THE VISIBILITY OF ENGINEERING RESEARCH IN SOUTH AFRICA, 1975-2005

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ABSTRACT

Engineering as a branch of science has a crucial role in the growth of the economy. The growth and development of engineering is therefore highly relevant. One way to understand this is to examine the characteristics of the scientific knowledge produced in the field of engineering. Drawing on the publications in engineering from the ISI Web of Science over the last three decades, this paper looks at the visibility and importance of engineering research in South Africa. The visibility of research publications is studied in terms of the number of citations a publication receives. The analysis shows that the visibility of South African engineering research is determined by the number of authors involved in the production of a paper, the presence of international collaboration, the degree of collaboration, and the journals in which the papers are published. Engineering research in South Africa, compared with that of all subjects, is clearly growing. But the visibility of South African engineering publications, in comparison with all other subjects, has been diminishing in recent years.

OPSOMMING

Ingenieurswese as ‘n vertakking van die wetenskap speel ‘n kardinale rol in die groei van die ekonomie. Die groei en ontwikkeling van die ingenieurswese is dus uiters relevant. Een manier om dit te verstaan, is om die eienskappe van die wetenskaplike kennis wat op die terrein van die ingenieurswese geproduseer word te ondersoek. Deur na die publikasies in ingenieurswese op die “ISI Web of Science” te kyk oor die afgelope drie dekades, bestudeer hierdie artikel die sigbaarheid en belangrikheid van navorsing in die ingenieurswese in Suid-Afrika. Die sigbaarheid van navorsingspublikasies word bestudeer aan die hand van die aantal sitasies wat ‘n gepubliseerde artikel ontvang. Die ontleding toon dat die sigbaarheid van Suid-Afrikaanse ingenieurswese-navorsing bepaal word deur die aantal outeurs betrokke by die artikel, die teenwoordigheid van internasionale samewerking, die mate van samewerking asook die joernale waarin dit gepubliseer is. Navorsing in die ingenieurswese in Suid-Afrika is duidelik aan die groei in vergelyking met ander vakgebiede. Daarteenoor, neem die sigbaarheid egter af wanneer dit met ander vakgebiede vergelyk word.

1. INTRODUCTION

The visibility, influence, and importance of publications in scientific research are often measured by citation analysis [12, 23]. Citation studies show how the production of scientific knowledge is used by the scientific community all over the world [25]. The visibility of publications works in favour of researchers who can enhance their standing in their own areas of research [2], and it can be improved through collaboration with well-known people in the field [31]. Citation analysis is also employed as a measure to assess the impact of a nation's scientific output [18, 19]. However, there are few citation studies of science in Africa [3]. Uys et al. [30] made an attempt to study how industrial engineering fields have been covered by the *South African Journal of Industrial Engineering*. Jacobs and Ingwersen [16] and Ingwersen and Jacobs [15] looked at the patterns of citations in specific fields of science. Another recent analysis [27] showed the inter-relationship between citations and collaboration of scientists in South African publications. This bibliometric study [27] reported that citations received by publications vary in relation to the types of collaboration that have happened in the production of scientific publications. Other studies [26, 29] examined the visibility of publications and journals. Okubo and Sjöberg [21] studied the influence of collaboration on the visibility of industrial publications. Acknowledging the importance of the visibility of research publications, Gevers et al. [10] identified a combination of factors such as publications in indexed high-impact journals, and e-publication in open access journals that enhance visibility. A number of studies [4, 5, 17, 20, 31] have indicated that scientists collaborate in order to gain professional visibility, prestige, reputation, and access to resources.

