Jointly published by Akadémiai Kiadó, Budapest
and Kluwer Academic Publishers, Dordrecht

Scientometrics,
Vol. 59, No. 3 (2004) 405–423

South African research in selected scientific areas: Status 1981–2000

PETER INGWERSEN,[a] DAISY JACOBS[b]

[a] *Department of Information Studies, Royal School of Library and Information Science, Copenhagen (Denmark)*
[b] *Department of Information Science, University of Pretoria, Pretoria (Republic of South Africa)*

The paper is a bibliometric study of the publication and citation patterns and impact of South African research 1981-2000 in five selected research fields: Animal & Plant sciences; Chemistry; Biochemistry; Microbiology & molecular biology, including genetics; and Physics, excluding Space science. Data are collected from Science Citation Index via the ISI product National Science Indicators. With the exception of Microbiology & molecular biology and Physics the results demonstrate a decrease of SA publications from 1986–1990. The SA world share declines for all five fields. First from the period 1994–1998 the Animal & plant sciences and Microbiology & molecular biology turn the decline into an increase.

Absolute citation impact is increasing for all the fields from 1989–1993, except for Chemistry. One reason for the increase is a lower publication output. General & internal medicine, as an supplementary volume-heavy field observed, declines in citations until that same period from which it becomes stable, also in impact, but with a marked decrease in cited paper proportion.

In citation world shares the five fields combined show positive signs also since 1989–1993, after which period the international eco-political embargo of SA was lifted. However, Biochemistry and Chemistry continue to decline during the 1990s. Citation impact relative to the world shows a similar pattern, but stagnation appears towards the end of the 1990s in all the observed fields combined. The trends are quite similar to those of Mexico and New Zealand. It is thus highly uncertain if a general citation embargo of SA occurred; yet, in some fields like the Animal & plant sciences, Veterinary science, Chemistry, and General & internal medicine there are signs that a mild citation embargo might have occurred. However, the economic embargo, combined with a significant brain drain, may have had an effect on the publication productivity, after it was lifted. For all indicators Chemistry is undergoing a marked decline during the last decade. This is in line with the negative trends for General & internal medicine, whereas some other medical specialities, biology, economics and other social sciences, the engineering fields and materials sciences keep stable or increase their production. SA is in line with the Mexican development but below that of New Zealand, seemingly losing ground to the developed countries.

Received December 22, 2003

Address for correspondence:
PETER INGWERSEN
Department of Information Studies, Royal School of Library and Information Science
Birketinget 6, DK-2300, Copenhagen S, Denmark
E-mail: pi@db.dk

0138–9130/2004/US $ 20.00

Introduction

Scientific activities have been growing tremendously in most of the third-world countries. Saracevic[1] reckoned that the rate of scientific activities in most developing countries had been tripling compared with the doubling tempo in the developed countries. Odeinde[2] and Alabi[3] have argued that while scientific and technical activities have increased, little or no attention has been paid to the need for a corresponding increase in spending on scientific information. Although their argument is almost two decades old and referred specifically to the Nigerian situation, the situation is similar if not getting worse, for the rest of Africa. Very recently, Narvaez-Berthelemot et al.[4] and Gaillard[5] raised the same concern when analysing 15 African countries' research production in S&T domains. The latter deems the situation very critical, with S&T systems and the working environments of scientists deteriorating in many countries. Already in 1983 this phenomenon also gave rise to an observation by Garfield[6] that most scientists in the west are not aware of the research that goes on in countries collectively called the "third world". What they do know about third world science, explained Alabi,[3] is dominated by the research of one or two third world research superpowers – India and Argentina.

This observation is quite appropriate for South Africa, which, in essence, has been described as both first and third world. One reason for this could be that scientists from some of these third world countries fail to publish the results of their research altogether or may not do so in reputed international journals. This is also true about South Africa, which, although it has a lot of scientific research and production, in addition was internationally "closed off" during a period up until 1994. This state of affairs meant that less became "known" overseas. Scientific research and publications are the backbone of any country, more so for a developing country like South Africa.

Comprehensive bibliometric studies have frequently been carried out in other parts of the world, some few including South African research compared to other countries. In a very recent snapshot study of twelve central scientific areas 30 countries are compared, including South Africa as the sole African representative.[12] Prior to that analysis only one larger study has been carried out in South Africa.[7] That investigation covered the 16 year period 1981–1996 with respect to four large areas of science, as defined by the National Science Indicators Database, standard version, produced by the Institute for Scientific Information (ISI), USA: Physics, including mathematics and astrophysics (space science); Chemistry, including organic and inorganic, nuclear and physical chemistry as well as chemical engineering; Plant and Animal Sciences, including veterinary medicine; and Biochemistry/Microbiology which incorporated

molecular biology and general biology. These broad fields covered approximately 43 percent of the total scientific output from South Africa.* The main observations from that study were: 1) a steady decline in productivity and world shares for most of the scientific fields, except for Physics, including mathematics and astrophysics. In particular the Plant and Animal Sciences suffered negative growth during the 1990s. However, the quality of the publications from South Africa, in terms of relative citation impact, increased since 1989–1993 and was expected to reach the level obtained during the 1980s around 1998. Also the actual number of citations given to SA papers did grow to a maximum obtained 1992–1996, and the citation world share seemed quite stable from 1989–1993.

The present paper seeks to investigate the entire period 1981–2000, in order also to observe the trends from 1996 and onwards, and to investigate the expectations mentioned above on absolute and relative citation impact in the selected fields as well as for those sciences combined. We have selected a number of narrow but central scientific fields to be studied, representing the same broad areas as in the previous study:[7] Animal sciences and Plant sciences; Chemistry proper; Biochemistry; Microbiology and Molecular biology, including genetics; and Physics proper. Where appropriate the field scores are compared to other scientific SA disciplines, and the SA trends are compared to those of Mexico, representing a developing country, and New Zealand, representing a developed country. The research activities of both countries are, except for a higher volume of Physics in Mexico, comparable in volume to that of SA.

