Does the Internet Promote Collaboration and Productivity? Evidence from the Scientific Community in South Africa

R. Sooryamoorthy
Sociology Programme
University of KwaZulu-Natal, South Africa

Wesley Shrum
Department of Sociology
Louisiana State University

Abstract

International collaboration among scientists has been passionately advocated by many in the developing world. Among the several conditions that support collaboration among members of a dispersed scientific community, Internet technology is crucial. We examine the relationships among electronic communication, collaboration, and productivity in South Africa, a country that has undergone remarkable change in the sphere of science and technology. We surveyed 275 scientists in selected research institutes and universities in the province of KwaZulu-Natal to address the questions: Is greater use of the Internet associated with international collaboration? Are collaboration and Internet use associated with publication in national and foreign journals? The results show that (1) Internet use, as measured by time spent on email, is positively associated with collaboration; (2) collaboration is *not* generally related to publication productivity; and (3) there is little evidence that South African academics benefit from international collaboration. While scientists who use email intensively are slightly more productive, this is not the case for foreign productivity in the case of academic scientists.

Introduction

This study addresses two persistent issues in the literature on scientific collaboration in the developing world context. First, is there any association between use of the Internet and scientific collaboration? Second, is there a relationship between Internet use, collaboration, and productivity? Using survey data from academics in universities and scientists in research institutes in two institutional settings in South Africa, we address questions first raised in a similar study (Duque, Ynalvez, Sooryamoorthy, Mbatia, Dzorgbo, & Shrum, 2005) carried out among academics and scientists in three developing countries in Africa and Asia as well as other studies among scientists in developed countries.[1] South Africa is a particularly interesting comparison, since it is the most "developed" scientific community in Africa.

The notion of collaboration itself is a multifaceted concept, encompassing an array of dimensions (Hackett, 2005; Sonnenwald, forthcoming 2007). What distinguishes it from many other organizational aspects of research (e.g., team size, bureaucractic structure) is that it is generally viewed as a symbiotic and mutually beneficial activity (Shrum, Genuth, & Chompalov, forthcoming 2007). Collaboration, mainly in large-scale, cooperative scientific enterprises, requires the support of new models of e-science (Boldyreff, Nutter, & Rank, 2004). E-science envisages the creation of a powerful infrastructure that supports entirely new ways of doing collaborative science (Hey & Trefethen, 2003).

Collaboration occurs among scientists from different continents and cultures through a spectrum of technologies, producing a mix of knowledge, products, and solutions. In the research process, collaboration is viewed as producing results through the transfer and sharing of information, skills, and expertise. International collaborative initiatives are passionately advocated by many in the science policy and development communities, for reasons of perceived mutual advantage. When such collaboration occurs between developing and developed areas, this advantage is thought to be particularly important for under-resourced partners in the developing world.

The excitement that attended the advent of the Internet in the early 1990s was related to its potential for collaboration, which is fundamentally related to the exchange of information and the coordination of activities. The possibilities for partnerships, projects, and scientific programs in the international arena seemed endless, as rapid, efficient, and effective communication and information transmission were now a reality. Electronic mail, long available in the U.S. and Europe, had emerged as the fundamental technology for collaborative science not just between institutions but across international boundaries. Since most regions in Asia, Latin America, and particularly sub-Saharan Africa lagged in Internet access, international programs such as the Leland Initiative as well as major forums such as the World Summit on the Information Society argued for the spread of Internet connectivity for development in general and scientific development in particular.

Access to the Internet for all universities and research institutes was adopted as a core component of the Declaration of Principles and Plan of Action for the developing world. According to this 'elixir' perspective, the developing world only stands to benefit from new communication technologies and research institutions will escape their marginalized position n world science (Davidson, Sooryamoorthy, & Shrum, 2002). Opportunities for collaboration will be strengthened as the virtual distance between developing and developed countries decreases, and current constraints on interactive work will be minimized (Walsh & Maloney, 2003). Emergent information and technologies may foster new types of collaboration (Sonnenwald, forthcoming 2007) and the productivity of collaborators may be improved (Lee & Bozeman, 2004).

Supportive evidence for an increase in collaboration itself is recorded extensively in the literature on scientific publication, including international collaboration (Frame and Carpenter, 1979). This has been attributed to the global increase in scientific institutions and the need for scholars in developing areas for collaborations and funding opportunities abroad. The basic phenomenon, as observed by Price (1963), is that scientists who become leaders of research groups increase their productivity levels by co-authoring with other scientists, a kind of "fractionalization" of research behavior. Other studies have confirmed a positive relationship between collaboration and productivity (Price, & Beaver, 1964; Lotka, 1926 cited in Lee & Bozeman, 2005; Pao, 1982; Zuckerman, 1967).