South Africa has a remarkable record of growth in engineering. Pouris' [24] recent analysis reveals that in the last 15 years South Africa has produced a stream of patents through the USA patent office (USPTO). The study [24] further states that South Africa occupies 12th position in class 075 specialised metallurgical processes. But, as is clear from the above review, attempts have to be made to understand the visibility and importance of engineering research in South Africa. This is important not only to understand the relevance of engineering research and its impact on the economy, but also pertinent from policy perspectives. Dastkhan and Owlia [8] in their recent analysis of several countries have found a strong correlation between the development in industrial engineering and industrial and economic development. This paper, for the first time, investigates the importance and visibility of engineering research in South Africa, as shown in the publication records of the ISI Web of Knowledge. The analysis extends over a period of 30 years from 1975 to 2005. The visibility in this study is measured broadly in terms of the count of citations received by the publications of South African engineers, in comparison with that of all publications in all subjects by South African researchers. Further, this study examines the effect of relevant variables such as the number of authors, sectors, publication outlets, and collaborators on the visibility of South African engineering research. The analysis then examines the predictive relationship between visibility and collaboration, a key factor in citation studies, using regression analysis.

2. DATA AND METHODS

Scientometric analysis is a most efficient and objective method to assess the research activities of any given area [24]. The data stored in databases such as ISI are useful for a variety of analyses, including visibility and scientific cooperation [9]. As an extensively used tool, scientometrics is helpful in assessing and mapping the state of science [3]. The Science Citation Index (SCI), the data used in this study, unlike similar databases, covers a wide range of recognised and high-quality published research and citation-based scientific journals. The journals in the SCI are indexed on certain strict citation criteria.

Data for this study were obtained in several successive stages from the ISI Web of Knowledge, the Science Citation Index (SCI) Expanded (1945-present) for a three-decade period from 1975-2005. In the first stage a relevant period of data was chosen. During the period 1945-1965 there were no papers by South African scholars in the ISI database: they

were not publishing, or were not yet appearing in the SCI-listed journals [28]. Until 1971 there were only a few publication records in the ISI database, but thereafter the number of publications began to rise. The year 1975 is chosen as the starting point, followed by another sample year for every five subsequent years. Thus the representative years of 1975, 1980, 1985, 1990, 1995, 2000 and 2005 were chosen for this analysis.

In the next step, the type of publications to be included in this analysis was selected. All publications appearing as 'articles' and 'reviews' for the selected years were gathered. These articles and reviews were required to have a minimum of one South African author. There were 18,466 such publications by South African authors and their partners in all seven selected years. Of these, 2,036 belonged to branches of engineering.

In the next stage the subject of the publication was determined. This being a study of engineering publications by South Africans, all the engineering publications listed in the subject category of the ISI records were collected. The subject category of engineering included publications in engineering, computer sciences, crystallography, instrumentation, materials science, mineralogy, remote sensing, transportation, and medical technology. For this classification and inclusion of the different branches of engineering, the system of classification developed by the Centre for Research on Science and Technology [7] was referred to. In order to do meaningful statistical analyses, all the basic details of the publication records from the database were gathered and entered manually into a statistical software program.

3. ANALYSIS AND RESULTS

Research in South Africa: Engineering vs others

South African engineers produced a total of 2,036 scientific publications over the seven sampled years of analysis (Table 1). In 1975 there were 86 publications; by 2005 this had risen to 574, an increase of more than six times. Between 1975 and 2005, the change in the number of engineering publications was consistently positive, accruing from two to six times of the base year of 1975. These publications are either sole-authored or co-authored by South Africans and their partners. The partners of South African engineers can be from within South Africa or from overseas. In 1975 there were 38 sole-authored and 48 co-authored papers. By 2005, these numbers had risen to 107 and 467 respectively. As for the change in these types of publications during 1975-2005, the number of sole-authored papers grew by 282%, and co-authored papers by 973%. The growth was more consistent for co-authored papers than for sole-authored ones. For the entire period of analysis, an average of 2.5 authors worked together to produce a publication in engineering. This average ranged between 1.78 and 2.93, with the highest average recorded in 2005. The increase in the number of authors per publication is clear: it moved from 1.97 in 1985 to 2.93 in 2005 – 160% more than the average figure recorded in 1975. On average, 2.27 countries per internationally co-authored paper participate in the production of engineering publications. This foreign collaboration in engineering research has been growing since 1975. In 2005 the mean number of foreign countries in internationally co-authored papers was 2.34, an increase of 10% over the average value reported in 1975.

