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Publication productivity and collaboration of researchers in South Africa: new empirical evidence

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Abstract Apart from a few bibliometrical studies the South African scientific system is a scantly researched area and asking for more empirical evidence. This empirical study of academics and researchers ($n = 204$) from a selected province of South Africa examines the interrelationship between publication productivity and collaboration, and the sectoral differences between higher education institutions and research institutes. The study highlights the specific context of the scientific system in South Africa with its characteristics features of productivity and collaboration and shows how they are structurally facilitated and hindered. Being a prominent contributor to the development of science in Africa the study offers some interesting findings.

Keywords South African science · Collaboration · Publication productivity · Sectoral differences

Introduction

One of the proven reasons for collaboration among researchers in science is the potential for enhancing the publication productivity of the partnering collaborators. This has been established in a considerable number of studies on scientific collaboration and productivity (Katz and Martin 1997; Sooryamoorthy and Shrum 2007; Abramo et al. 2009; Defazio et al. 2009; Vasileiadoua and Vliegenthart 2009; Ponomariova and Boardman 2010; Sooryamoorthy 2010). New evidence to this effect continues to accumulate.

This paper is based on an empirical study of 204 academics and scientists working in the higher education institutions and research institutes in South Africa. It reports on the relationship between productivity and collaboration. Being a novel effort this research highlights the prominent features of the African scientific system viewed through the lens of the science of one of the prominent players—South Africa—in Africa. In particular, the

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paper illustrates how productivity is affected by a variety of collaboration patterns that the respondents undertake in their research careers. This is done using a specific set of measures as elaborated in the "Data and Methods" section.

Investigating the collaborative behaviour of two comparable teams of researchers in 35 US universities and government laboratories Porac et al. (2004) found that research alliances have contributed to an increase in productivity. Scientific productivity as reflected in publication output tends to increase in relation to the size of the scientific teams involved. Adams et al. (2005) reported that the size of the scientific team and collaboration determine the research output (papers and citations) of researchers at universities. Lee and Bozeman's (2005) empirical study of academic scientists probed the effect of collaboration on productivity. The question they sought to answer was whether collaboration was positively related to publication productivity (measuring both the normal and fractional counts of publications) and, if collaboration was correlated with productivity, did research collaboration affect productivity at all? They concluded that collaboration had a significant effect on publication productivity, but only on the normal count of publication productivity and not on the fractional count of publication. Exploring the association between these variables in three countries, namely, India, Ghana and Kenya, Duque et al. (2005) demonstrated that collaboration might enhance productivity but not in the case of every country.

In their study of university researchers Landry and Amara (1998) found that the researchers brought in more publication assets—number of book chapters and papers in journals—when they worked in collaborative research. Ponomariova and Boardman (2010), focusing on the effect of university research centres on productivity and collaboration, researched on how access to opportunities and resources positively changed the overall productivity of researchers. Their hypothesis was that the more resources and collaborators a researcher had, the more productive s/he became. They accepted the hypothesis that when the respondents were affiliated to the chosen research centres they were more likely to be more productive, produce more papers with industrial collaborators, and collaborate more with their colleagues and other institutions. Ponomariova and Boardman (2010) report that the strongest impact was to be seen in the collaborative behaviours of the researchers underlying their publication output. In the Croatian research system (Prpic 2007) the duality of knowledge production and productivity in which teamwork, applied research, and the structural improvements in the productivity of researchers was accompanied by a reduction of the researchers in their projects.

As Belkhodia and Landry (2007) observed among researchers in the natural sciences and engineering researchers in Canadian universities and government agencies, the likelihood of them collaborating increased their productivity. A greater productivity would have a positive effect on collaboration. Similarly, Basu and Aggarwal (2001) established the inter-relationship between international collaboration, productivity and impact factor in Indian science. However, notable inter-institutional differences in international collaboration impact on productivity positively. Defazio et al. (2009) presented different scenarios for the association between collaboration and productivity in EU-funded projects. Although EU-funding is linked to collaboration, the connection between collaboration and productivity was seen in the post-funding phase and not during the funding period.