Lee and Bozeman (2005), examining the assumption that research collaboration has a positive effect on productivity, found that while the number of collaborators is a predictor of publishing productivity using a normal count of peer-reviewed journal papers, it is not so apparent in the fractional count of papers. This implies that although collaboration may be associated with some kinds of productivity, the relationship between them may not be straightforward owing to various individual, institutional, and environmental factors. This finding could have important consequences for collaborations between developing and developed countries.

Until recently, there has been little empirical evidence on the process of collaboration from the developing countries themselves. Duque, et al. (2005), reporting findings from Ghana, Kenya, and India, suggest a "paradox of collaboration" in developing areas: Those conditions that make the relationship between collaboration and productivity problematic can also undermine the collaborative benefits of information and communication technologies. This study showed that the African sites were *more collaborative but less productive* than the Indian sites, a finding that casts a shadow over policies based on the assumed benefits of collaboration. However, many of the researchers in these East and West African countries still found Internet access problematic at the time of the study, as contrasted with South Africa, where access in the research community is nearly universal. The present study is based on a similar survey and methodology, as well as the important distinction between the two major knowledge-producing sectors in the developing world, universities and research institutes. In the following sections we present the context and the method employed in this study.

Context and Method

The study is set against the background of the scientific community in South Africa, a country that has been undergoing rapid changes, particularly since its liberation from the circumstances that controlled and prevented opportunities for interaction and collaboration with the external scientific community. We surveyed scientists in universities and research institutes in KwaZulu-Natal, the largest populated province of South Africa. We measured professional characteristics, collaborative behavior, and productivity as well as institutional access to and use of ICTs.

Data for the study were gathered from 16 departments and 10 research institutes situated in five major centers of academic and research activity (Durban, Pietermaritzburg, Cedara, Edgecombe, and Umhlanga) in KwaZulu-Natal, the largest populated province in the country. South Africa has the highest scientific output of any African country, generated by over 12,500 researchers based primarily in universities and research institutes.[2] The higher education system began a transformation in 2004, merging and incorporating small universities into larger institutions and formerly white and black universities. Our academic sample was drawn from one of three categories of universities, called "traditional" universities, that offer theoretically-oriented university degrees.[3] However, it is important to include the non-academic research sector as well. South Africa has eight statutory science councils that carry out research for social, scientific, and technological development: the Agricultural Research Council, Council for Scientific and Industrial Research, Council for Geosciences, Human Sciences Research Council, Medical Research Council, Mintek, and South African Bureau of Standards. Each council operates various research institutes throughout the country. We interviewed researchers from institutes under the Agricultural Research Council, Council for Scientific and Industrial Research, Council for Geosciences, and Human Sciences Research Council.

Interviews were conducted with 275 respondents from the selected departments of a university and a college (n=170), as well as national and regional research institutes (n=105) during 2004-2005. The survey instrument and methods were based on previous studies beginning in 1994 and repeated in 2000-2002 in Ghana, Kenya, and India (Kerala). The questionnaire was a modified version of that used in the 2002 Ghana study, with several pages of items on information and communication technologies. We attempted to interview all respondents in the chosen departments and the institutes[4] representing the fields of biology and biotechnology (35%), agriculture (25%), chemistry and physics (17%), engineering and IT (11%), and social sciences (4%). All respondents were either full-time academics in the universities or full-time researchers in research institutes.

Our dependent dimensions in this analysis are collaboration and productivity. In contrast to studies that use bibliometric techniques, this study uses self-reported publication productivity. Bibliometric measures are inadequate as indicators of scientific productivity outside the developed world (Gaillard, 1991; Shrum, 1997; Ynalvez, Duque, Sooryamoorthy, Mbatia, & Shrum, 2005). We asked separately for the number of articles published in national and foreign journals for a period of five years before the date of the face-to-face interview (1999-2004). An additive scale to measure total publications was also used in our analyses. As the distribution of publications is positively skewed, we employ natural logarithms of self-reported productivity in our analyses.

