Science in South Africa: The dawn of a renaissance?

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This article reports the findings of a scientometric analysis of South Africa's research performance during the period 2000–2010. A multitude of government incentives were introduced during the period and their effects have appeared in the country's research outputs. In contrast to earlier investigations, it was found that South Africa's world share of publications is on the verge of reaching the highest contribution ever. South Africa improved its international ranking by two positions during 2000–2010 and was ranked 33rd in the world during 2010. It is argued that, provided the plan of the Minister of Science and Technology to increase the research and development expenditure in the country materialises, South Africa may be on the verge of a scientific renaissance.

Introduction

Science in South Africa has been the subject of a multitude of changes during the most recent 10 years. At the beginning of the decade (2001), social sciences researchers were introduced to the evaluation and rating system of the National Research Foundation (NRF).[1] They joined natural science researchers and engineers in the evaluation and rating system of researchers in higher education that is based solely on previous performance and outputs in research. The Department of Science and Technology (DST) introduced the Ten-year Innovation Plan in 2007,[2] and established the Technology Innovation Agency and the South African National Space Agency during 2008. The *Intellectual Property Rights from Publicly Financed Research and Development Act, 2008* (*Act No 51 of 2008*) was also promulgated in 2008.

The DST Ten-year Innovation Plan[2] sets high objectives for the innovation system in the country. The plan outlines the following vision for South Africa:

- Becoming one of the top three emerging economies in the global pharmaceutical industry, based on an expansive innovation system using the nation's indigenous knowledge and rich biodiversity
- Deploying satellites that provide a range of scientific, security and specialised services for the government, the public and the private sector
- Achieving a diversified, supply secured sustainable energy sector
- Achieving a 25% share of the global hydrogen and fuel cell catalysts market with novel platinum group metal catalysts
- Becoming a world leader in climate science and the response to climate change
- Meeting the 2014 Millennium Development Goals to halve poverty

Similarly, the Department of Education introduced the New Funding Formula (NFF) for higher education institutions. The NFF was published in the *Government Gazette* (no. 1791) on 09 December 2003 and was implemented in the 2004/2005 financial year. According to Steyn and De Villiers[3], the NFF financially supports the higher education institutions according to their research outputs (number of publications and number of postgraduate students produced).

The pinnacle of all initiatives probably was the DST Strategic Plan for Fiscal Years 2011–2016, which was accompanied by a statement by the Minister of Science and Technology, namely that 'South Africa will be able to spend R45 billion on research and development by 2014 and reach its target for gross expenditure on research and development of 1.5% of GDP'[4]. It should be mentioned that the DST indicated that during 2008/2009 (the most recent year for which figures exist), the country spent R21 billion or 0.92% of GDP on research and development.[5]

The above initiatives should be seen in the context of past assessments, which invariably had identified a decline in the country's science outputs. In a 1996 assessment by Pouris[6], he commented, 'It is an unfortunate irony that South Africa was relatively strong in science at a time when this activity was less crucial than it is today in determining economic performance and international competitiveness'. Similarly, after an investigation during 2003, Pouris[7] stated that 'the country's publications are losing ground to scientifically emerging countries in Asia, South America and Europe and the decline in the late 1980s continues to characterise South Africa's science'. Tijssen[8] also confirmed the above findings.

This article aims to identify the country's science performance to the year 2010 as the various incentives start to affect the system. The questions that were asked are:

- How is South African science faring during the last 10 years as it is manifested in the number of publications with at least one South African address?
- How has South Africa's share of world publications changed during the recent decade?
- Which are the major scientific disciplines emphasised by the country's research system in terms of activity and impact?

Method

Bibliometric analysis is used internationally for the monitoring and assessment of research systems. The philosophy underlying the use of bibliometric indicators as performance measures has been summarised in De Solla Price's[9] 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'. The use of bibliometric indicators has a number of advantages. For example, they are consistent in the sense that they are clearly defined and unambiguous. They also allow categorisation, which makes it possible to quantify performance in particular scientific disciplines and to make international comparisons.