Lee and Bozeman (2005) put forward a model. According to this model collaboration is a strong predictor of publication productivity of academics. They however distinguish between the normal count and fractional count of publication productivity with differing levels of influence by the variable of collaboration. In the case of the normal count of publications, which is the total number of publications, collaboration is strongly related. Whereas in the fractional count, which is calculated by dividing the number of publications

by the number of co-authors, collaboration is not significantly related. As a cautionary note they report that all collaborations are not created equally and that some collaborations enhance productivity while others do not. As the relationship is reported in the normal count of publication we use only the normal count, and not the fractional count of publications.

Referring to the National Research and Technology Audit of the Government of South Africa in 1996, Mouton (2000) summarised the key findings of the audit. The audit concluded a positive correlation between multiple authorship and scientific output. There was a significant difference between the average scientific output of those who produced sole-authored papers and those who produced multiple-authored papers. The output was high for those who published multiple-authored papers (Mouton 2000). In contrast, a bibliographic analysis of the publications of South African medical researchers for a relatively extended period of time had revealed that research partnerships were unlikely to increase the publication productivity. Rather, the linkage between productivity and research partnerships were found to be country- and subject-specific (Sooryamoorthy 2010).

Empirical studies that specifically analyse the inter-relationship between publication productivity and collaboration in South Africa are yet to appear in the literature. One exception to this is the research by Sooryamoorthy and Shrum (2007). This concluded that there was a relationship of productivity with the internet and email usage among academics and researchers in higher education institutions and research institutes in South Africa. This investigation showed that while the usage of internet and email were positively associated with collaboration, the latter was not associated with publication productivity. In the case of the total productivity of the respondents, collaboration affected only those in the universities and not at research institutes (Sooryamoorthy and Shrum 2007).

Why collaboration results in increased productivity? Collaboration in science offers opportunities for the participants to pool and share their resources, expertise and sources of data. This collective enterprise ushers in research outcomes such as publications. Unlike in solitary research ventures publication is an essential constituent in collaborative research and the partners are keen that their findings are published in reputed scientific outlets. The conditions of the funding agencies sometimes facilitate publication outcomes. Collaborations are meant for prestige and visibility in the respective fields of the partners and for their increased productivity (Lee and Bozeman 2005). As Abramo et al. (2009) reported knowledge sharing, a consequence of shared work, effects an increase in research effectiveness. The measure of research effectiveness and research performance takes into account publication as an integral component. Collaboration happens when like-minded researchers join together to achieve some substantial scientific objectives, and these objectives are not to be shelved but to be released for the public through publications. The potential and possibility for publication trigger collective research activity.

Collaboration is also advantageous for the participating collaborators who are able to work simultaneously on different projects that finally build up to a higher productivity level (Abramo et al. 2009). Depending on the number of collaborators in the team productivity could increase as partners divide their work among themselves, allowing them to put together the different pieces of their research for publications in several outlets.

The point Schmoch and Schubert (2008) making is very relevant. They believe that cooperation at the international level as opposed to national level is highly demanding and a substantial level of investment will be made only if corresponding pay off (read productivity) is expected. Collaboration that brings together resources has a higher level of expectation of productivity.

Networking with collaborators helps increase productivity. Partners through their connections receive invitations to write chapters, books and papers. For novice researchers collaboration is a means to get their research published and increase productivity through such associations and co-authorships. The emerging scholars find collaboration as an opportunity to enter the world of scientific publication and visibility, which naturally leads to their productivity (Yoshikane et al. 2009). It has also been reported that young scholars tend to increase their publication potential with co-authorships and thus improve their performance (Prpic 2000). This indicates that young scientists are assisted in their productivity through collaboration.

This paper reports on the relationship between productivity and collaboration of South African academics and scientists. It highlights the prominent features of the African scientific system. In particular, the paper illustrates how productivity is affected by a variety of collaboration patterns which the respondents undertake in their research careers. This is done using a specific set of measures.

Data and methods

The respondents for this study came from two higher education institutions and seven research institutes in the province of KwaZulu-Natal in South Africa. They represented two sectors—university (academics) and research institute (scientists)—across a range of science disciplines. A total of 22 science departments and research institutes was selected. The disciplines of the respondents included agricultural science, engineering science, life science and the natural sciences. All the academics and scientists in the chosen institutions who had agreed to participate in the study were contacted during 2007–2008. Face-to-face interviews were undertaken in their respective work settings. Interviews ($n = 204$) were held in a number of places—Durban, Pietermaritzburg, Cedara, Mt. Edgecombe and Umhlanga—within the province where the academic institutions and research institutes were located.