The paper is organised as follows. First, the methodology is described, followed by the results of the analysis. Initially, the publication trends and publication world shares 1981–2000 are shown for the five fields and their combination. Secondly, the same analyses are carried out for the citations. Other comparative fields, like General and internal medicine, Biology general, Space science, and Veterinary medicine, are shown with respect to publications, citations and impact. Third, the citation impact in absolute terms as well as relative to the world is shown, followed by the ratios of cited papers for SA 1981–2000. The next section discusses the results in the same order as well as comparatively, and the paper ends with concluding remarks.

* Due to an error during the data processing in that contribution[7] (Table 1, p. 79) the published publication numbers for the Biochemistry & Microbiology area became exaggerated and should be disregarded. The analysis only covers 43% of the total SA output – not 70% as stated. The remaining results and trends shown and discussed in the article, however, are valid.

Methodology

The National Science Indicators Database (NSI), deluxe version 1981–2000, made by ISI 2001, was used to collect data for the study. NSI indexes Science Citation Index as well as the two other ISI citation databases on Social Sciences and the Humanities. In contrast to other available versions of Science Citation Index each journal, and their articles, notes and reviews in NSI are generally assigned only one subject category from *Current Contents*. The country affiliations for all the authors are indexed and it becomes thus possible to cross-tabulate research fields and disciplines by countries in relation to publications and received citations over time. The deluxe version of NSI offers 105 more narrow scientific research categories than does the standard version (with only 24 categories) that was used in the earlier study covering 1981–1996.[7] For instance, Physics in the present contribution does not contain mathematics and space science (astrophysics), but is Physics proper. From the broad Animal & Plant Science area are chosen the Animal science and Plant science categories in NSI deluxe version. From the Chemical science area is selected Chemistry proper. We have selected Biochemistry as an independent field and Microbiology & molecular biology, including genetics, as another independent field, both taken from the broad area of Biochemistry & Microbiology in the standard NSI version. Hence, scores in the present investigation do not correspond to the results obtained in the earlier study, but the trends are similar. The present analysis of the five selected standard fields covers approximately 21% of the total SA scientific output from all fields, including the humanities and social sciences, i.e., half of the population of the previous study.[7]

In NSI there exists four baselines: The World; European Union; Latin America; and Asia-Pacific. In those regions all the country overlaps of articles have been eliminated to form a true baseline to which single countries can be related. However, one should be aware that NSI operates within the ISI citation landscape, that is, only citations given by ISI source journals to ISI source journals are counted. The development of publications and citations over time depends thus of which journals that actually form part of that landscape.

Four scientometric indicators are applied to the South African (SA) publication activity and citation impact for the period 1981–2000, covering the five scientific disciplines mentioned above. 1) The actual number of SA papers published in the central journals indexed by NSI, i.e., Science Citation Index, in running five-year periods. One may hence observe trends in the growth rate associated with each discipline; 2) the proportion in percent of South African papers per discipline as well as for the five fields combined, relative to the world output; 3) the proportion of citations

given to South African papers over the period, and relative to the world. This ratio indicates whether this proportion follows the same pattern as the field in general. When compared to the SA publication world share for identical periods one may detect if changes in citation impact relative to the field impact is caused by the publication or the citation factors, respectively; 4) the absolute SA citation impact as well as relative to the impact of New Zealand, Mexico and the world for each discipline, as well as for the five disciplines combined. When calculating the impact relative to the world, i.e., to the relevant field, the calculation follows that of May,[8] i.e., $(c/p)/(C/P)$: c denotes the number of citations received by SA publications p for a given period in a field, divided by the world impact of that field, that is, the number of citations C received by the field divided by the number of publications P published in the world in the same research field during the same period. When appropriate, supplementary major SA fields of science, like Medical fields or Engineering, are compared to. This addition brings the total analysis to cover more then 35% of the SA output 1996–2000; 5) finally, we observe the percentage of SA papers cited at least once for the entire period. This is carried out to observe how broad the citation base actually is for each field.

Results

First we display the results of the development for the SA research production in the five scientific fields, in order to observe if the growth in SA follows the trends of the fields at world level. This is followed by citation analyses, impact studies and cited paper analysis.

Analyses of the South African publications

The growth rate for the South African publications in all five areas is 48% against 36% by the world during the entire period of 1981–2000. However, there has been some draw backs concerning the SA developments during that period, see the figures in bold, Table 1. These points of decreased productivity largely centre on the period of international economic embargo from the mid-1980s to 1994 and beyond in some of the investigated fields. Some decrease in production is thus observable in the later years; but basically the productivity is from then on rather stable for all five fields combined.