On the other hand, the production of scientific papers in South Africa as a whole (in all subjects) was not as rapid as in engineering research. Of the total of 18,466 publications generated by South African researchers during this period, the increase from 1975 (1,212) to 2005 (4,161) was only three-fold (Table 2). Sole-authored papers in all subjects have not grown in number in the way that co-authored papers have. While the increase was 120% for sole-authored publications, it was 449% for co-authored papers. It is also notable that the production of sole-authored papers throughout the years was not steady. It grew to 161% in 1980, but fell thereafter. In all the years of analysis, co-authored papers regularly increased. The average number of authors per publication is relatively higher for all subjects. For the period it was 3.33, which is 0.83 more than for engineering publications. The increase over the years of analysis was consistent and, most significantly, in 2005 the

average count reached its highest figure of 4.56. In internationally co-authored papers the mean number of countries involved was 2.56 (higher than engineering's 2.27) for the 30-year period. In 1975 there were 2.1 countries in international collaboration; by 2005 this had grown to 2.74. This means an increase of about 30% over the 1975 figure.

Publications	*Year*															
	1975		*1980*		*1985*		*1990*		*1995*		*2000*		*2005*		*All*	
No. of papers	86		201		222		244		359		350		574		2036	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
No. of authors	1.84	0.893	1.78	0.976	1.97	1.065	2.17	1.33	2.52	1.50	2.81	2.51	2.93	2.30	2.48	1.90
No. of countries in co-authd (intern'l) papers	2.13	0.35	2.13	0.35	2.06	0.24	2.11	0.42	2.23	0.54	2.32	1.00	2.34	1.17	2.27	0.94
No. of times cited	10.35	17.07	5.07	11.11	6.84	11.75	7.17	13.78	9.30	56.23	4.25	7.42	1.02	3.44	5.20	25.34
Sectors	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
University	0.71	1.00	0.55	0.75	0.78	0.86	0.94	0.81	1.18	0.94	1.77	1.01	1.96	1.07	1.35	1.09
Research Institute	0.29	0.67	0.29	0.52	0.34	0.53	0.22	0.53	0.16	0.48	0.24	0.68	0.21	0.62	0.23	0.58
Industry	0.34	0.81	0.25	0.51	0.21	0.48	0.14	0.34	0.21	0.48	0.19	0.60	0.14	0.48	0.19	0.51
Government	0.41	0.91	0.18	0.46	0.07	0.25	0.09	0.30	0.10	0.31	0.02	0.16	0.01	0.08	0.08	0.32
Authorship	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
All South African authors	40	83.3	86	85.1	101	74.3	138	83.1	216	75.0	175	61.2	279	59.7	1035	69.4
SA authors within the same orgn/dept	35	72.9	17	37.8	22	30.1	22	34.4	31	20.7	233	81.5	379	81.3	739	65.2
Type of publications	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Sole-authored	38	44.2	100	49.8	86	38.7	78	32.0	71	19.8	64	18.3	107	18.6	544	26.7
Co-authored	48	55.8	101	50.2	136	61.3	166	68.0	288	80.2	286	81.7	467	81.4	1492	73.3
Publication outlets	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
SA journals	21	24.40	75	37.30	33	14.90	32	13.10	27	7.50	67	19.10	80	13.90	335	16.50
Non-SA journals	65	75.60	126	62.70	189	85.10	212	86.90	332	92.50	283	80.90	494	86.10	1701	83.50