A range of determinants is responsible for the productivity of researchers. Among them are the characteristics of age, institutional background, gender, experience, career, discipline and reward system. Apart from these, the patterns of collaboration are now being suggested as a determinant of productivity (Defazio et al. 2009; Dennis 1956; Kyvik 1990). Melin (2000) used co-authorships as a direct way to measure collaboration at the individual level. Porac et al. (2004) found that the duration of collaboration is also positively related to productivity. Drawn from these studies important control variables such as age, gender, marital status, and degree were identified. The present study explores these variables along with other variables such as academic age, institutional age and variables that capture the collaborative dimensions of research and productivity.

Background factors, productivity and collaboration data were gathered directly from the respondents. From this raw data several new variables were constructed for multivariate regression analysis.

The publication productivity of the respondents is inferred from the following:

- Papers presented at national workshops held within the country
- Papers at international conferences outside the country
- Production of research reports
- Papers in national and foreign journals
- Co-authored papers in national and foreign journals

- Chapters in books, books (edited and original)
- Co-authored books in the last 5 years

The aggregate count of papers in national and foreign, co-authored papers in national and foreign journals, and total publication productivity (combined measure of papers in national and foreign journals, chapters in books, and books (edited/original) were also calculated. This self-reported information on productivity pertained to 5 years prior to the year when the data was collected.

The three dependent variables in the study were:

- The productivity of papers (combined measure of papers published in national and foreign journals during the 5 years prior to the interview)
- Co-productivity of papers that blends co-authored papers published in national and foreign journals
- Total productivity that merges papers, chapters, and books (both original and edited)

Control variables employed in the study were:

- Gender
- Highest degree attained
- Academic age (years after obtaining the highest degree)
- Number of research projects
- Collaboration variables (collaborated projects, collaborated partners and years in career, duration of collaborative projects, partners in collaborative projects, intercontinental projects and international projects)

In order to analyse the nature of the research activities of the respondents information about the research projects they were currently involved was collected. Details of a maximum of three research projects were sought from the respondents. Several multivariate regression models were run to find the relationship between productivity and collaboration variables and only relevant models are presented in this paper.

Results and analysis

Academics and scientists

Most of the respondents (69 %) were affiliated to the academic sector. As Tables 1 and 2 shows the respondents were predominantly male, white, and were born in the country. They have a PhD, are married, are either lecturers or scientists, and worked in the field of natural sciences. Academics, on average, were older than those in the research institutes in the province. A similar trend was repeated in their institutional age (years working in the same institution) and academic age (years after obtaining the highest degree) as well. The legacy of apartheid was evident in Indians and Africans being in the minority amongst the respondents. More than half of them had earned a PhD while another quarter had successfully completed their Masters in their respective disciplines. Sector-wise, two-thirds of the academics had a PhD as against one-fifth of the scientists in research institutes. Academics were more experienced than scientists as seen from their institutional age. This also means academics remain at their institutions more than scientists stay in research institutes. The academic age of the respondents was relatively higher for the academics in the university sector than those in the research institutes.