Table 1. Production of South African papers 1981–2000 in five scientific areas and in the total of all sciences (Source: NSI, ISI, 2001)
Figures in **bold** signify negative growth

	Anim. & Plant	Biochemistry	Chemistry	Microbiol. & Mol. Biol.	Physics	All 5 fields	All sciences
1981-85	1406	247	318	308	285	2564	12145
1982-86	1597	268	341	359	341	2906	13146
1983-87	1794	294	347	403	377	3215	14292
1984-88	1930	312	348	461	406	3457	15255
1985-89	2116	333	**341**	503	421	3714	16147
1986-90	2241	**319**	**320**	548	436	3864	16648
1987-91	**2215**	**305**	**314**	559	437	**3830**	16867
1988-92	**2210**	**287**	**288**	**555**	443	**3783**	**16821**
1989-93	2299	294	295	565	456	3909	16877
1990-94	**2229**	**276**	314	570	504	**3893**	17102
1991-95	**2186**	272	327	576	526	**3887**	17399
1992-96	**2150**	**256**	332	598	534	**3870**	17423
1993-97	**2079**	**244**	349	613	536	**3821**	17462
1994-98	**1995**	**216**	**345**	627	562	**3745**	17615
1995-99	**1991**	**211**	**337**	640	574	3753	17817
1996-00	2022	**207**	**329**	681	**554**	3793	17866

With respect to world shares the SA article production demonstrates a steady decline from 1989–1993 for all fields combined (Figure 1) as well as for, in particular, the Animal & plant sciences and Biochemistry, ending 1994–1998 with a turn into a small increase.

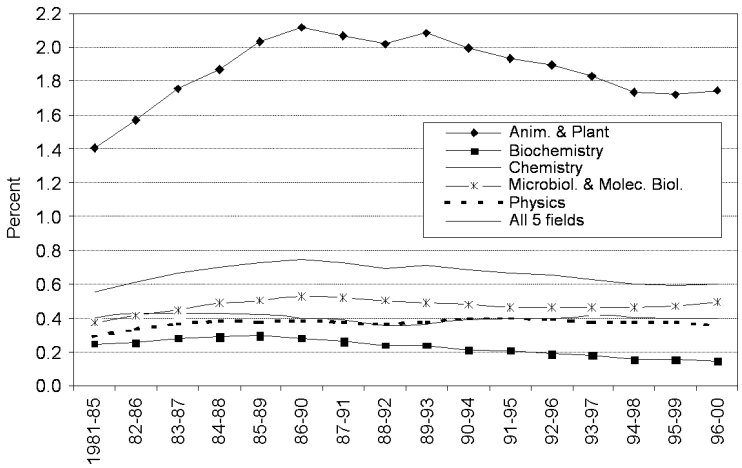

Figure 1. South Africa: World shares of papers 1981–2000 (Source: NSI, ISIS, 2001)

Analyses of citations to South African research

The quality or recognition by (international) peers of the SA production, as assessed by obtained citations, is demonstrated in Table 2 that provides a somewhat more muddled picture with many fluctuations across the five research areas than the productivity analysis. We observe that in general the five areas cover 25% of all citations received by South Africa from 1984–1988 and onwards. During the last period 1996–2000, however, the citation growth reaches a stand still for the five areas combined. This is because the three areas of Animal & plant sciences, Chemistry and, in particular, Microbiology & molecular biology all drop in received citations.

While the Animal & plant sciences steadily increase their amount of citations from 1990–1994, Biochemistry shows a long period of decline starting in 1986–1990 and continuing with a few ups until recently. Chemistry demonstrates a stand still 1985–1993 and receives fewer citations in recent years. Even Physics has two periods of decline. Only Microbiology & molecular biology demonstrate a continuous increase until 1996–2000 in received citations. Significantly, all five fields of international stature receive their minimum of citations during the period 1987–1993. From that time on they experience a steady increase in citations. All the SA sciences combined demonstrate no draw back during the entire analysis period.

Table 2. Reception of citations by South African papers 1981-2000 in five scientific areas and in the total of all sciences (Source: NSI, ISI, 2001)
Figures in **bold** signify negative growth

	Anim. & Plant	Biochemistry	Chemistry	Microbiol. & Mol. Biol.	Physics	All 5 fields	All sciences
1981-85	1443	830	549	915	517	4254	19572
1982-86	1613	873	582	1223	664	4955	21297
1983-87	1780	**795**	569	1298	790	5232	22235
1984-88	1853	1029	656	1608	960	6106	24191
1985-89	2030	1166	**596**	1890	1015	6697	25985
1986-90	2062	**1078**	613	2094	1045	6892	26752
1987-91	2074	**1038**	**582**	2222	**891**	**6807**	27330
1988-92	**2039**	**970**	624	2274	1005	6912	28245
1989-93	**1945**	**947**	627	2297	1078	**6894**	28796
1990-94	2081	**896**	719	2475	1273	7444	30691
1991-95	2245	1006	**617**	2707	1408	7983	32059
1992-96	2695	**912**	726	2915	**1274**	8522	33736
1993-97	2852	**887**	**678**	3494	1404	9315	35194
1994-98	2882	928	698	3820	1470	9798	36970
1995-99	3082	**786**	**643**	3979	1626	10116	38903
1996-00	**3053**	1033	**581**	**3650**	1800	10117	40616

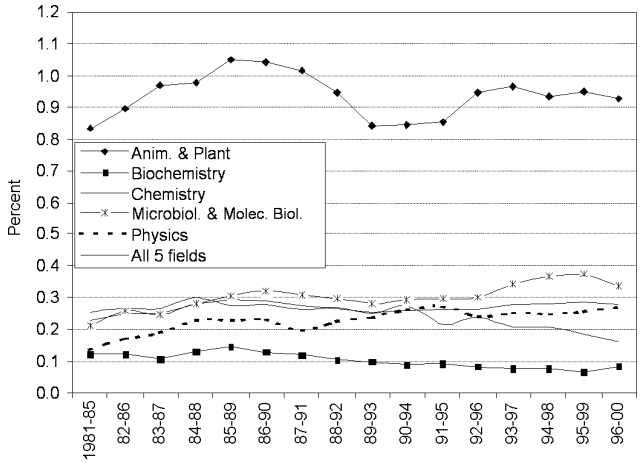

Figure 2. South Africa: World shares of citations 1981–2000 (Source: NSI, ISI, 2001)

