different countries may be misleading because of differences in the criteria used, the ease with which patents are awarded, bias towards local patents, etc. The obvious way to avoid such shortcomings is to use a common denominator such as an external patent system with an objective approach to awarding patents – i.e. the USPTO. The USPTO examines claims according to a number of criteria. These are [12]:

- **Subject matter**: An invention must fall into one of the categories that the patent law uses for patentable subject matter.

- **Utility**: An invention must fulfil the substantive requirement of 'utility'. An invention must perform a designed function or achieve some minimum human purpose.

- **Novelty**: An invention has to be novel.

- **Non-obviousness**: The knowledge in the technological field at the time of invention must not make the invention obvious to one of ordinary skill in that area.

- **Definiteness**: One skilled in the art must understand the limits of the invention based on the claim language.

Second, the US represents the most important single market for technology-related sales, and thus is a key drawing card for technology-based products. Owners of important commercial inventions will make sure that they are protected in the USA market. Third, the

costs involved and the complexity of filing foreign patents in the USA tend to screen out trivial patents.

Although patents facilitate the development of a number of useful indicators, they have a number of drawbacks. Patented inventions do not necessarily represent all the inventions produced in a country or organization. Many inventions are not patented because there are other barriers to entry (e.g. lack of brand names among the competitors), because inventors may undertake other measures of protection (e.g. the encapsulation of products in epoxy resin to deter imitation), or because inventors consider that the invention will be profitable even if imitators may appear in the foreseeable future. Similarly, high costs for applications or monitoring infringement, as well as lack of appreciation, are additional reasons that may limit the number of patents from a particular country or organisation.

The USPTO classifies the patents in different classes and subclasses. The class breakouts represent major divisions of technology in the US Patent Classification System (USPCS). The USPCS currently contains approximately 460 classes and 150,000 subclasses. The classification of the patents to subclasses is done according to information disclosed in the patent. If more than one technology is identified as pertinent to the patent, one subclass is designated as the primary classification, and the remainder are designated as cross-reference classifications. Counting patents by primary classification ensures that each patent is counted only once. The residence of the first-named inventor listed on the patent grant determines patent origin.

Furthermore, the USPTO classifies patents as utility patents (i.e. patents for invention), reissue patents, plant patents, design patents, and statutory invention registrations and defensive publications. In our investigation we utilize only utility patents.

Data for this analysis were received from the USPTO databases.

The South African applications in the Patent Cooperation Treaty (PCT) system are also reported. The PCT is an international treaty, administered by the World Intellectual Property Organization (WIPO), among more than 125 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single 'international' patent application instead of filing several separate national or regional patent applications. The granting of patents remains under the control of the national or regional patent offices in what is called the 'national phase'. Data have been obtained from the WIPO databases.

Briefly, an outline of the PCT procedure includes the following steps:

- **Filing:** The inventor files an international application, complying with the PCT formality requirements, in one language, and s/he pays one set of fees.

- **International search:** One of the world's major patent offices identifies the published documents that may have an influence on whether the invention is patentable, and establishes an opinion on the invention's potential patentability.

- **International publication:** As soon as possible after the expiration of 18 months from the earliest filing date, the content of the international application is disclosed to the world.

- **International preliminary examination:** One of the world's major patent offices may, at the inventor's request, carry out an additional patentability analysis, usually on an amended version of the application.

- **Entry into the national/regional phase: A**fter the end of the PCT procedure, the inventor starts to pursue the grant of the patents directly in the countries in which s/he wants to obtain them.