Table 1 Background of academics and researchers

Background variables	Academics ($n = 141$)		Scientists ($n = 63$)		All ($n = 204$)	
	N	(%)	*N*	(%)	*N*	(%)
Gender[*a]						
Male	104	73.2	38	26.8	142	69.6
Female	37	59.7	25	40.3	62	30.4
Race[ns a]						
White	77	70.6	32	29.4	109	53.4
Indian	34	70.8	14	29.2	48	23.5
African	25	61	16	39	41	20.1
Coloured	2	66.7	1	33.3	3	1.5
Others	3	100	0	0	3	1.5
Born in South Africa[***a]	86	61	55	39	141	69.5
Highest qualification[***a]						
PhD	95	88	13	12	108	53.2
Masters	36	66.7	18	33.3	54	26.6
Bachelors	7	31.8	15	68.2	22	10.8
Diploma	2	11.8	15	88.2	17	8.4
Others	0	0	2	100	2	1
Marital Status[ns a]						
Married	93	71.5	37	28.5	130	63.7
Single	36	59	25	41	61	29.9
Divorced	8	88.9	1	11.1	9	4.4
Separated	2	100	0	0	2	1
Widowed	1	100	0	0	1	0.5
Partnership	1	100	0	0	1	0.5
Position***[a]						
Lecturer	59	100	0	0	59	29.1
Sr. Lecturer	32	100	0	0	32	15.8
Associate Professor	13	100	0	0	13	6.4
Professor	22	100	0	0	22	10.8
Others	6	100	0	0	6	3
Jr. Scientist/Researcher	3	100	0	0	3	1.5
Scientist/Researchers	5	10.4	43	89.6	48	23.6
Sr. Scientist/Researchers	0	0	1	100	1	0.5
Others	0	0	19	100	19	9.4
Discipline[**a]						
Agriculture	10	66.7	5	33.3	15	7.4
Engineering	6	42.9	8	57.1	14	6.9
Life Sciences	41	71.9	16	28.1	57	27.9
Natural Sciences	78	75.7	25	24.3	103	50.5
Others	6	40	9	60	15	7.4

Table 1 continued

	Mean	SD	Mean	SD	Mean	SD
Institutional experience	10.68	10.83	8.92	9.47	10.13	10.43
Age***[b]	44.07	10.78	37.51	9.56	42.06	10.83
Academic age***[b]	31.9	6.64	28.97	6.08	30.99	6.6

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

[a] Tested with Chi square

[b] Results of t test

Collaboration in research projects

Collaborated projects showed some variation between academics and scientists (5.17 and 4.68 respectively) despite being statistically insignificant. Scientists in research institutes, having a higher number of research projects, associated less collaboratively than their counterparts in academic institutions. The count of the collaborative partners in their whole academic and research careers was more for those in the research institutes than for the academics (15 and 20 respectively). The measure of the number of years spent in collaborative research was significantly in favour of academics.

The majority (85 %) reported undertaking specific collaborative projects in their careers. Here again the difference between the academics and scientists is statistically significant in the Chi square test, with increased percentages of respondents skewed towards the academic segment. About 90 % of all the respondents had a first project to do. In the case of this first project 85 % were collaborative. As regards the type of collaboration for this first project, 57 % were regional (within the province), 31 % were national, 10 % were within Africa but outside South Africa, and 40 % were outside Africa. The respondents for their first reported project worked on average with six research partners for a duration of about 4 years.

Fifty-eight percent of all the respondents had a second research project, with a significantly higher percentage grouped among the academics. Of this, 86 % were collaborative, half of them were located within the province, a quarter were within the country, 7 % were in Africa and 28 % were outside Africa. The second project had an average of five research partners (with a significant difference between academics and scientists) with a mean collaboration duration of 4.6 years.

As to third projects, 67 respondents reported positively (33 % of the total). Most of them (87 %) were collaborative. Half of these were regional, 30 % were within South Africa, 9 % were within the continent, and 27 % were from outside Africa. In this third project there were 4.6 research partners with an average project duration of 4.13 years.

The research projects were domestic, intra-continental and international. On average, the respondents reported 1.19 domestic collaborative projects, 0.14 inter-continental projects, and 0.65 international collaborative projects. Academics had more domestic, inter-continental and international collaborative projects than the scientists in research institutes. The difference between sectors ("Academics and scientists") in domestic and international collaborative projects was statistically significant. As to the duration of all three collaborative projects, this was 7.37 years for all respondents, with a significant difference between academics and scientists (a higher score for academics). Taking all the three collaborative projects together, on average they had the opportunity to work with about 16