Table 3. Publication, reception of citations and impact of South African papers 1981-2000 in five comparable scientific areas (Source: NSI, ISI, 2001)
Figures in **bold** signify negative growth

	Medicine, gen. & int.			Biology. general			Mat. Sc. & Eng.			Space sciences			Veterinary medicine		
	Imp.	Cit.	Pap.	Imp.	Cit.	Pap.	Imp.	Cit.	Pap.	Imp.	Cit.	Pap.	Imp.	Cit.	Pap.
1981-85	1.22	2848	2335	4.31	310	72	1.17	187	160	3.88	845	218	0.56	260	466
1982-86	1.30	3048	2342	4.64	418	90	1.23	243	197	4.25	999	235	0.65	289	448
1983-87	1.25	**2911**	2331	2.99	326	109	1.19	240	202	4.14	1147	277	0.77	347	453
1984-88	1.19	**2589**	**2172**	2.56	312	122	1.04	232	224	4.29	1235	288	1.26	643	511
1985-89	1.18	**2374**	**2016**	2.66	380	143	1.01	248	246	4.81	1477	307	1.31	722	553
1986-90	1.19	**2254**	**1887**	2.97	451	152	0.97	244	251	5.29	1667	315	1.19	**682**	575
1987-91	1.27	**2203**	**1738**	2.47	391	158	0.92	221	240	5.31	1620	**305**	1.23	723	590
1988-92	1.45	**2140**	**1479**	2.86	458	160	0.98	283	290	4.73	1437	**304**	1.42	825	**582**
1989-93	1.71	2222	**1301**	2.28	376	165	1.25	402	322	4.79	1470	**307**	1.20	**643**	**535**
1990-94	1.77	**2043**	**1151**	2.44	405	166	1.64	558	341	4.57	1514	331	0.96	**499**	**518**
1991-95	1.61	**1596**	**989**	2.76	480	174	1.75	624	356	4.77	1862	390	1.09	541	**497**
1992-96	1.79	1620	**903**	2.51	**461**	184	2.12	782	369	4.97	2009	404	1.08	545	504
1993-97	1.76	**1499**	**853**	2.70	483	179	1.89	**631**	**333**	4.90	2028	414	1.08	**525**	**488**
1994-98	1.88	1661	885	2.89	547	189	1.83	**563**	**307**	5.18	2279	440	0.99	**485**	489
1995-99	1.73	**1540**	891	3.77	721	191	1.67	**522**	**313**	5.51	2346	**426**	1.11	512	**460**
1996-00	2.21	1931	**874**	4.37	948	217	1.70	549	322	6.18	2404	**389**	1.31	601	**458**

Figure 2 shows the world shares of citations received by South Africa. For all the five scientific areas combined the development is positive since 1989–1993. It follows the world pattern. But the overall amount of citations received is quite small,

as we can detect in terms of low citation world shares for 4 out of the 5 areas – all constantly below the 0.40 percent. Only the Animal & plant sciences manage to cover nearly one percent of the world citations in those fields.

Table 3 displays the publication and citation volumes and the citation impact ratios for five alternative fields that are comparable in size and national importance to the standard scientific fields of the present analysis. The production heavy area General & internal medicine demonstrates patterns very similar to that of the Animal & plant sciences, Tables 1-2, with respect to publication and citation trends, except that its long and highly dramatic decline already initiates in 1984–1988 to continue into 1993–1997 as publications are concerned. During that period the output volume is more than halved. Veterinary medicine behaves also like the Animal & plant sciences, but in a less dramatic fashion. The Space sciences (formerly Astrophysics) follow the Physics trend. The remaining fields demonstrate stability or a steady increase during the entire period and thus contribute to the overall light increase of all the SA sciences, shown in Table 1. Other fields behaving similarly stable in publication volume are Economics (1989–1993: 135 – 1996–2000: 142), Sociology (134 – 142) and most other social sciences. Some medical fields like Cardiovascular & respiratory systems only decline vaguely (274 – 234) or, like Clinical immunology & infectious disease, rather explode in articles (86 – 219).

Citation impact analyses

Figures 3-5 demonstrates that SA and Mexico on average obtain similar citation impact ratios over the period 1988–2000 and constantly at a value below half of that of the world – Figure 6. In the most recent period, 1996–2000, the impact reaches almost 2.7 citations received per published paper on average for both countries. For New Zealand, the impact attains almost 4.2.

Figure 3 demonstrates the development across the five research areas for South Africa in absolute citation impact. One observes the relative high impact of Microbiology & molecular biology that is also quite high relative to the field – Figure 6. Biochemistry is also displaying a substantial impact over the years but constantly below that of New Zealand, Figure 5, and after 1987–1991 in line with that of Mexico – Figure 4. The trend for SA Physics is constantly positive and the Animal & plant sciences follow the trend of all five fields combined. Only Chemistry fails to pursue the same pattern by a constant decline in impact from 1992–1996 onwards.