Table 1: Engineering publications in South Africa, 1975-2005

Publications	*Year*															
	1975		*1980*		*1985*		*1990*		*1995*		*2000*		*2005*		*All*	
No. of papers	1212		1828		2355		2748		2801		3361		4161		18466	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
No. of authors	2.33	1.53	2.33	1.68	2.64	2.71	2.83	1.84	3.3	6.44	3.66	6.99	4.56	10.25	3.33	6.43
No. of countries in co-authd (intern'l) papers	2.10	0.62	2.15	0.64	2.17	0.68	2.24	0.77	2.50	1.87	2.59	3.10	2.74	1.67	2.56	2.03
No. of times cited	17.26	83.97	14.46	41.94	12.97	23.90	13.17	28.61	13.00	36.58	9.74	18.36	2.75	8.55	10.54	33.60
Sectors	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
University	1.24	1.16	0.95	0.95	1.14	1.03	1.33	1.13	1.51	1.18	1.97	1.19	2.13	1.17	1.59	1.21
Research Institute	0.22	0.59	0.22	0.50	0.27	0.57	0.27	0.58	0.22	0.53	0.38	0.81	0.46	0.86	0.32	0.69
Industry	0.05	0.30	0.04	0.23	0.04	0.24	0.03	0.22	0.05	0.26	0.04	0.29	0.05	0.29	0.05	0.26
Government	0.24	0.68	0.18	0.47	0.09	0.32	0.11	0.39	0.14	0.42	0.05	0.28	0.04	0.24	0.10	0.38
Authorship	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
All South African authors	715	59.0	1026	56.1	1438	61.1	1812	65.9	1652	59.0	2159	64.2	2189	52.6	10991	59.5
SA authors within the same orgn/dept	441	36.4	338	24.1	353	19.9	448	23.1	464	22.5	2645	78.7	3234	77.7	7923	42.9
Type of publications	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Sole-authored	390	32.2	628	34.4	623	26.5	549	20.0	491	17.5	501	14.9	469	11.3	3651	19.8
Co-authored	822	67.8	1200	65.6	1732	73.5	2199	80.0	2310	82.5	2860	85.1	3692	88.7	14815	80.2
Publication outlets	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
SA journals	423	34.90	773	42.30	866	36.80	788	28.70	457	16.30	622	18.50	597	14.30	4526	24.50
Non-SA journals	789	65.10	1055	57.70	1489	63.20	1960	71.30	2344	83.70	2739	81.50	3564	85.70	13940	75.50

Table 2: All South African publications, 1975-2005

Sole-authored papers in engineering increased by almost three-fold between 1975 and 2005 (from 38 to 107). After a sudden spurt in 1980 the production declined until 2000, but picked up again in 2005 (row 11, Table 1). In contrast to this, co-authored publications recorded an impressive growth during the period, increasing almost ten-fold from 48 to 467. This growth was steady and stable. Sole-authored papers for the whole period formed 27% of the total, while the remaining 73% were co-authored publications.

Analysis from year to year revealed more details. Sole-authored publications in 1975 were 44% of the total publications, rising to 50% in 1980. In 1985 they declined to 39%, and this

trend continued for the rest of the period: 32% in 1990, 20% in 1995, 18% in 2000, and 19% in 2005. On the other hand, co-authored publications in the total count of engineering publications grew at a faster pace: 56% in 1975, 50% in 1980, 61% in 1985, 68% in 1990, 80% in 1995, 82% in 2000, and 81% in 2005.

As co-authored publications are the product of collaborative efforts, collaborators deserve further analysis. Two variables assist here: (1) the proportion of South African authors among the co-authors (row 9 in Table 1), and (2) the affiliation count of South African authors belonging to the same institution (row 10 in Table 1). These two measures display the nature of collaboration in the production of co-authored publications in engineering. In 1975, 40 publications had South African authors, but this reached 279 in 2005 – an increase of 700%. The year 1990 stands out as the start of a substantial increase in the proportion of co-authored publications in engineering. In the second measure – the affiliation of South African authors – 65% of the South African authors belong to the same institution. In the case of publications in all subjects, 10,991 publications were produced solely by South African authors. This is 60% of the total publications in all subjects. South African authors within the same institution are found in 43% of the publications.

The affiliation of the authors shows the sectors in which engineering research is taking place in the country (rows 5-8, Table 1). In order of importance, the four major sectors active in the production of engineering research in South Africa are: universities, research institutes, industry, and government. The mean values of authors representing each of these sectors indicate that universities produce the greatest number of publications, followed by research institutes (about half of what universities produce), industry (close to research institutes), and government (about one-fourth of what universities produce).

As for publications in all subjects, universities also lead the other sectors. Research institutes in the country produced only half as many publications as the universities, and the government sector contributed more than half the number generated by institutes. Unlike their performance in engineering research, industry is at the lower end of total production, with one-fifth of what the university sector contributes (Table 2).