Table 2 Research activity and collaboration

Project details	Academics		Scientists		All	
	Mean	SD	Mean	SD	Mean	SD
Research projects*	5.26	5.702	7.64	11.71	5.98	8.07
Projects directed	3.32	4.07	4.72	10.15	3.75	6.6
Collaborated projects	5.17	9.5	4.68	5.83	5.02	8.56
Collaborated partners in career	15.4	18.38	20.4	27.81	16.8	21.51
Collaborated years in career**	9.35	9.65	6.38	8.02	8.43	9.27
	N	(%)	*N*	(%)	*N*	(%)
Any collaborative projects in career*a	124	71.7	49	28.3	173	84.8
First project reported[ns a]	128	70.3	54	29.7	182	89.2
Collaborated project	115	74.7	39	25.3	154	84.6
Located in the province	66	75.0	22	25.0	88	57.1
Located in the country	33	68.7	15	31.3	48	31.2
Located in Africa (outside South Africa)	11	73.3	4	26.7	15	9.7
Located outside Africa	52	85.2	9	14.8	61	39.6
	Mean	SD	Mean	SD	Mean	SD
Partners	5.94	10.56	7.62	4.75	6.37	9.45
Beginning year of the project	2002.60	5.08	2003.08	8.244	2002.72	6.03
Duration of collaboration (year)	4.15	3.23	3.15	2.53	3.88	3.08
	N	(%)	*N*	(%)	*N*	(%)
Second project reported***a	96	80.0	24	20.0	120	58.8
Collaborated project	85	82.5	18	17.5	103	85.8
Located in the province	48	80.0	12	20.0	60	50.0
Located in the country	22	73.3	8	26.7	30	25.0
Located in Africa (outside South Africa)	8	100	0	0	8	6.7
Located outside Africa	30	88.2	4	11.8	34	28.3
	Mean	SD	Mean	SD	Mean	SD
Partners*	4.59	3.94	6.69	4.11	4.94	4.02
Beginning year of the project	2002.43	5.61	2002.63	11.51	2002.5	6.86
Duration of collaboration (year)	4.81	4.83	1.87	1.19	4.33	4.58
	N	(%)	*N*	(%)	*N*	(%)
Third project***a	56	83.6	11	16.4	67	32.8
Collaborated project	50	86.2	8	13.8	58	86.6
Located in the province	29	87.9	4	12.1	33	49.3
Located in the country	16	80.0	4	20.0	20	29.9
Located in Africa (outside South Africa)	6	100	0	0	6	9.0
Located outside Africa	15	83.3	3	16.7	18	26.9
	Mean	SD	Mean	SD	Mean	SD
Partners	4.72	4.92	4.67	2.65	4.71	4.61
Beginning year of the project	2002.78	4.77	2004.86	1.57	2003.04	4.54
Duration of collaboration (year)	4.37	4.33	2.29	1.38	4.11	4.13

Table 2 continued

	Mean	SD	Mean	SD	Mean	SD
Domestic collaborative projects***	1.33	1.08	0.86	0.86	1.19	1.04
Inter-continental (African) collaborative projects	0.18	0.55	0.06	0.25	0.14	0.48
International collaborative projects***	0.8	0.94	0.32	0.67	0.65	0.89
Duration of all three collaborative projects (in years)***	8.47	7.27	4.08	3.1	7.37	6.75
Partners in all collaborated projects	15.13	10.43	19	7.71	15.77	10.1

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

[a] Tested with Chi square

[b] Results of *t* test

partners. The variation between academics and scientists was not statistically evident in this regard.

Publication productivity

Table 3 presents the productivity of respondents. Some of these measures had significant differences between the sectors of respondents: the number of papers written in the past year (more for academics), papers presented at national workshops (more by academics), reports (done in large numbers by scientists rather than academics), papers published in foreign journals (higher number for academics), co-authored papers in foreign journals (again, more for academics), co-authored papers in national journals (more by academics), edited books, books and co-authored books (all in favour of academics). Statistically significant differences in *t* test were clear in measures such as the combined productivity of papers in national and foreign journals, co-authored papers in national and foreign journals, and total publication productivity. On all these measures academics fared best.

Publication productivity and research collaboration

Having considered the data on publication productivity and research collaboration of the respondents, the relationship between the independent variables and productivity was explored. The models in Table 4 present the results of regression analysis. Three models each for three types of productivity—productivity of published papers, co-productivity, and total productivity—were run and the standardised beta coefficients and significance are shown in the table.

The control variables included in the analysis were gender, higher degree of PhD, academic age, the number of research projects, collaborated projects, partners in the entire stretch of their career, collaborated years throughout the career, the duration of collaboration, partners in all collaborated projects, and the number of domestic, inter-continental and international collaborative projects.