In the United States of America, the National Science Foundation[10] uses bibliometrics to monitor the health of American science and technology on a continuous basis; in Europe, the European Commission[11] uses similar approaches to monitor the health of the European innovation system and the Organisation for Economic Cooperation and Development[12] uses indicators for monitoring and comparative purposes. Similarly, following the example of Braun et al.[13], a number of research articles that are published annually assess research systems,[14,15] disciplines[16,17] and relationships in the research system.[18,19] Recently, Schmoch and Schubert[20] investigated the possibility of substituting peer review with bibliometrics in order to alleviate the difficulties of peer reviews. The uses of bibliometrics are wide and expanding.

A prerequisite for any bibliometric analysis is the use of an appropriate database. The ISI-Thomson Reuters databases (Science Citation Index Expanded, Social Sciences Citation Index and Arts and Humanities Citation Index) were identified as the most appropriate for the objectives of the investigation. The combined databases comprehensively cover the most prestigious journals in the world in all fields of research endeavour and constitute a unique information platform for the objectives of this effort.

While the ISI-Thomson Reuters databases are among the most comprehensive sources of readily accessible information on national research outputs, they have certain limitations that have been discussed extensively in the literature. Criticisms emphasise that ISI covers English language journals only; the coverage of countries in the scientific periphery is not adequate; the average statistics used for estimating the impact factors are inappropriate as citations do not follow a normal distribution; journal coverage is better in life sciences than in the physical sciences and others.[21,22]

However, for South Africa these databases are particularly appropriate, as there is an effort by educational authorities and university administrations to direct researchers to publish mainly in journals included in the ISI-Thomson Reuters databases. Although a degree of incompleteness in coverage may exist, the majority of research in the field will thus be captured in the databases.

The indicators reported for the assessment are the country's contribution in terms of the number of publications in the international literature, the country's share in the world literature, the activity index and the relative citation index.

The activity index is defined as the ratio of the country's share of the world publication output in a given field to the country's share of the world publication output in all science fields. An activity index of one indicates that the country's research output in the given field corresponds to the world average; an indicator larger than one reflects a higher than average emphasis in the field and vice versa. Similarly, a relative citation index above one indicates that the country's publications in the particular field attract more than average citations and an index of less than one indicates that the field attracts fewer citations.

South Africa's research performance

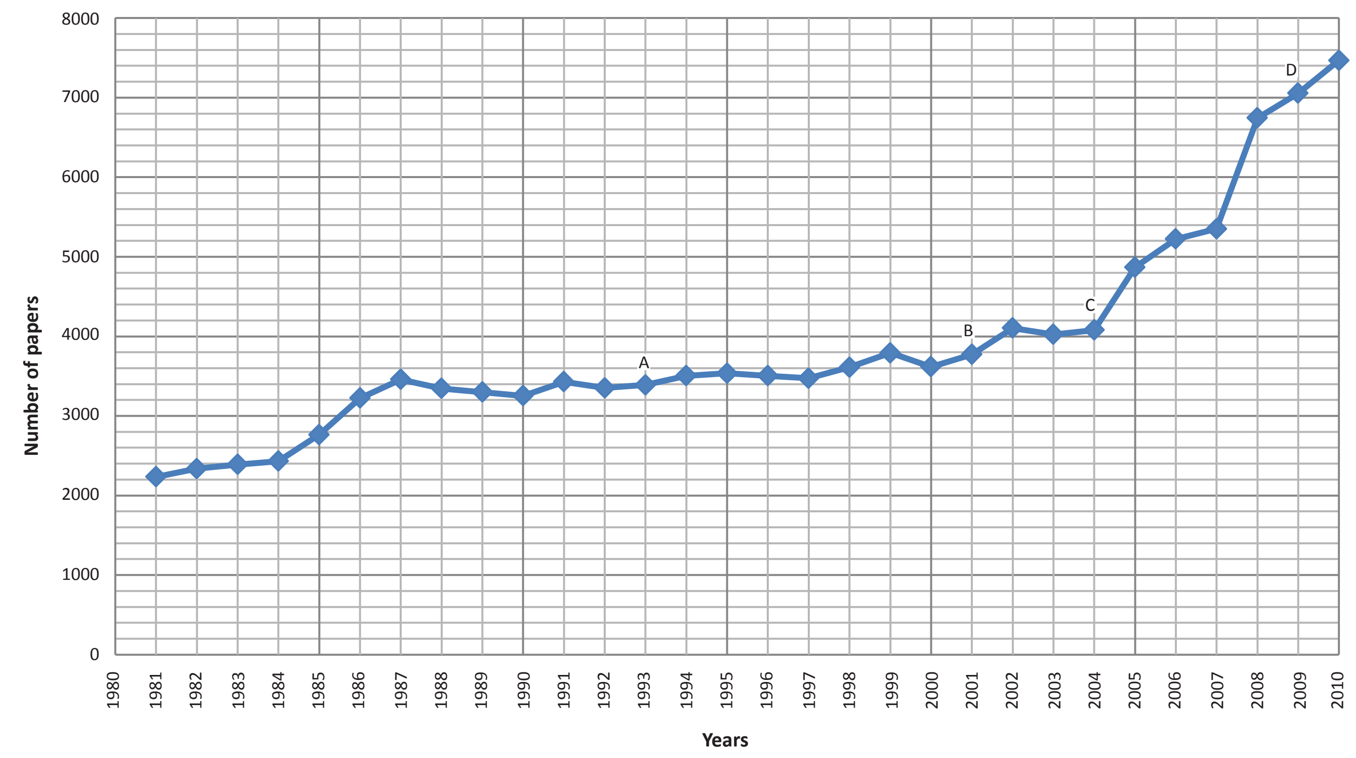
Figure 1 shows the number of South African publications for the period 1980–2010. After a long period of consolidating around 3500 publications per year, the number rose steeply between 2004 and 2010. In 2010, the database contained 7468 articles with at least one South African address.