Publications by South African engineers appear in both local and foreign-originated journals. For the entire period, only 17% of the total published papers appeared in local journals, while the majority (83%) appeared in foreign-originated journals (rows 13 and14, Table 1). The absolute number of publications in local journals grew from 21 to 80. The number of papers in foreign journals in 1975 was 65, rising to 494 in 2005. This is more than a seven-fold growth over the first figure reported in 1975, whereas the growth for papers in local journals between 1975 and 2005 was only four-fold. In contrast, 25% of the publications in all subjects appeared in local journals for the entire period, while the remaining 75% appeared in foreign journals (rows 13 and 14, Table 2). Over the years, the publications in both local and foreign journals grew in number, but the growth was more conspicuous for publications in foreign journals than in local journals: between 1975 and 2005 local publications rose 140%, while foreign publications rose 450%.

The visibility and importance of a publication is revealed in the number of citations that a publication receives. Engineering publications of South African authors have earned an average of 5.2 citations per publication in the last 30 years. As the figures in row 4 of Table 1 suggest, the citation count declined from 10.4 to 1.02. Omitting the year 2005 (because it is too early to look at the citations) the count reduced to 4.25 in 2000. This is just 41% of the citations received in 1975. South African engineering publications have so far gained a total of 10,591 citations. However, of the 2,036 engineering publications, 37% (761) did not receive any citations at all. The median value of the citations is 1. One publication, 'A global-model of natural volatile organic-compound emissions', attracted the highest citation count of 1,048. This paper was published 15 years ago, in 1995. One other publication obtained the next highest count of 103 citations.

The number of citations received by South African publications in engineering has declined substantially. From the base year of 1975, the count declined to 49% in 1980, 66% in 1985, 69% in 1990, 90% in 1995, and 41% in 2000. When the average year-on-year change was calculated, it was negative by11.78 percentage points (-51 in 1980, 17 in 1985, 3.2 in 1990, 21 in 1995, and -48 in 2000).

Compared to these citation figures for engineering publications, the average citation figure per publication for all subjects for the full period of analysis was 10.54. This is more than double the figure for engineering. All the publications (18,466 records) jointly gained 194,669 citations. Among these citations, the highest number achieved by a paper was 2,808. While 37% of the engineering publications were not cited at all, for all subjects the mark was 19% (3,465). Although citations for all subjects were also declining, the drop was not as great as that for engineering. For all subjects, too, the average year-on-year change was negative (-8.7), but still only about half of that for engineering publications.

Visibility and other variables of importance

Following the analysis of the features of publications in engineering, and the comparison of engineering with all subjects, the focus now turns to the number of citations and its relationship with other pertinent variables. Pearson correlation tests in Table 3 illustrate the relationship between citation and the year of publication, number of authors, number of countries involved, presence or absence of all South African authors (and in the same organisation), international collaboration, multi-country international collaboration, domestic collaboration, degree of collaboration, and the publications in foreign journals. The degree of collaboration is a measure that takes into account the presence of any kind of collaboration.

Independent variables	*Citations*	
	Correlation Coefficient	*Significance*
Year of publication	-0.262	0.000
Log number of authors	0.119	0.000
No. of countries involved	0.082	0.000
All South African authors (1=yes, 0=others)	-0.095	0.000
SA authors in the same organisation (1=yes, 0=others)	-0.046	0.115
International collaboration (1=yes, 0=no)	0.096	0.000
Multi-country international collaboration	0.063	0.176
Domestic collaboration (1=yes, 0=no)	-0.084	0.001
Degree of collaboration	0.092	0.000
Publications appeared in non-local journals (1=yes, 0=others)	0.127	0.000

Table 3: Pearson's correlations between citations and other variables

It can be inferred from the correlation coefficients (Table 3) that the number of authors, international collaboration, the degree of collaboration, and the publications in foreign journals are positive and significantly related to the number of citations received by the publications in engineering. But the year of publication, absence of all South African authors, and domestic collaboration are significant but negatively related to the count of citations. In other words, the increase in the count of these variables produces a corresponding increase in the number of citations. At the same time, the negative relationship between citation and the year in which the papers are published, domestic collaboration, and the involvement of all South African authors agrees with the positively associated variables. It is clear from this correlation analysis that the number of citations is likely to be influenced by these independent variables, negatively or positively. More recent publications get fewer citations. The greater the number of authors, the more the

citations. International collaboration increases the visibility of South African engineering research more than domestic collaboration, as the citation count is positively related. Multi-country participation improves the visibility of engineering publications to a certain extent. Publications that appear in foreign-originated journals, as the correlation coefficient suggests, receive more citations than those carried in locally-published journals.