In the first category—the productivity of papers—there are three separate models for all respondents, academics and scientists respectively. In the first model representing all respondents, independent variables of gender, the highest degree (PhD), academic age, the number of research projects, the duration of all collaborative projects, and the number of international collaborative projects were significantly associated. This model explains a substantial variance of 43 % ($R^2 = 0.436$). The respondents who were male and have a higher degree of PhD were likely to produce more papers in national and foreign journals.

Table 3 Productivity of academics and researchers during the last 5 years

Productivity	Academics		Scientists		All	
	Mean	SD	Mean	SD	Mean	SD
Papers written (in the past year)*	3.65	3.55	2.58	3.52	3.32	3.57
Papers at national workshops*	4.94	6.63	2.98	4.55	4.35	6.13
Papers at international conferences	3.76	5.63	3.33	13.28	3.63	8.62
Reports***	2.49	3.86	11.05	14.49	5.23	9.63
Papers in foreign journals**	7.10	18.65	1.26	2.66	5.36	15.90
Co-authored papers in foreign journals**	6.90	18.60	1.04	2.23	5.16	15.86
Papers in national journals	2.37	8.71	1.46	3.22	2.08	7.42
Co-authored papers in national journals*	1.73	3.38	0.84	1.54	1.45	2.96
Chapters in books	1.02	2.80	0.48	1.27	0.85	2.44
Edited books*	0.21	0.49	0.19	0.52	0.20	0.50
Books*	0.16	0.52	0.02	0.14	0.08	0.35
Co-authored books*	0.11	0.41	0.02	0.14	0.08	0.35
Productivity of papers (national and foreign)*	9.02	27.27	2.70	4.99	7.03	22.91
Total publication productivity*	9.82	29.82	3.11	5.19	7.68	24.94
Co-authored articles in national and foreign journals**	8.27	19.78	1.88	3.12	6.25	16.69
Professional awards	0.29	0.46	0.22	0.42	0.27	0.45

Total productivity includes papers in foreign and national journals, chapters, edited book and books

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

The negative correlation between academic age and productivity explained that an increase in academic age did not necessarily lead to a corresponding increase in the publication of journal articles. An increase in the publication productivity, as the model suggested, was likely to happen if there were more research projects, the duration of collaborative projects was longer, and when there were more collaborative projects to be associated with.

In the second model of the productivity of papers representing academics, three variables—the highest degree of PhD, academic age, and the number of international collaborative projects—were significantly correlated. Academic age was negatively associated, as in the previous model for all respondents. The academics who had a PhD and more international collaborative projects to manage would produce more journal articles in both national and foreign journals.

The third model under productivity of papers for scientists in research institutes explained a variance of 49 %. Two variables were especially significant in the publication of papers in journals. Scientists who were male and had a higher number of research projects were likely to enjoy a higher level of productivity.

The variable of co-productivity of respondents computes the collaborative output achieved through research publications. The three separate models for all respondents, academics and scientists employing the same independent variables are evident in Table 4. In the first model, co-publication of articles in journals was significantly correlated with the highest degree of PhD, academic age, the duration of collaborative projects, and the number of international collaborative research projects the respondents had. Both the duration of the collaborative projects and the number of international collaborative projects had seemingly influenced the production of co-authored papers in academic journals while

Table 4 Regression of publication productivity on collaboration and other factors

Independent variables	Productivity of papers			Co-productivity of papers			Total productivity		
	1 All	*2* Academics	*3* Scientists	*1* All	*2* Academics	*3* Scientists	*1* All	*2* Academics	*3* Scientists
Gender (1 = male, 0 = others)	0.144*	−0.018	0.483**	0.113	0.085	0.194	0.081	−0.098	0.458**
Highest degree (1 = PhD, 0 = others)	0.332***	0.351***	0.254	0.443***	0.422***	0.454	0.425***	0.470***	0.327
Academic age	−0.254***	−0.246*	0.068	−0.195**	−0.231***	−0.114	−0.289***	−0.225**	−0.054
Research projects	0.155*	0.063	0.437*	0.076	0.325**	−0.145	0.156	0.066	0.436*
Collaborated projects	0.053	0.026	−0.211	0.046	−0.212	0.438	−0.009	0.081	−0.365
Collaborated partners in career	0.066	0.005	0.019	0.003	−0.104	0.156	0.182**	0.103	0.133
Collaborated years in career	0.121	−0.038	0.113	0.027	−0.013	−0.253	0.162*	−0.047	0.147
Duration of all collaborative projects	0.205**	0.174	0.203	0.213*	0.121	0.204	0.193**	0.152	0.177
Partners in all collaborated projects	−0.099	−0.028	−0.194	−0.024	0.091	−0.478*	−0.106	−0.069	−0.169
Domestic collaborative projects	0.055	0.062	0.165	0.082	0.016	0.313	0.053	0.015	0.199
Inter-continental (African) collaborative projects	−0.066	−0.009	−0.083	0.069	0.090	0.186	−0.007	0.051	−0.035
International collaborative projects	0.270***	0.305**	0.171	0.223**	0.251**	0.467*	0.214**	0.172	0.263
R^2	0.436	0.446	0.491	0.514	0.583	0.406	0.468	0.462	0.501
N	117	82	33	117	83	33	117	76	31