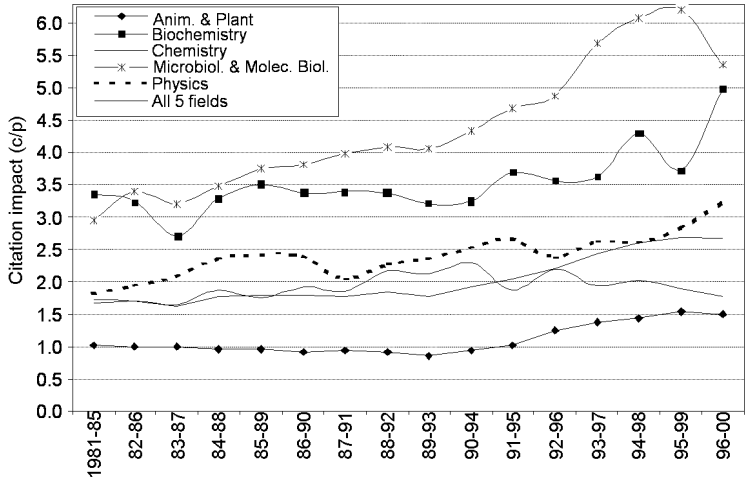

Figure 3. South Africa: Absolute citation impact 1981–2000 (Source: NSI, ISI, 2001)

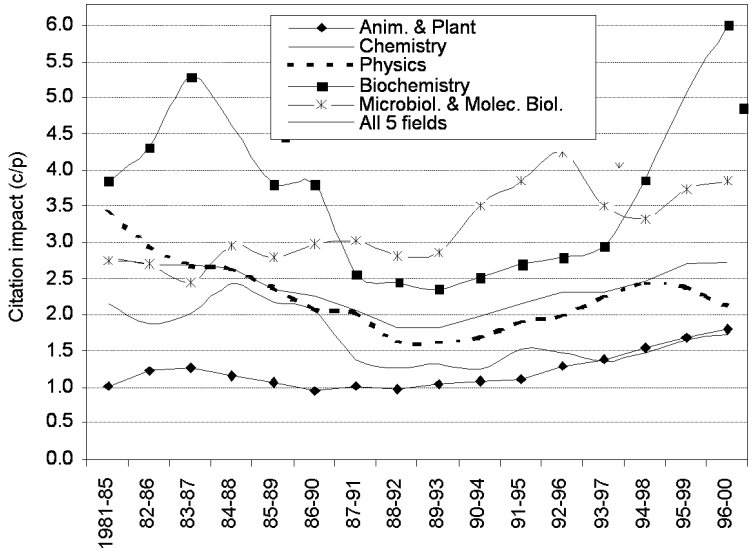

Figure 4. Mexico: Absolute citation impact 1981–2000 (Source: NSI, ISI, 2001)

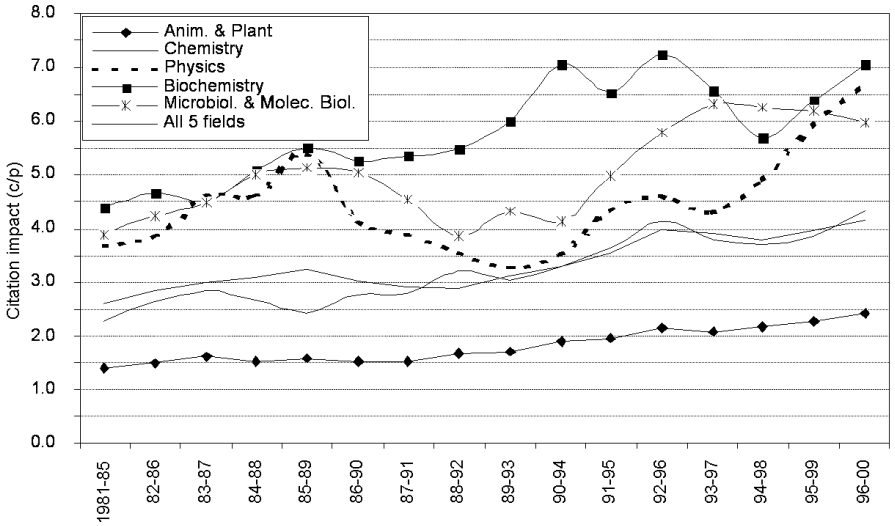

Figure 5. New Zealand: Absolute citation impact 1981–2000 (Source: NSI, ISI, 2001)

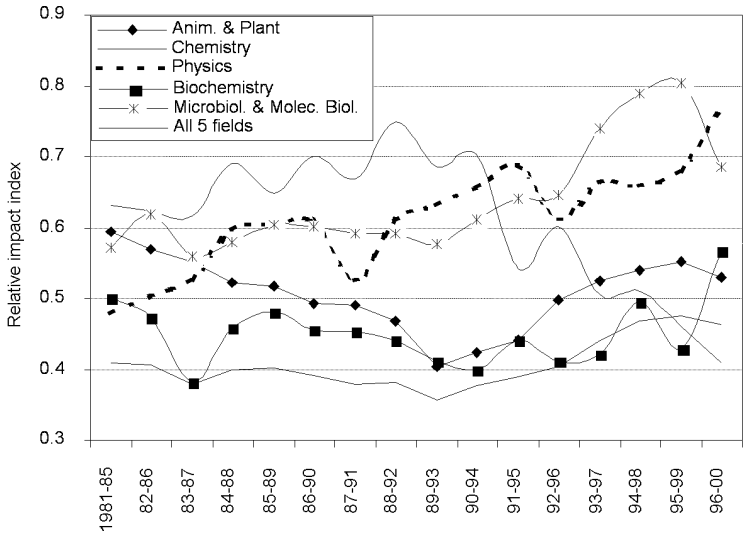

Figure 6. South Africa: Citation impact 1981–2000 relative to the World (Source: NSI, ISI, 2001)
World impact (C/P; index: 1.0), all five fields combined 1996-00: 5.76; Animal & Plant: 2.85; Biochemistry: 8.82; Chemistry: 4.31; Molecular & Microbiology: 7.82; Physics: 4.23.

Compared to Table 3, one observes that the five alternative fields commonly display stability from approximately 1989–1993 towards recently, where an increase takes place. Only Biology initiates stable impact already from 1983–1987 until 1994–1998, and then shows such a marked increase that it regains the impact achieved at the start of the 1980s.