The advantages of the PCT system, according to the WIPO web site, are as follows:

1. You have up to 18 months more than if you had not used the PCT to reflect on the desirability of seeking protection in foreign countries, to appoint local patent agents in each foreign country, to prepare the necessary translations and to pay the national fees;

2. you can rest assured that, if your international application is in the form prescribed by the PCT, it cannot be rejected on formal grounds by any PCT Contracting State patent office during the national phase of the processing of the application;

3. on the basis of the international search report and the written opinion, you can evaluate with reasonable probability the chances of your invention being patented;

4. you have the possibility during the optional international preliminary examination to amend the international application and thus put it in order before processing by the various patent offices;

5. the search and examination work of patent offices can be considerably reduced or eliminated thanks to the international search report, the written opinion and, where applicable, the international preliminary report on patentability that accompany the international application;

6. since each international application is published together with an international search report, third parties are in a better position to formulate a well-founded opinion about the potential patentability of the claimed invention; and

7. for you as an applicant, international publication puts the world on notice of your application, which can be an effective means of advertising and looking for potential licensees.

3. SOUTH AFRICA'S INVENTIVE PERFORMANCE

Figure 1 shows the number of patents awarded to South African inventors by the USPTO during the period 1963 to 2004. The figure makes it clear that the number of South African patents granted by the USPTO increased until the early 1990s, and thereafter stabilized around a figure of 110 patents per year.

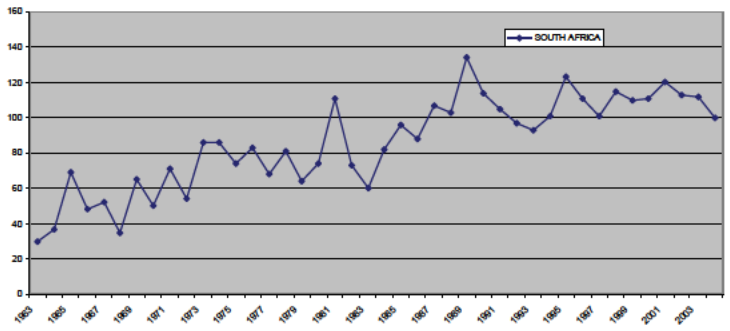

Figure 1: Number of South African patents - USPTO 1963-2004

Figure 2 shows the South African share in the USPTO for the period 1963-2004. The South African share of the total number of patents granted, and of the number of foreign patents granted, is shown. The graph of the number of South African patents compared with the number of foreign patents granted indicates a long-term decline. The number of patents granted to inventors from countries other than South Africa has increased much faster than

the number of patents awarded to South African inventors, and thus the relevant ratio has declined from above 0.5% in 1965 to 0.1% in 2004. The ratio of the number of South African patents to the total number of granted patents - which is substantially lower owing to the large number of USA patents - shows a smaller variation because of a relative decline in the number of USA patents over time. We elaborate on the above issues in the discussion section.

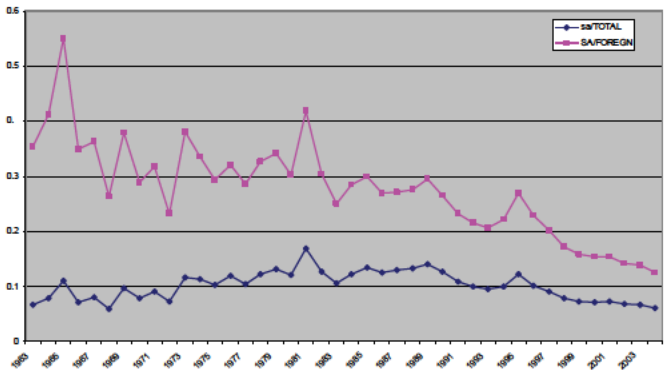

Figure 2: South African share of patents - USPTO 1963-2004

Table 1 shows the number of patents granted to South African inventors and inventors from a selected set of other countries during 1991, 1994, 2000, and 2004. The countries have been selected because they started the 1990s with fewer patents than South Africa; yet during 2004 they were producing substantially larger numbers. For example, Indian inventors were awarded 22 patents during 1991, while in 2004 they were awarded 363 patents - a more than 16-fold increase. Similarly, inventors from Hong Kong and Singapore (relatively small countries in terms of population) have been able to increase the number of their patents substantially within a decade.