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

there was negative association for the variable, academic age. The model explained a variance of 51 %.

For the academics, the production co-authored papers was determined by the presence of a PhD, academic age, the number of ongoing research projects, and the number of international projects. In the third model pertaining to scientists only, two variables had emerged with significant association: the number of partners in collaborative projects (negative association), and the number of international collaborative projects (positive association). This model also explained a significant percentage of variance ($R^2 = 0.406$).

Finally, there are three regression models for the total productivity of the respondents. Total productivity—an aggregate measure of articles, chapters and books—of all the respondents seemed to be determined by PhD, academic age, the number of collaborated partners in the whole career, total collaborated years, duration of collaborative years, and the total number of international collaborative research projects. But, as the second model implied, for the academics PhD and academic age were significant denominators. However, for the scientists in research institutes, only two variables—gender and the number of research projects—had an influence on their total publication productivity.

Discussion

This empirical study demonstrates prominent features of South African science. It identifies trends in the research behaviour of academics and scientists working in higher education institutions and research institutes. The relationship between collaboration and productivity was examined. This revealed that it varied with the types of collaboration. Relevant measures drawn from the literature were used in the analysis. However, being a cross-sectional study, the cause-effect relationship is not unidirectional.

The characteristic features of South African academics and scientists were evident from the study. The findings that those in research institutes worked with more research projects, directed a higher number of projects, were involved in fewer collaborative projects than academics, and had more collaborative partners but fewer number of collaborated years in their careers suggest the significance of research collaboration in their careers. As full-time researchers, respondents in research institutes normally engage in a substantial number of projects at any given point in time. This, in turn, determines the number of projects they administer and direct—more research projects normally imply more projects to direct. Although the number of collaborated projects was less for the scientists in research institutes, they had a relatively greater number of partners. This could be due to the nature and size of the projects that required a good number of participants and association. The interests of the respondents to associate with others in their research were also obvious from their responses to the questions on collaboration.

The regression models supported the connection between productivity and the nature of collaboration the respondents had in their research endeavours. To summarise the findings of the models, productivity was influenced by the number of research projects the respondents had, the number of international collaborative projects in which the respondents were currently involved in, the duration of the collaborative projects, the number of collaborators, and the length of collaboration. The literature on collaboration and productivity also provides evidence to corroborate this finding. Thus Basu and Aggarwal (2001), Navarro and Martin (2004), Belkhodia and Landry (2007), Sooryamoorthy and Shrum (2007), Defazio et al. (2009), Ponomariova and Boardman (2010) and numerous others have confirmed the relationship between collaboration and productivity.

As is evident from the data, both academics and scientists were productive in terms of their publications in academic journals and co-authored publications. The difference between the figures for the productivity of papers in both national and foreign journals, and the figures for co-authored articles in both national and foreign journals was not significant for academics and scientists (7.03 and 6.25 respectively). This result substantiates the preference of the respondents to work collaboratively rather than individually in the production of research papers. Books and co-authored books have shown no difference in production between respondents. The publication of papers in national and foreign journals nevertheless revealed a different picture. While the respondents published an average of 2.08 papers in national journals during the past 5 years, co-authored ones were 1.45 papers. In foreign journal publications the count were 5.36 and 5.16 respectively; i.e. almost all papers were co-authored. What is unique here is the presence of international collaboration and corresponding international publications of the respondents. This merits further exploration.