Collaboration was studied here as an inter-organizational process (collaborations internal to the organization were excluded) and measured in two ways. Our survey asked about the extent to which the respondent's main research projects are collaborative.[5] We asked each of them to describe briefly up to three specific projects, coding them dichotomously to indicate whether the project involved collaboration or not. The degree of collaboration was indicated by an additive scale measuring the number of collaborative projects (0 to 3). Next we asked about the location of these projects as an indicator of whether they were local (within the country) or external (outside the country); this allowed us to create another additive scale for the total number of international collaborations.[6] Further, we obtained information on the total number of projects that the respondent was engaged in and more detailed information on up to three of their most important current projects.

The control variables used in our analyses were derived from prior studies on scientific productivity and collaboration. For example, Garg and Padhi (2000) have shown the effect of contextual factors on productivity. Several authors (e.g., Campion & Shrum, 2004; Goel, 2002; Prpic, 2002) have found gender differences in productivity while others have not (Gupta, Kumar, & Aggarwal, 1999). Duque, et al. (2005) used gender, age, marital status, educational credentials and professional variables in their analysis. Our control variables include sector (coded as a dummy variable with university scientists as the reference group), gender (1=male; 2=female), age, marital status (1=married;0=not married), education (1=doctorate; 0=non-doctorate), professional involvement (membership in a professional association), and professional status (held an office in a professional association).

Cummings and Kiesler (2003) reported that the use of more communication mechanisms had positive effects in collaborative projects. ICT tools, including the World Wide Web and email, have facilitated "migration of minds without the migration of bodies" (page number not available as it is sourced from the web) in developing countries (Oldham, 2005) and supported collaboration (Sonnenwald, forthcoming 2007). Yet the use of electronic mail remains the primary technology of collaboration for communication between individuals and teams of scientists and scholars. Indeed, in the case of our own six-country collaboration over the past five years, we are hard pressed to think of even a single ICT application that approaches electronic mail in frequency of use. Virtually all of the respondents in our sample have access to the Internet, so access alone is not an issue.[7] What distinguishes the researchers we studied is the degree of Internet use. Qualitative interviews conducted in 2003-2004 showed that scientists vary markedly in the extent that they employed a facility that was available to all. After examining a variety of indicators of Web, computer, and electronic mail practices, we settled on a single indicator for Internet use. *Intensity of email use* is measured by asking the respondents how much time they spent on email in a given week (0=not at all, 1=less than one hour, 2=between one and five hours, 3=between five and ten hours, 4=between ten and twenty hours, 5=over twenty hours).

Table 1 presents basic socio-demographic characteristics of the sample: education, cosmopolitanism, professional activities, productivity, research projects, and collaboration. We note in particular that only one-third of the respondents were born in South Africa, while the rest moved to the country later at various stages of their lives and careers. This is highly unusual for sub-Saharan Africa and reflects the particular characteristic of the South Africa research system. Yet on average, immigration took place 20 years ago, and the respondents had been in the country for a significant proportion of their careers, given the average age of 41 years. By sector, South African birth is more characteristic of scientists in research institutes, while those who were not born in South Africa made their move approximately six years before their university counterparts did.

Variables	*Academic*	*Research Institute*	*Total*	*N*
1	*2*	*3*	*4*	*5*
1. Father's occupation (% rural) a	8.3	12.4	9.9	274
2. Born in South Africa (%)*** a	57.1	79	65.5	275
3. Year moved to South Africa * b	1986.65	1980.15	1985.24	92
4. Gender (% male)* a	75.9	58.1	69.1	275
5. Age*** b	42.85	37.17	40.68	275
6. Ethnicity (%) a				275
Whites	69.4	68.6	69.1	
Africans	14.1	9.5	12.4	
Indians	12.4	20	15.3	
Coloreds#	0	1	0.4	

7. Married (%)** a	67.6	54.3	62.5	275
8. Number of children *** b	1.29	0.77	1.09	271
9. Spouse employed in education sector (%) a	23.7	24.6	24	179
Education and Cosmopolitanism				
10. Advanced degree (%) *** a	84.7	70.5	79.3	275
11. Doctoral degree (%)***a	60.6	26.7	47.6	275
12. Any degree from developed countries (%) * a	31.8	16.2	25.8	275
13. Year spent outside the country for higher education *** b	3.74	0.71	2.58	274
14. Years spent in developed countries*** b	6.73	2.57	5.15	275

Table 1. Background, education, and cosmopolitanism

Notes: ***, **, * significant at the .01, .05, .1 levels respectively

a. Tested with Chi-square

b. Results of t-test

It is an official category for mixed races in South Africa.