Granting year	*1991*	*1994*	*2000*	*2004*
South Africa	105	101	120	100
China, HK	50	57	179	311
Singapore	15	51	218	449
India	22	27	131	363
Ireland	53	48	121	186
Brazil	62	60	98	106
Norway	111	126	248	243
New Zealand	41	37	107	142
China, P Rep	50	48	119	404
Foreign Origin	45,334	45,610	72,426	80,022

Table 1: Number of USPTO patents granted to South Africans and residents of selected countries

Table 2 shows the top 30 countries in terms of number of patents granted during 2004. The table shows the number of patents granted to inventors from different countries as well as their relative share of patents in the USPTO. The USA tops the table with 84,271 patents, which constitute 51.5% of the total number of patents granted. Japan follows with 35,350 patents or 21.6% of the total. South Africa and Mexico are at the bottom of the list (29th

and 30th positions respectively) with 0.1% of the patents each. It should be mentioned that South Africa was 21st in 1991.

	Country	*Number*	*Percentage*
1	USA	84,271	51.5%
2	Japan	35,350	21.6%
3	Germany	10,779	6.6%
4	Taiwan	5,938	3.6%
5	South Korea	4,428	2.7%
6	United Kingdom	3,450	2.1%
7	France	3,380	2.1%
8	Canada	3,374	2.1%
9	Italy	1,584	1.0%
10	Sweden	1,290	0.8%
11	Switzerland	1,277	0.8%
12	Netherlands	1,273	0.8%
13	Israel	1,028	0.6%
14	Australia	953	0.6%
15	Finland	918	0.6%
16	Belgium	612	0.4%
17	Austria	540	0.3%
18	Singapore	449	0.3%
19	Denmark	414	0.3%
20	China, P. Rep.	404	0.2%
21	India	363	0.2%
22	China, HK	311	0.2%
23	Spain	264	0.2%
24	Norway	243	0.1%
25	Ireland	186	0.1%
26	Russia	169	0.1%
27	New Zealand	142	0.1%
28	Brazil	106	0.1%
29	**South Africa**	100	0.1%
30	Mexico	86	0.1%
	TOTAL	**163,682**	**100%**

Table 2: Number and percentage of patents granted in year 2004 by country of origin (USPTO): Top 30 countries

Table 3 shows the number of patents awarded to a number of corporations for comparative purposes. IBM, at the top of the list, was granted 3,248 patents during 2004. The table makes it clear that some corporations are substantially bigger in terms of patents than most countries. Canon, for example, is granted more patents than Belgium, Austria, and Denmark put together. During 2004 only 10.6% of the patents granted by USPTO went to individuals. Table 4 shows the patent classes in which South Africa was granted more than 10 patents

from 2000 to 2004. Class 210, 'Liquid Purification or Separation' is top of the list with 26 patents. Class 424, 'Drug, Bio-Affecting and Body Treating Compositions', is second with 22 patents. The eight classes in the table (out of more than 400 classes) include 23% of the total number of patents granted to South African inventors.

Organisation	*Number*
IBM	3,248
Canon	1,805
HITACHI	1,514
TOSHIBA	1,311
Matsushita Elec Ind Co	1,934
NEC	813
Sony	1,311
Fujitsu	1,296
Samsung	1,604
Honda Motors	736
University of California	422
NASA	102
Microsoft	629
University of Texas	99
California Inst Technology	135

Table 3: Number of patents from prolific organisations (2004)

Class	*Class Title*	*2000*	*2001*	*2002*	*2003*	*2004*	*Total*
210	Liquid Purification or Separation	7	9	5	4	1	26
424	Drug, Bio-Affecting and Body Treating Compositions (incl. Class 514)	5	4	5	7	1	22
340	Communications: Electronic	5	7	2	3	1	18
075	Specialised Metallurgical Processes, Compositions for Use Therein, Consolidated Metal Powder Compositions and Loose Metal Particulate Mixtures	1	7	2	2	4	16
423	Chemistry of Inorganic Compounds	2	3	3	2	3	13
532	Organic Compounds (incl Classes 532-570)	2	2	3	3	3	13
518	Chemistry: Fischer-Tropsch Processes; or Purification or Recovery of Products Thereof	1	2	2	1	5	11
198	Conveyors: Power Driven	3	3	2	0	2	10

Table 4: Patents granted to SA inventors by technology class

Tables 5 to 12 present the ranking of countries according to the number of patents they have been awarded in specific technology classes. For example, Table 5 shows that in class 518, 'Chemistry: Fischer-Tropsch Processes; or Purification or Recovery of Products Thereof', the top country in the period is the USA with 145 patents. Japan, the United Kingdom, France, and South Africa follow with 15, 12, 11, and 11 patents respectively. South Africa shares fourth position with France.