How can the visibility of South African engineering publications be predicted on the basis of some of these known variables? To answer this question, several regression models were run; three relevant models are presented in Table 4. The control variables for the first model consist of the year of publication, number of authors (log transformed), international collaboration, and the degree of collaboration. The standardised beta coefficients of this model show that two control variables are positively related to the citation count of engineering publications. International collaboration and the number of authors, as seen in this model, contribute to an increase in citations. Year of publication is significantly related to citation, but negatively. The significance of the variable, the degree of collaboration, is not very high but negative. This model explains a variance of 15% as shown in the R^2 value. Clearly, this model is in agreement with the findings reported in the previous correlation tests.

	Model 1		*Model 2*		*Model 3*	
Year of publication	-0.372	***	-0.374	***	-0.369	***
Log number of authors	0.132	***	0.126	***	0.148	***
International collaboration (1=yes, 0=no)	0.111	***	0.091	**	0.109	***
Degree of collaboration	-0.055	*	-0.058	*	-0.047	
European collaborators			0.042			
North American collaborators			0.998			
African collaborators			-0.019			
Authors from university					-0.034	
Authors from research institute					0.000	
Authors from industry					-0.144	***
R^2	0.154		0.156		0.173	
N	1662		1662		1662	

Note: ***P<.000; ** p<.05; *p<.1

Table 4: Regression of publications in engineering on citations

The second model examines the inclusion of three more variables that represent the regional location of the research partners of South African engineers: the European, North American, and African collaborators. This model, however, does not offer any improvement over the first model, as the newly-inserted variables do not exert any significant influence on citations. This is clear from the standardised coefficients and the R^2 value. The only difference noticed in this model from the previous model is its negative correlation of African collaborators with citations. But this correlation is statistically insignificant.

In model 3, the influence of the three additional variables of the sectoral affiliation of authors was examined. The new variables are the authors from the sectors of university, research institute, and industry. Apart from the original variables in the first model (the year of publication, the number of authors, and international collaboration), authors from industry is a significant variable in this model. But the 'authors from industry' sector is

negatively associated. This model is an improved version of the previous two models, as it explains the 17% of variance (R^2 =.173) of the data.

4. CONCLUSIONS

As is evident in the scientific publications stored in the ISI Web of Science, engineering research in South Africa has grown considerably in the last three decades. This growth compares well with South African publications in all subjects. Sole-authored publications in engineering declined substantially during the period of analysis. At the same time, co-authored publications expanded reasonably from 56% to 81%. This reversal in the type of publications became conspicuous from 1990 onwards, when the proportion of co-authored publications formed more than two-thirds of the total publications in engineering.

The majority of the publications in engineering are now produced in research collaborations. More importantly, the collaborators are mostly South Africans, particularly those who work in the same institutions. This signifies the predominance of domestic collaboration in engineering research, which is more noticeable than in all subjects.

South African engineers lag behind other South African researchers in international collaboration. In terms of the number of foreign countries in international collaboration, South African engineers are not on a par with their counterparts in all subjects. Perhaps the relatively low level of international collaboration (compared with domestic collaboration) in engineering has several reasons. First, South African engineers or their counterparts in other countries are not keen to establish research tie-ups that would eventually lead to innovative technological advancement. Second, as collaboration is inspired by a host of factors including the sharing of resources, learning new skills, and gaining expertise in particular fields of engineering, South African engineers (or foreign scholars) do not find much to gain from mutual international collaborative ventures. Third, South African engineering has international standing and recognition, and it compares well with what exists in many first world countries. This might discourage initiatives and interests from both sides in international research collaboration that leads to scientific publications.