Table 1 also shows the predominance of men in the sample: Only 30% of our respondents are females.[8] Most are married (63%), have an average of one child, and one-quarter of their spouses are employed in the education sector. Similar to the national employment in the agricultural sector, 10% of the respondents come from farming backgrounds. However, the most important factor in South Africa is race. With implications of its own in the post-apartheid era, the country is passing through a period of transformation supported by policies of affirmative action to increase the proportionate visibility of the previously disadvantaged sections in employment. Whites remain the majority in our sample, with 70%, while Africans, Indians, and others constitute the rest. The composition of our sample is almost the reverse of the country's population, where whites represent only 9.5% and Africans 79%.

Education, Cosmopolitanism, and Involvement

Education and training of scientists in developing areas has been one of the most critical research and policy areas since the post-colonial period (Shrum & Campion, 2000). Only half of the full sample had a doctoral degree at the time of interview, with academics being more likely to have one than researchers in government institutes. An advanced degree such as a master's degree had been obtained by 80% of the sample. A quarter of the participants earned this degree from a developed country after spending about 2.5 years there for their higher education. On average, respondents had spent 5.2 years in developed countries, or 12% of their lifetime (the average age being 41 years) in such countries. South Africa, unlike other African countries, was isolated for nearly half a century by an international community that did not maintain diplomatic ties. The country attracted much of its scientific and academic talent after 1994, as reflected in the fact that 37% of our respondents moved to South Africa after the democratic era dawned.

Results

Table 2 shows that our respondents are professionally active, in terms of membership in professional organizations, editorial work, and professional meetings, working an average of 50 hours a week, with 21 hours (40% of the total work) devoted to research.

Variables	*Academic*	*Research Institute*	*Total*	*N*
1	*2*	*3*	*4*	*5*
Work and Professional Activities				
1. Job title (%)				275
Lecturer/Sr. Lecturer	33.5			
Associate Professor	6.2			
Professor	12.0			
Others (tutors/res.assts)	9.5			
Sr. Researchers/Sr. Scientists		14.5		
Jr. Researchers/Jr. Scientists		18.2		
Others (technicians, assts)		6.2		
2. Weekly hours worked ** b	50.54	47.23	49.28 (92)	275
3. Hours spent on research (%)***a	17.14	27.99	21.3 (75)	274
4. Held office in a professional organisation (%)**a	43.5	33.3	39.6	
5. Member of professional organisation (%)*a	85.9	70.2	79.9	274
6. Professional meetings attended (%)***a	31.27	68.72	45.53	273
7. Served on the editorial board of journals (%)**a	25.9	11.5	20.4	274
Productivity (1999-2004)				
8. Total articles *** b	6.1	2.8	4.84 (2.03)	274
9. Articles in foreign journals** b	4.32	1.58	3.27 (1.95)	275
10. Articles in national journals ** b	1.76	1.22	1.55 (1.71)	274
Projects and Collaboration				
11. Number of research projects*** a	4.41	6.04	5.03 (40)	275
12. Any current collaboration (%)	83.9	84.6	84.2	259
13. Number of collaborative projects**a	1.52	1.77	1.62 (3.00)	275
14. Number of international collaborations*** a	1.19	0.64	0.96 (3.00)	217

Table 2. Professional activities, internal networks, projects, and collaboration by sector
Notes: ***, **, * significant at the .01, .05, .1 levels respectively.
a. In percentage, tested with Chi-square b. Results of t-test.
Figures represent within each sector, namely, university and research institute. Figures in parentheses represent range.

Collaboration and the Internet

Our first question pertains to the relationship between collaboration and the use of the Internet, interpreted here as the intensity of email use. Table 2 indicates that scientists in research institutes report more total projects than do academics; this is not surprising since they spend more time on research and have few, if any, teaching responsibilities. There is no significant difference in the presence of collaboration by sector, with the vast majority of respondents reporting some research collaboration at the time of the interview. However, scientists in research institutes differ in terms of their pattern of *collaboration*, as shown in rows 13 and 14 of Table 2. Academics have significantly fewer collaborations overall (1.52 as compared with 1.77 for scientists in research institutes), but these collaborations are more likely to be international in character (1.19 versus .64).