Japan	**15**
United Kingdom	12
France	11
South Africa	**11**
Italy	7
Russian federation	7
Norway	6
Canada	3
China P. Rep.	3
Germany	3
Netherlands	3
South Korea	2
Belgium	1
Switzerland	1
Denmark	1
Trinidad/Tobago	1

Table 5: Top patenting countries in USPTO in class 518 (Chemistry: Fischer-Tropsch Processes; or Purification or Recovery of Products Thereof) 2000-2004

Japan	*279*
Germany	81
Austria	53
Canada	52
Sweden	41
France	37
Australia	29
South Korea	26
Switzerland	25
United kingdom	20
South Africa	**16**
Finland	11
Venezuela	9
Italy	8
Norway	8
India	7

Table 6: Top patenting countries in USPTO in class 075 (Specialized Metallurgical Processes, Compositions for Use Therein, Consolidated Metal Powder Compositions, and Loose Metal Particulate Mixtures) 2000-2004

Japan	*511*
Germany	378
Canada	236
France	184
United Kingdom	111
Sweden	87
Australia	76
Netherlands	71
Taiwan	57
Finland	52
South Korea	52
Italy	50
Switzerland	33
Israel	30
Austria	28
South Africa	**26**
Belgium	23

Table 7: Top patenting countries in USPTO in class 210 (Liquid Purification or Separation) 2000-2004

Japan	*987*
Germany	453
Taiwan	207
Canada	193
United kingdom	173
France	148
South Korea	84
Israel	71
Sweden	55
Australia	45
Switzerland	39
Italy	34
Austria	28
Netherlands	23
Finland	19
South Africa	**18**
China,Hong Kong *S.A.R.*	13
Singapore	10

Table 8: Top patenting countries in USPTO in class 340 (Communications: Electrical) 2000-2004

Germany	*317*
Japan	272
Italy	149
Canada	101
Switzerland	89
Netherlands	53
France	52
Sweden	43
Austria	42
United Kingdom	40
Denmark	23
Taiwan	20
Finland	16
Australia	15
Spain	13
South Korea	12
South Africa	**10**
Norway	7
Belgium	5

Table 9: Top patenting countries in USPTO in class 198 (Conveyors: Power-driven) 2000-2004

Japan	*452*
Germany	246
France	137
Canada	80
United Kingdom	66
South Korea	40
Netherlands	26
India	25
Italy	25
Denmark	23
Sweden	23
Australia	22
Belgium	19
Taiwan	19
Finland	17
Norway	17
China P. Rep.	15
Russian Federation	14
South Africa	**13**

Table 10: Top patenting countries in USPTO in class 423
(Chemistry of Inorganic Compounds) 2000-2004

Japan	*2347*
Germany	2246
France	609
United Kingdom	600
Switzerland	373
Italy	282
India	272
South Korea	252
Netherlands	218
Canada	203
Taiwan	114
Israel	113
Belgium	102
Sweden	92
Austria	68
Denmark	68
Australia	66
Spain	63
Finland	56
Hungary	43
Russian Federation	31
China P. Rep.	27
Norway	25
South Africa	**13**

Table 11: Top patenting countries in USPTO in class 532 (Conveyors: Power-driven) 2000-2004

Table 13 summarises South Africa's ranking in the technology classes in which the country produced more than 10 patents over the five- year period 2000-2004. South Africa is in 4th position in class 518, 'Chemistry: Fischer-Tropsch Processes', and 12th in class 075, 'Specialised Metallurgical Processes…'. The technology classes in Table 13 reveal the technological areas in which South Africa has internationally recognised expertise.