Figure 2 shows the country's share of the world's publications for the same period. The share indicates a peak during 1987 (0.65%) and then a decline, which appears to have reached its lowest point in 2003 (0.47%). Since then, the share increased gradually to 0.65% in 2010 and reached the 1987 peak.

These figures should be seen in context. It has been argued that what is of importance in assessing a country's scientific research performance is its position in relation to its competitors[7]:

> A country may increase its number of publications and its world share, yet still lose ground in its scientific standing. Scientific competition is like running a marathon race. As long as the participant keeps running as fast as or faster than the other runners, he or she may stay in the leading group and competitors will have to keep trying to catch up. If, however, the researcher (or discipline) slackens off, the rest of the field will pass and he or she will join the strugglers.

The above point is shown in Table 1. Table 1 shows that South Africa was ranked 35th in the world in terms of its number of research publications during 2000. In 2010 South Africa was



A, sanctions were lifted; B, social sciences were incorporated under the National Research Foundation; C, the new funding formula was introduced; D, the number of South African journals indexed by ISI was increased.

FIGURE 1: Trend in South African publications (1981–2010) amidst policy interventions.

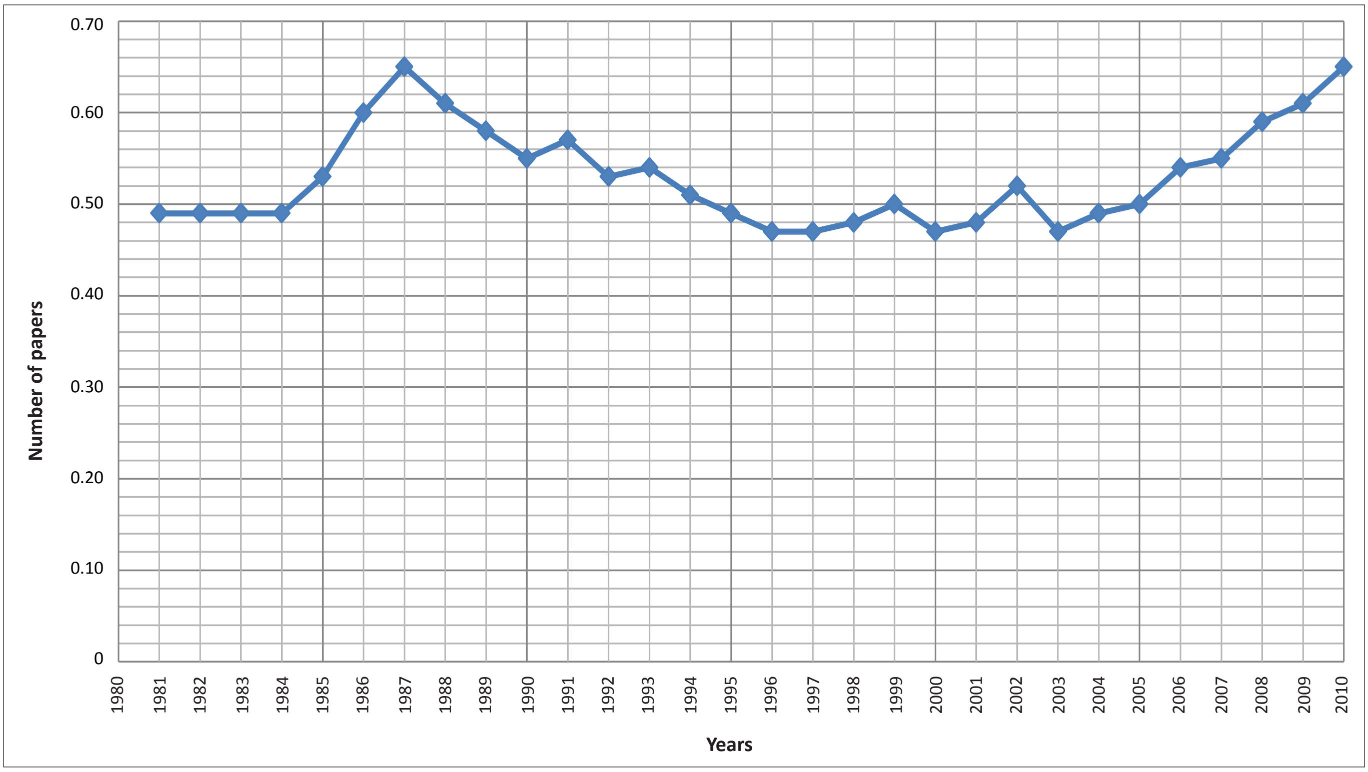


FIGURE 2: South Africa's share of world publications in all fields, 1981–2010.

ranked 33rd – an improvement of two positions – although the country more than doubled its number of publications. During that period South Africa overtook Argentina, New Zealand, the Ukraine and Hungary, but Portugal and Iran overtook South Africa in the same period.

From Table 1, it is interesting to note that the BRIC (Brazil, Russia, India and China) countries are all scientifically stronger than South Africa in terms of scientific knowledge produced. In 2010 China produced 124 822 publications, India 40 711, Brazil 31 274 and Russia 26 374. During that year, South Africa produced only 7468 publications. While South Africa has become the fifth member of the group, any efforts for scientific collaboration should take into account the differences in scientific capabilities.