The relevance of international projects in the careers of respondents was clear from the publication of journal articles. International collaboration in research has enhanced the chances of publication, which was not the case with domestic collaboration. Perhaps the results of the domestic projects are not normally translated into publishable papers in journals. Alternatively, the researchers do not think that it is an essential outcome of domestic projects. Many of the research projects conducted in research institutes, as the interviews revealed, were commissioned for specific application and policy purposes. Publication of the findings of these projects in journals is thus not a necessity for them.

Why is there a difference in publication productivity—less in number for scientists in research institutes—between sectors with the exception of research reports? One plausible explanation for this is the funding academics receive in South Africa for every publication they produce in approved and recognized journals. While the government provides R150,000 for every single authored paper, the universities distribute R20,000–30,000 to authors—depending on the institution they are affiliated to—per single authored (divided among authors in co-publications) publications in the ISI, IBSS or government (Department of Education) approved journals. This advantage is not available to scientists in research institutes in the country.

Another relevant factor for publication is the value attached to publications for career advancement and promotions. Most of the universities in South Africa have set up norms about the number of publications an academic should produce every year. It has become part of the performance assessment. Although it varies from institution to institution, usually it is one full paper for lecturers, one-and-a-half paper for senior lecturers, and two for associate, and two-and-a-half for full professors. Some universities have begun to recognize highly productive academics through a system of special rewards. Scientists in institutes are not yet subject to this kind of publication requirements or rewards for their career advancement.

Prior research shows that the productivity of academics and researchers declines with age. Gonzalez-Brambila and Veloso (2007), looking at the determinants of research output of researchers in Mexico and their impact in terms of citations, reported a quadratic relationship between age and the number of publications. As their age increases over the course of their careers, their motivation to publish diminishes (Levin and Stephan 1991). This agrees with what was found in the present study. The models presented in this paper consistently illustrated that the productivity of the respondents had a declining pattern as their academic ages increased. The strength of motivation and encouragement for publication in the early part of their career wanes towards their career's end.

The collaborative prescriptions for funding that encourages collaborative research have been reported in a study by Defazio et al. (2009). This does not happen in South Africa under the contemporary scientific system. As indicated earlier, the sole author of a paper would receive full subsidy; if the paper is coauthored the subsidy will be divided among all the authors. The result is less money for more partners. This does not necessarily encourage collaboration when researchers are seeking as much research funding as possible. The sources of such funding are limited and they are also very competitive. Single authored publications are therefore advantageous from the point of view of funding to carry on with their research and for the further production of publications. No serious academic or scientist would wish to break this cycle of research, publication and funding by engaging in with collaborative publications that often is a result of collaborative research.

Pouris (2012) in his recent analysis has identified three major factors for the increase in the production of research papers by South African researchers: the introduction of social sciences researchers since 2001 to the National Research Foundation fold and its rating system, the increase in the number of publications covered by ISI indexed journals, and the incentives provided by the government for publication outputs. Pouris acknowledges the importance of incentives in productivity to the country.

Compared to those on the African continent, South African researchers are highly productive. According to one estimate, South African researchers (16,000 in total) produced 7,000 research papers a year (Gevers 2006). The contribution of South Africa to world science over the last 10 years has increased, reaching 0.65 % in 2010 (Pouris 2012). The ranking of South Africa in terms of research publications has moved from 35th in 2000 to 33rd position in 2010.

If collaboration has the probability of increasing productivity, as is evident from this study, efforts should be geared towards supporting collaborative alliances between institutions and partners from within the country and different parts of the world. More significantly, potential publication opportunities are not the only reason for academics to establish collaborative links with peers. The literature indicates collaboration is motivated by reasons including the need for resources (funds and equipment), improvement of one's skills and expertise in the field, expansion of knowledge, and for increased visibility in the area of research. As Schubert and Sooryamoorthy (2010) noted South African scientists demonstrate strategic behaviour in seeking collaboration which is underpinned by the possibilities of resources, reputation of the partners and funding. Both funding and an effective incentive system for co-authored publications are as important as for single authored publications in order to strengthen productivity and improve the ranking of South Africa in world science. One way forward is to reward full subsidy to a co-authored paper with partners from abroad.

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