Figure 6 displays the development of the SA citation impact relative to the world impact (RCI) in the five standard research areas. One observes the steady increase of all the fields, except Chemistry, at least from 1990–1994 onwards. The latter field falls behind in a rather dramatic way. For General & internal medicine its highest relative impact was actually achieved in the period 1989–1994 (index value: 0.48). Since then it remains quite stable on values between 0.35 and 0.40 – but at a halved publication volume compared to the 1980s, Table 3.

Proportion of cited papers

In order further to understand why some fields have certain citation impact behaviour the percentage of papers cited at least once during the analysed period is displayed on Table 4 as index values of the corresponding world ratio. One observes immediately for the Animal & plant sciences that a low index value exists until 1992–1996 – with its lowest value in 1988–1994 (35.19). The field balances between 45% and 55% cited papers at world level. The SA average value informs that 60% of the papers in this field did not even receive self-citations 1981–2000. This phenomenon contributes probably to the decline for the Animal & plant sciences both in absolute citation impact and relative to the world, ending 1989–1993.

Biochemistry demonstrates the same pattern but with an extended low index value period, 1988–1997. Generally the field demonstrates higher index values and a higher coverage (57 – 63%). Towards the end of the 1990s there is a significant increase of cited papers. However, the world level is constantly between 71% and 77% in this field.

Chemistry is a weak field in this respect, also at world level, with cited paper proportions at values ranging from 50% to 57%. Like for the previous two fields the lowest index values are reached 1988–1994 with 45 – 46% cited papers; but one observes also the repeated decline in index values from 1993–1997, coinciding with the heavy plunge in impact, Figure 6.

General & internal medicine is incorporated in this analysis since its behaviour is particular. The SA field is commonly above index value 1.0 until 1992–1996, but the cited paper proportion at world level is low (approx. 40% on average). From then on the decline in index score and proportion for SA is marked. This behaviour is different from

the Animal & plant science field and Biochemistry/Chemistry by displaying decreasing values simultaneously with that other fields start to increase theirs. Also, Medicine acts differently from the remaining fields, like Microbiology & molecular biology or Physics and related alternative disciplines analysed above. Both show high index values, the former with a steady increase of index score and a high proportion on average of cited papers (world average 72%); the latter demonstrating very constant and high index values.

Table 4. Index of cited papers in South Africa 1981–2000 relative to the world in six scientific areas (Source: NSI, ISI, 2001). (World index = 1.0); SA average percent of cited papers for entire period given below each field
Figures in **bold** signify negative growth

	Anim. & Plant	Biochemistry	Chemistry	Gen. & Int. Med.	Microbiol. & Mol. Biol.	Physics
1981-85	0.82	0.85	1.04	1.18	0.98	0.81
1982-86	**0.74**	**0.78**	1.03	1.23	0.95	0.86
1983-87	0.79	0.82	1.08	1.17	**0.89**	0.97
1984-88	0.79	0.92	1.09	1.14	0.95	1.00
1985-89	0.82	0.90	1.10	**1.11**	0.99	1.07
1986-90	0.81	0.89	1.05	**1.12**	0.98	1.08
1987-91	0.82	0.97	0.96	1.18	0.97	1.01
1988-92	**0.81**	**0.93**	**0.89**	1.21	0.97	1.00
1989-93	**0.78**	**0.85**	**0.91**	1.22	**0.91**	0.97
1990-94	**0.79**	**0.83**	**0.88**	1.22	0.94	1.01
1991-95	**0.80**	**0.81**	1.00	**1.13**	0.97	1.00
1992-96	0.89	**0.80**	1.05	**1.02**	0.98	0.99
1993-97	0.88	**0.77**	**0.93**	**0.96**	0.96	1.04
1994-98	0.90	0.90	**0.91**	**0.93**	**0.88**	0.99
1995-99	0.87	0.87	**0.87**	**0.88**	0.90	0.97
1996-00	0.86	0.91	**0.84**	**0.84**	0.94	0.98
SA average %:	39.65	63.46	51.61	45.85	66.43	57.74

Discussion

As in the previous study by Jacobs & Ingwersen,[7] of the five standard fields under analysis, the Animal & plant sciences and Veterinary medicine suffered most from 1987/1988–1991/1992 with respect to publication volume and world shares. This is

confirmed in the present study – Tables 1 and 3 and Figure 1. These negative trends are also found for Chemistry and Biochemistry, but starting 1985–1989; indeed, for the volume-heavy supplementary field of General & internal medicine the decline initiated already in 1984–1988.

For most other fields, if any decline in production exists it commonly ends 1989–1993 with an increase in research activity and world shares of publications, i.e., following the world trend; but this did not happen to the fields mentioned previously. Their common pattern is that the negative trend (and a stability for Chemistry) continues beyond 1989–1993 and up to, at least, 1994–1998. This is a dramatic development, in particular for the maintenance of public health, and a serious matter since agriculture is one of the central production areas in SA in relation to exports. In absolute numbers the biochemical and chemical fields are just at level with the output 1981–1985. Since the Animal & plant sciences are very large research areas in output volume, it is not surprising that the same somewhat negative picture shows up on Table 1 and Figure 1, associated with the total of the five standard fields. The fields analysed above under continuous decline cover 22% at present, but did cover almost 40% of the total SA output 1981–1985.

For two scientific areas, i.e., the Animal & plant sciences, including Veterinary medicine, as well as General & internal medicine, one might argue that the economic embargo internationally imposed on SA began to have a visible effect from the mid-1980s on the research activity, and thus the publication output some few years later, i.e., from around 1990. To General & internal medicine (and to a degree for fields like Cardiovascular & respiratory systems or Oncology) brain drain may in particular play a serious role early on, since SA medical scientists were well known and respected internationally at that period. Table 3 demonstrates a decrease of article output from 1984–1988 to 1989–1993 of 40%, just over 10 years, from which the field has not recovered thus far.