The performance of the country's main scientific disciplines was also investigated. Table 2 shows the world share and activity indices of 22 scientific disciplines for the two periods 2000–2004 and 2006–2010. Only three scientific disciplines exhibited a decline in their world share over the period – Geosciences, Molecular Biology and Multidisciplinary. Plant and Animal Sciences remained static, contributing 1.57% of the world literature.

The activity indices for 2006–2010 show that Space Science, Immunology and Social Sciences have moved into the fields of revealed priorities that are overemphasised in the country (activity index above one). However, a number of important disciplines like Materials Science, Molecular Biology and Engineering are underemphasised.

In comparison with the findings during the 1990s,[7] Social Sciences appear to be the discipline with the highest growth. This field grew from a world share of 0.52% during 1990–1994 to 1.22% during 2006–2010.

Table 3 shows the relative citation index (an indicator of research quality) of the various disciplines for the periods 2000–2004 and 2006–2010. An index of one means that the average South African article in the particular discipline attracted the same number of citations as the average article in the discipline in the world. Only three disciplines out of 22 appear to have deteriorated during the period – Computer Science, Molecular Biology and Psychiatry/Psychology. The country's relative citation index has increased from 0.69 during 2000–2004 to 0.88 during 2006–2010.

Discussion

South Africa's scientific performance during the period 2000–2010 was analysed. The analysis identified that research publications in South Africa are on an ascending path. The country's world share of publications is on the verge of reaching its highest contribution in history. Finally, the country improved its international ranking by two positions during the period, and was ranked 33rd in the world during 2010.