Table 14 shows the number of patents that have been co-invented between a South African and a foreign inventor (patents with at least two co-inventors declaring different country address). During the period 2000-2004 there were 117 co-invented patents out of the 556 patents granted to South African inventors (21%). The USA is the main technological collaborator with South Africa, with 37% of the collaborative efforts (43 patents). Germany and the UK follow with 22 and 18 patents respectively.

Table 15 shows the companies appearing as first assignees in the set of South African patents during 2000-2004 and during 1969-2004. The table shows that SASOL Technology Ltd had the most patents during the more recent 5-year period. It is interesting to note that there are a number of companies with substantial patenting activity during the period 1969-2004 and limited activity during the more recent period. For example, AECI appears with 41 patents during 1969-2004, but with only one patent during 2000-20004. It would be

important for policy purposes to identify the reasons for the decline (e.g. closed down, bought/merged with another organisation, etc). It should be mentioned that the above data do not take into account changes in ownership after the award of patents, and they are only indicative of intellectual property owned by particular organisations, as organisations may own IP through other organisations locally and abroad or other types of agreements

Japan	*2800*
Germany	2417
France	1819
United Kingdom	1775
Canada	980
Italy	554
Switzerland	406
Sweden	400
Israel	351
Denmark	317
Australia	273
South Korea	271
Belgium	253
Netherlands	248
India	246
Taiwan	120
Spain	117
China P. Rep.	94
Finland	93
Austria	72
New Zealand	70
Norway	64
Hungary	54
Russian Federation	45
Ireland	40
Argentina	33
South Africa	**22**

Table 12: Top patenting countries in USPTO in class 424 (Drug, Bio-Affecting and Body Treating Compositions) 2000-2004

Class		***Ranking***
518	Chemistry: Fischer-Tropsch Processes	4
075	Specialized Metallurgical Processes	12
210	Liquid Purification or Separation compositions	17
198	Conveyors: Power Driven	18
423	Chemistry of Inorganic Compounds	20
532	Organic Compounds	25
424	Drug, Bio-Affecting and Body Treating Compositions	28

Table 13: International ranking of South Africa according to technology class

Country	*Number of patents*	*Percentage*
USA	43	37
Germany	22	19
UK	18	15
Australia	8	7
Canada	7	6
Switzerland	5	4
Netherlands	4	3
France	3	3
Sweden	2	2
South Korea	2	2
Poland	1	< 1
Ireland	1	< 1
Israel	1	< 1
Total	**117**	**100**

Table 14: Number of patents with co-inventors from other countries: SA 2000-2004

First Named Assignee	*2000-2004*	*1969-2004*
SA Invention Development Corp	0	80
AECI	1	41
CSIR	8	36
Rotary Profile Anstalt	0	32
SASOL Tech Ltd	29	31
MINTEK	3	21
Tobacco Research and Development Institute	1	19
Technology Finance Corp	5	17
Circuit Breaker Industries Ltd	2	17
DENEL	6	14
WRC	6	14
Windsor Tech Ltd	11	11
Implico BV	5	9
ESKOM	4	8
Ipcor NN	6	6
SASOL Chemical Industries	1	6
Sentrachem Ltd	0	6
Supersensor Ltd	6	6
University of Pretoria	3	6
Claas Selbstfahrende Entemaschinen GMBH	5	5

Table 15: Companies appearing as first assignees in the set of South African patents during 2000-2004 and during 1969-2004

Table 16 shows the number of South African PCT international applications. The table shows that even though more than 300 inventors utilise the service, less than half go ahead to protect their invention through an application in an international patent office. While there are a number of different reasons for this gap (e.g. applications are identified as deficient, patents are applied for through other patent offices, etc) it is interesting from a policy perspective to identify the reasons behind the reluctance of inventors to proceed and protect their intellectual property.