Simultaneously, other SA fields like Microbiology & molecular biology, Biology proper and Materials science & engineering as well as Physics and Space science, do not suffer any serious decline over the entire period 1981–2000. On the contrary, they increase their production and maintain world shares.

The brain drain is seen as the major reason for South Africa's decline in publication output in certain scientific fields after 1993. According to SANSA[9] statistics, three-quarters of SA emigration are to the United Kingdom, the United States, Australia, Canada and New Zealand and a total of 233,609 South Africans emigrated in the period 1989–1997. Most of the emigrants are professionals or people with high technical skill levels. A total of 24,196 professionals are recorded by South Africa as having emigrated

during the period of 1994–1997. This is probably understated as many of those who emigrate does not register in South Africa as they emigrate from South Africa. According to SANSA, the brain drain has been increasing since 1994 and the annual emigration of professionals was 56% higher than for 1989–1994. The US statistics show that 77% of South African emigrants to US have got tertiary education and most of them in natural sciences and medicine. Estimates from Australia and New Zealand show that during the last decade, 10,000 South Africans engaged in S&T occupations and similar number in health and medicine emigrated. The South African Medical and Dental Council estimates that about 150 doctors emigrate each year which approximates 0.7% of the current stock.

Research by Kaplan[10] and others[11] found that 28% of the University of Cape Town's (UCT) students who graduated with the highest degree, namely doctorate have immigrated to developed countries. Further analyses show that the percentage of doctorates from UCT known to be located abroad are: Medicine (43%), Commerce (30%), Education (27%), Science (26%) and Engineering (25%). The better facilities and higher wages offered to scientists and doctors encourage them to leave the country as soon as they graduate.

Another reason for the decrease in publications after 1993 was the government's policy to employ foreigners only if no South African could fill the post. This measure reduced the inflow of African and European scientists into the country. The government's drive to educate and train the local population to fill scientific positions also took the emphasis off research and placed it on training and education.

In terms of citations received, citation world shares, citation impact, and cited papers the patterns are different.

The Animal & plant sciences and Veterinary medicine see a momentary decrease in received citations and proportion of cited papers 1988–1993/1994. This period of decline is extended to 1993–1997 for the same indicators for Biochemistry. Chemistry displays a draw back 1987–1991, plus again several times towards 2000 in received citations, but suffers quite much in negative trends for cited papers over the entire period 1988–2000. Also Physics suffers somehow 1987–1991 in citations, like all the five standard fields combined, but not Space science (Table 3).

Again General & internal medicine demonstrates different patterns. Its decline in received citations and cited papers starts already 1983–1987, prior to all other fields and to its decline in production. This phenomenon may be caused by the internationalisation of the field which, during the intensified international discussions on an eco-political embargo, might have triggered a moderate international citation reluctance. For this argument speaks the fact that the continuous decline of citations given to SA in that

field stops, at least for a moment, with the period 1988–1992, to occur again later in small fluctuations. Against this argument one may find 1) that since the number of publications started to drop so dramatically and constantly already from 1984–1988, it is only natural that the corresponding citations drops in the next five-year periods; 2) the proportion of cited papers does not increase after 1989–1993. On the contrary, it continues to drop towards 2000. With the stop of a citation embargo, one would have expected this proportion to rise.

All other analysed fields, i.e., Microbiology & molecular biology, Biology proper, Materials science & engineering and Space science display no (or a very few) periods of decline; they simply increase their volumes of citations.

In terms of citation world shares the Animal & plant sciences, Biochemistry and Chemistry demonstrate a decline from 1986–1990 to 1989–1993 with Biochemistry and Chemistry continuing the decrease due to less and less citations received. Also Microbiology & molecular biology show weakness in periods similar to the Animal & plant sciences, but the trends are insignificant due to a small volume.

With respect to cited papers a constant decline in index values continues after 1989–1993 only for Chemistry and General & internal medicine.

This leads to some significant citation impact scores and trends. In absolute terms the citation score for all five standard fields combined is stable until 1989–1993, where it increases – as does the impact for the Animal & plant sciences and Biochemistry. The former is due to increased number of citations received and proportion of cited papers, and because the volume of articles produced decline at the same time. The latter field impact development is due to a higher decrease in papers produced than the decline in citations received. Physics and Space science develops slowly positively, mainly because of the stability in paper production and proportion of cited papers with a slight increase in citations. Microbiology & molecular biology develops fast and positive because the increase in volume of papers is less pronounced than the increase in citations. Besides, the proportion of cited papers is constant and close to the world average. Biology proper is different. Its citation impact drops rather constantly from 1982–1986 (4.64) to 1989–1993 (2.28) to be stable until 1995–1999 from where it increases. The drop is caused by a decline in citations in parallel with a slight increase in articles.

Chemistry is the only of the ten standard and supplementary SA fields that actually drops its impact from 1990–1994, after it increased constantly since 1981–1985. During this recent period SA Chemistry shows stability in paper world shares but looses citation shares. Hence, the drop.

In General & internal medicine the trend is a steady impact increase from 1986–1990, mainly because the loss in publication output is larger than the loss in citations. However, due to a constant decline in cited paper proportions, compared to the world, the recognition of that large medical SA field seems to slide until the most recent period.