It is interesting to briefly discuss the forces that contributed to the growth of science in South Africa.

Kahn[23] investigated the country's publications for two periods (1990–1994 and 2004–2008) and suggested that the growth during the period was the result of a multiplicity of factors. He stated:

> There are greater rewards for publishing; there is a shift toward health science fields with high publication rates, there are more South African journals indexed by the Web of Science in which to publish, there may be more PhD students available to assist with research and the system is more open for co-publication with foreign parties.

TABLE 1: Country ranking according to number of publications in 2000 and 2010.

Country	Ranking		Publications	
	2000	2010	2000	2010
USA	1	1	255 099	330 339
Japan	2	5	72 029	72 607
UK	3	3	71 775	90 004
Germany	4	4	67 272	86 978
France	5	6	48 065	62 324
Canada	6	7	33 649	53 519
Italy	7	8	31 157	50 691
Russia	8	15	28 629	26 374
China Mainland	9	2	24 566	124 822
Spain	10	9	22 230	43 693
Australia	11	12	21 386	38 753
The Netherlands	12	14	19 169	30 532
India	13	10	16 538	40 711
Sweden	14	19	15 055	19 770
Switzerland	15	17	14 185	21 960
South Korea	16	11	13 448	39 397
Brazil	17	13	10 465	31 274
Belgium	18	21	9977	16 535
Poland	19	20	9751	19 192
Israel	20	24	9678	11 574
Taiwan	21	16	9652	23 715
Denmark	22	23	7900	11 702
Finland	23	27	7494	9777
Austria	24	25	7105	11 284
Turkey	25	18	5303	21 846
Norway	26	28	4896	9227
Greece	27	26	4876	10 105
Mexico	28	29	4862	9170
New Zealand	29	34	4465	7172
Argentina	30	35	4402	7123
Czech Republic	31	32	4322	8684
Ukraine	32	43	4306	4422
Hungary	33	41	4105	5061
Singapore	34	31	3634	8811
South Africa	35	33	3617	7468
Portugal	36	30	3141	8975
Ireland	37	36	2697	6492
Egypt	38	39	2290	5386
Romania	39	37	1955	6356
Chile	40	42	1906	4623
Slovenia	41	45	1616	3193
Pakistan	45	44	620	4232

Figure 1 also shows the timeline of a number of interventions or changes that may have affected the country's publication performance. The introduction of social sciences researchers into the NRF's scope, the increase in the number of publications covered by the ISI-Thomson Reuters databases and the provision of incentives by the Department of Education to universities are some of the important instruments that were introduced during the period.

Inglesi-Lotz and Pouris[1] used the 'before/after control impact (BACI) method' in order to identify the impact of the NRF researcher rating system on the Social Sciences publications in the country. They found that the number of Social Sciences' publications in South Africa was increased by 24.7% after 2001 because of the NRF's evaluation and rating system. While the authors explained the increase to be

TABLE 2: South Africa's world share and activity indices by discipline.

Discipline	2000–2004		2006–2010	
	World share	Activity index	World share	Activity index
Agriculture Science	0.58	1.18	0.70	1.19
Biology and Biochemistry	0.35	0.71	0.54	0.92
Chemistry	0.31	0.63	0.39	0.66
Clinical Medicine	0.40	0.82	0.45	0.76
Computer Science	0.22	0.45	0.28	0.47
Economic and Business	0.46	0.94	0.86	1.46
Engineering	0.32	0.65	0.38	0.64
Environmental/Ecology	1.26	2.57	1.39	2.36
Geosciences	1.19	2.43	1.09	1.85
Immunology	0.49	1.00	1.09	1.85
Material Sciences	0.25	0.51	0.28	0.47
Mathematics	0.46	0.94	0.58	0.98
Microbiology	0.57	1.16	0.78	1.32
Molecular Biology	0.25	0.51	0.24	0.41
Multidisciplinary	2.93	5.98	1.60	2.71
Neuroscience and Behaviour	0.17	0.35	0.22	0.37
Pharmacology and Toxicology	0.39	0.80	0.42	0.71
Physics	0.24	0.49	0.28	0.47
Plant and Animal Science	1.57	3.20	1.57	2.66
Psychiatry/Psychology	0.45	0.92	0.69	1.17
Social Sciences, General	0.76	1.55	1.22	2.07
Space Science	0.89	1.82	1.05	1.78
Overall country	**0.49**	-	**0.59**	-

TABLE 3: Relative impact of South African publications during 2000–2004 and 2006–2010.