Against all subjects, and in terms of the percentage of publications, engineering produces proportionally more scientific publications. The growth in the percentage since 1975 was in favour of engineering. Fewer local and more foreign publications originate from South African engineers, compared with publications in all subjects. The affiliating sector of authors showed some variations between engineering and publications in all subjects. In engineering, industry is a major player, after universities and research institutes. But industry comes last in the production of scientific research when all publications are considered.

The visibility of South African engineering publications clearly has been diminishing, most notably since 1995. Compared with South African publications in all subjects, the visibility of engineering has faded on the counts of the average citation per publication, the number of publications that received no citations, and the average year-on-year change in citations. This is portrayed in Figure 1. The number of citations a scientific publication attracts depends largely on the quality of the research, its scientific importance, relevance, and the application that is presented in the publication. The reputation, credibility, quality, and impact factor of the journal in which the publication appears is also crucial in the count of citations. Access to such journals is another determining factor in the number of citations. If South African engineers take these things into consideration, there would be a high likelihood that they would gain an increased number of citations, thereby enhancing the visibility of their publications.

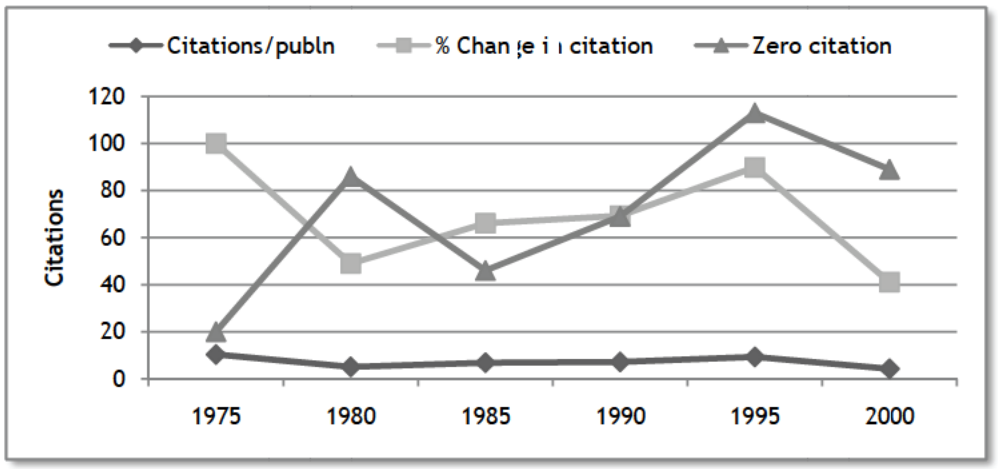

Figure 1: The visibility of engineering research in South Africa, 1975-2000

The study also identifies the determining variables in the visibility of engineering research in South Africa. The correlation and regression analyses prove that visibility in terms of the number of citations a publication receives tends to improve depending on the number of authors per publication, the presence of international collaboration in research that leads to the publication of scientific papers, the increasing degree of collaboration, and the possibility of the publication appearing in foreign-originated academic journals. Any change in these decisive variables is likely to effect a corresponding change in the visibility of South African engineering research. Publications in foreign-originated journals tend to improve the visibility of research. This has been established in other studies as well. For instance, the study by Guan and Ma [13] has shown that papers published in Chinese domestic journals do not have as much international visibility as papers published in international journals. Studies have provided evidence to show that visibility can be maximised through collaboration with renowned research groups [1], through research conducted in international collaboration [11, 21], or via publication in the most visible journals [10,22].

This analysis shows that engineering research in South Africa has been growing, particularly since 2000. Focused efforts are required to stem the diminishing importance and visibility of South African engineering. The collaborative component in engineering research at national and international levels has contributed significantly to the positive change over the last few years. Universities and research institutes are the major centres of production of engineering knowledge. If industry in South Africa could take a serious interest in engineering research, the profile of this research would change drastically. Not only can industry contribute to the production of more research publications, but it can also lead to many more new areas of knowledge, research, and innovation, and subsequently to the growth and development of the discipline and the economy. As Blankley and Moses [6] noted, innovative economies exhibit higher rates of growth and higher productivity that can promote the capacity of the economy.

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