Year	*Number of applications*
1997	84
1998	114
1999	317
2000	387
2001	419
2202	384
2003	357
2004	410
2005	360

Table 16: Number of PCT applications filed by South Africans, by date of filing

4. SUMMARY AND DISCUSSION

This article aims to identify and analyse the inventive activity of South African institutions. Inventive activity is analysed in terms of patents awarded to South African inventors by the USA Patent Office. As Griliches [3] has pointed out, "patent statistics remain a unique source for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and potential industrial, organizational, and technological detail".

Our analysis indicates that South Africa has produced a constant stream of patents through the USPTO during the last 15 years. The technological class 518, 'Chemistry: Fischer-Tropsch Processes; or Purification or Recovery of Products Thereof', appears to be the most inventive for South Africa. South Africa shares fourth position with France in that class. The Fischer-Tropsch process was developed by the German researchers Franz Fischer and Hans Tropsch, working at the Kaiser Wilhelm Institute in the 1920s. SASOL is one of only a few companies that have commercialized the Fischer-Tropsch technology.

South Africa occupies 12th position in class 075, 'Specialised Metallurgical Processes…'. Those technologies constitute the country's technological strengths, and government has the opportunity, in the national interest, to build upon them as technological platforms.

We further identified the most prolific SA companies in terms of patents, and the countries with which SA collaborates in the production of inventions.

An important finding is that South Africa appears not to have participated in the international explosion of patents during the last 15 to 20 years. During the past two decades most of the industrialised countries have experienced a substantial increase in patenting activity.

Two hypotheses have been offered to explain that increase: the pro-patent policy hypothesis [13]; [14] and the fertile technology hypothesis [15]; [16]; [17;]. Merges [13] has suggested that the jump in patenting activity reflects an increase in the propensity to patent inventions, driven by changes in the legal environment for patent holders. The recent international surge in patent applications may be a direct consequence of a major

institutional change. Since the 8th round of General Agreements on Tariffs and Trade (GATT), industrialized countries have changed their standards for protecting intellectual property via patents. The changes have not only broadened the rights of patentees, but have also strengthened the protection of intellectual property rights. These changes have been widely regarded as 'pro-patent', and, it has been argued, they are reflected in the increase in patent filing [17].

A different explanation for the recent jump in patenting stresses the type of technological revolution that has been widening the set of technological opportunities [16]. Connected with this is the explosion of new firm formation and innovation in the high-technology sector, particularly in the biotechnology, information technology, and software industries. Further, the application of information technology to the discovery process itself may have substantially increased the productivity of research and development [15]. Another possibility is that changes in the management of R&D facilities, in particular a shift to more applied activities, have increased the yield of patentable innovations [18]. Still another possibility is that the increased level of patenting activity is the result of an overall increase in inventive input (higher levels of R&D and/or changes in the composition of R&D). The above set of ideas can be grouped together as the 'fertile technology hypothesis' to explain why patenting has surged.

As no substantial increase can be detected in the number of South African patents, it is reasonable to suggest that neither the policy environment nor factors determining technological fertility (as mentioned above) have changed in South Africa during the last two decades.

There are a variety of reasons that can be offered as possible explanations for the inability of the country to increase its number of patents in the USA market. Some of these are: the high cost of protection in the USPTO; the small number of large companies; the lack of high technology industries and research in the country; the orientation towards other sources of funding for universities and research councils; and others.

The Department of Science and Technology is currently introducing new legislation in order to address some of the above concerns. It will be important to monitor the effect that the introduction of the South African Intellectual Property Rights from Public-Financed Research Bill will have on inventive capacity in the country. However, it should be emphasized that the Bill affects only publicly-financed research and, as we discussed, the majority of patents internationally are produced by private organisations.

Finally, comparison of the various indicators identifies promising areas for further research. For example, we identify that a number of inventors utilise the PCT services, but only a limited number of them go ahead to apply for patents. Similarly a number of companies that were prolific patent holders in the past have stopped applying for patents. Why should that be? Answers to that question have the potential to provide policy insight and guidance.

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