Discipline	Relative impact	
	2000–2004	2006–2010
Agriculture Science	0.74	0.82
Biology and Biochemistry	0.56	0.81
Chemistry	0.65	0.70
Clinical Medicine	0.86	1.15
Computer Science	1.10	0.90
Economic and Business	0.38	0.40
Engineering	0.81	0.85
Environmental/Ecology	0.83	0.95
Geosciences	0.79	0.89
Immunology	0.71	1.09
Material Sciences	0.76	0.77
Mathematics	0.82	1.12
Microbiology	1.00	1.27
Molecular Biology	0.79	0.76
Multidisciplinary	0.36	0.41
Neuroscience and Behaviour	0.63	0.71
Pharmacology and Toxicology	0.58	0.70
Physics	0.71	0.93
Plant and Animal Science	0.72	0.93
Psychiatry/Psychology	0.67	0.61
Social Sciences, General	0.81	0.86
Space Science	0.77	1.35
Overall country	**0.69**	**0.88**

as a result of the inclusion of the Social Sciences, it should be mentioned that this discipline contributed only 10.6% to the country's publications (2008). An estimation of the number of South African publications published in the journals added in the databases during 2008 (700 additional journals) by ISI-Thomson Reuters, indicates that this contribution is approximately 450 articles per year.

Kahn[23] speculated that increased collaboration of South African researchers with those abroad is also an important factor. However, the collaboration argument cannot explain the radical increase in the number of publications after 2004. International collaboration increased from 7.9% of the total number of SA articles in 1980 to 47.2% during 2010. However, most of the growth took place during 1990–1995 and 1995–2000.

The across-the-board increases in the number of publications suggest that the increases were the result of a factor which was introduced during the early 2000s and affected all scientific disciplines.

The obvious intervention appears to be the NFF for higher education institutions. The new funding framework for higher education institutions was published in terms of the *Higher Education Act, 1997* (*Act No. 101 of 1997*), in the *Government Gazette* (No. 1791) on 09 December 2003. The new funding framework was implemented in the 2004/2005 financial year.

The NFF financially supports the higher education institutions according to their research outputs (number of publications and number of postgraduates).[3] Universities receive approximately R120 000 (US$17 000) for each article a staff member produces. Universities, in turn, provide incentives to their members of staff to improve their publication profile.

It should be mentioned that the funding system has a long history. Reynhardt[24] has identified that the country's research system was suffering from three challenges in the 1970s: resources for research and development were limited; the higher education system did not produce enough graduates and there was an emphasis on teaching among academic staff. It was in that environment that the funding of universities was linked to a funding formula as suggested by Melck[25].

It becomes apparent that the particular policy instrument has yielded the desirable effect – an increase in the number of the country's publications. It should be emphasised, as we mentioned earlier, that since the early 1980s, the government has funded universities at least partially according to their research outputs. However, it seems that the amount allocated for research publications reached a critical threshold only during the 2000s. Similarly, the universities started to transfer the incentive to individual authors only recently.

The funding formula is not perfect by any means and a number of critiques have been published [26,27] A recent article[28] provides a list of problems and shortcomings and even suggests alternatives to the current system. Addressing a number of these problems would provide further impetus to the system. For example, Vaughan[28] has identified that 'there are six institutions which earn a greater development grant than actual grant, thus establishing a perverse incentive'. Similarly, it is mentioned that differences in publication patterns among disciplines are not recognised by the formula. Obviously, if the Department addressed these concerns appropriately, the funding formula would become a more potent instrument.

Provided that the existing incentives continue and the plan of the Minister of Science and Technology to increase the research and development expenditure in the country materialises, South Africa may be on the verge of a scientific renaissance.

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Competing interests

I declare that I have no financial or personal relationships which may have inappropriately influenced me in writing this paper.

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