The comparison to the absolute citation impact trends for Mexico and New Zealand demonstrates some significant patterns. In all three countries there exist a kind of low impact period from around 1986–1990 to 1989–1993 for the five fields combined. For the Animal & plant sciences and Microbiology & molecular biology the trends are similar for the three countries, with NZ at a higher level of impact. However, in contrast to SA Mexico, for instance, indeed increases its output volume over the entire period in those fields. It is an added increase in citations that makes Mexico (and New Zealand) improve their impact curves. Also Physics and Biochemistry in SA and NZ demonstrate similar trends – but with NZ at a higher impact level.

The gap between New Zealand and the two developing countries seems to widen slightly during the 1990s. One should also observe the fact that the average citation impact of New Zealand at least is one citation per paper higher than that of SA and Mexico.

In sum, when observing the SA citation impact relative to the world for the five standard fields analysed, it seems evident that something has happen citation wise 1985–1993 for the Animal & plant sciences, Microbiology & molecular biology and Biochemistry: they all drop in relative impact until 1989–1993/1994. Physics constantly increase relative impact, as was also observed in the analysis by Jacobs & Ingwersen,[7] while Chemistry constantly increases its relative impact only until 1990–1994, from which period it drops markedly. Many of the fields indeed reach the impact levels obtained in the 1980s, as predicted,[7] but at quite lower publication output levels.

As has been discussed above, there are several different reasons for the impact figures depending on the discipline analysed. Both negative and positive developments take place simultaneously associated with the interplay between citations and publications. There are no trends as to citation patterns common to all the fields, although a superficial glance at the impact curves may mislead an observer. Historically, the eco-polotical embargo took place from the mid-1980s to approximately 1993/1994. The question is whether a general international citation embargo also took place? When observing the Mexican pattern, (Figure 4) which indeed demonstrates the very trends one would have expected to observe for SA – and in addition the comparable New Zealand trends, (Figure 5) one cannot state that such an event took place.

Perhaps one may argue that some international citation reluctance happened to General & internal medicine, because the decline of citations received starts prior to the similar decline in papers (Table 3). But against this speak, as stated above, the proportion of cited papers that did not – as one would expect – increase after the eco-political embargo was lifted.

What might have taken place in some fields is that a negative effect of the embargo appeared with a delay, after it was lifted – combined with the general international economic recession at that time around 1990–1995. To some extend this would explain the decline in output which started exactly 1989–1993 in fields like Animal & plant sciences, Veterinary medicine and Biochemistry – but not in General & internal medicine where it started much earlier. Additional causes seems to be a serious brain drain and novel priorities instituted for South African research during and after the transition period by the government.

Conclusions

The present investigation has demonstrated that South African research in some of the ten selected standard and supplementary scientific areas posed problems concerning article production, world share developments, and received citations, also after 1993/1994. Several of the research fields are making progress but are vulnerable due to the small volume of publications and citations. Some central and volume-heavy fields like the Animal & plant sciences and, in particular, General & internal medicine, are loosing research activity in terms of published articles. The latter field is also constantly decreasing its proportion of cited papers, but not citations.

On the other hand, the general citation impact is increasing from 1993/1994 – also relative to the World – but still at a quite low level, i.e., often around half of the world impact. In the fields analysed absolute impact has now reached or surpassed the level of absolute impact obtained during the 1980s – as predicted in previous analyses[7] – but in some cases only obtained by a decreasing volume of publications.

A general citation embargo imposed by the international community on South African science has not been traced. In some larger fields, like General & internal medicine, some mild citation embargo from abroad might have taken place. What seems to (have) happen is that the international economical pressure – and brain drain in particular – has had negative effects on the research activities measured in articles production in some of the analysed fields, with detected decrease of publications after the embargo was lifted. Additional reasons for this decrease might be a combination of general economical recession during the period and altered local political priorities.

References

1. T. SARACEVIC, *Quantitative Indicators of Scientific and Technical Communication* (unpublished). Case Western Reserve University. Cleveland, Ohio, 1977.
2. T. O. ODEINDE, *Study of the Information Needs and the Use of Such Information by Scientists in Nigeria: A Technical Report*. Federal Ministry of Education, Science and Technology. Lagos, Nigeria, 1984.
3. G. A. ALABI, The citation pattern of Nigerian scientists. *International Library Review*, 21 (1) (1989) 129–137.
4. N. NARVAEZ-BETHELEMOT, J. M. RUSSELL, R. ARVANITIS, R. WAAST, J. GAILLARD, Science in Africa: An overview of mainstream scientific output. *Scientometrics*, 54 (2) (2002) 229–241.
5. J. GAILLARD, Overcoming the scientific generation gap in Africa: An urgent priority. *Interdisciplinary Science Reviews*, 28 (1) (2003) 15–25.
6. E. GARFIELD, Third World research …High impact journals, most cited articles and most active areas of research. *Current Contents*, 34 (1983).
7. D. JACOBS, P. INGWERSEN, A bibliometric study of the publication patterns in the sciences of South African scholars 1981-96. *Scientometrics*, 47 (1) (2000) 75–93.
8. R. M. MAY, The scientific wealth of nations. *Science*, 275 (1997) 793–796.
9. SANSA – http://www.uct.ac.za/org/sansa
10. D. KAPLAN, Migration of the professional, semi-professional and technical occupations in South Africa: past patterns, current trends and policy. In: J. CHARUN, J.-B. MEYER (Eds), *International Scientific Migrations Today*, Orstom-Colcians, Paris-Bogota, 1998 (CD-ROM).
11. J. R. E. LUTJEHAMS, J. A. THOMPSON, Commercializing the CSIR and the death of Science. *South African Journal of Science*, 89 (1993) 8–14.
12. W. GLÄNZEL, A. SCHUBERT, T. BRAUN, Relational charting approach to the world of basic research in twelve science fields at the end of the second millennium. *Scientometrics*, 55 (3) (2002) 335–348.