A: All Collaboration	*University*	*Research Institutes*
1	*2*	*3*
Email intensity	.19**	.20*
Gender (1=male, 2=female)	-.02	-.24*
Doctoral degree (1=PhD, 0=less than PhD)	.33**	-.04
Professional status (1=high, 0=low)	.22**	.09
R^2	.26	.09
N	169	104
B: International collaboration		
1	*2*	*3*
Email intensity	.23**	.06
Gender (1=male, 2=female)	-.24**	-.002
Doctoral degree (1=PhD, 0=less than PhD)	.27**	.21
Professional status (1=high, 0=low)	.31**	.25*
R^2	.33	.12
N	128	87

Table 3. Regression of all collaboration and international collaboration on email intensity and background factors

Notes: **p<.01, *p<.05

Professional status: Held office in a professional association

Email intensity: 0=Not at all; 1= Less than one hour; 2= Between one and five hours; 3= Between five and ten hours; 4= Between ten and twenty hours; 5 = Over twenty hours per week

Panel A of Table 3 shows the results of regressing collaboration on email intensity and three control variables that were significantly associated with collaboration in a variety of model specifications.[9] Separate columns display the results for scientists in research institutes and academics in university settings, given the different task, promotion, and incentive structures prevailing in these two organizational types. While the amount of explained variance is not large (26% for universities and 9% for research institutes), Panel A supports the hypothesis that greater email use is associated with greater collaboration for both settings. For scientists in research institutes, the only other significant effect is gender, with women scientists engaging in fewer collaborations than men. For academics, gender has no impact on the degree of collaboration. Instead, doctoral degree and professional status (as measured by holding office in a professional association) are associated with more collaborative behavior. In sum, the findings in Panel A indicate that email intensity is the only factor that consistently predicts involvement in collaborative research, without regard to its location.

Of course, collaboration itself is nothing new, as the sociology of science has shown since the 1960s (Price, 1963). The promise of the Internet resides in its ability to facilitate collaboration over long distances, particularly national boundaries. We defined "international collaboration" as the total number of collaborative projects outside South Africa. Panel B of Table 3 shows the results of regressing collaboration on email intensity and the same control variables. We saw in Table 2 that academics are engaged in significantly more international collaboration than their counterparts (nearly three-quarters of all academics engaged in at least one international collaboration, as compared with only 38% of scientists in institutes). As Table 3 shows, we are able to account for one-third of the variation in international collaborative behavior of academics with a model including the four specified variables. Gender is highly significant for international collaboration, with significantly less collaboration for women scientists. Possession of a doctorate degree, professional office-holding, and use of email are strongly positive. However, the most interesting finding in Panel B may be the *absence* of any significant effect of email intensity for scientists in research institutes.[10] As we will see in the final tables, email intensity does not have uniform effects across research sectors.

Productivity and Collaboration

In examining the relationship between productivity and collaboration, there is a strong temptation to view the former as the dependent and the latter as an independent variable.[11] This temptation should be resisted. First, our data are cross-sectional, and no causal relationship can be ascribed. Second, highly productive individuals may be viewed as valuable collaborators and receive opportunities as a result of their published work. Supporting that notion in Table 3 is the positive coefficient for professional status. This indicates that high professional status, as measured by holding office in a professional association, is associated with greater collaboration, which may be due to such a process of attraction. Office holding, by contrast, is not associated with publication productivity, so we employ a measure of professional *involvement*: membership in one or more professional associations. We saw in Table 2 that respondents publish an average of one article per year. Measured in terms of the self reported papers published in foreign and national journals in the last five years, the productivity (1999-2004) for the full sample is 4.9 papers, with academics publishing at about twice the rate of scientists working in research institutes.[12]

Is collaboration positively associated with publication productivity for scientists in developing areas? Table 4 presents several models for total publication, national publication, and foreign publication, controlling for email intensity and total collaboration. Table 5 has models for total publication, national publication, and foreign publication, controlling for email intensity and the subject that is our key interest here, *international* collaboration. As prior research suggests, measures of "total" publication, combining national and foreign articles, are difficult to interpret in the context of the developing world (Shrum, 1997; Ynalvez, et al., 2005). As in our previous analysis, we control for gender and education, but add controls for marital status and professional involvement. Table 4 (Panel A) presents standardized beta coefficients and levels of significance for models of total productivity for university and institute scientists. We are able to explain about 40% of the variance in total productivity with largely similar predictors for both organizational settings. Email intensity, professional involvement, and a doctoral degree are positively associated with total productivity for both university and institute respondents, while collaboration is important only for the university researchers. Possession of a doctoral degree, high levels of professional involvement, and greater use of email are associated with greater productivity of researchers, irrespective of sectoral affiliation. Collaboration is positively associated with the total productivity of only university researchers. The negative coefficient for gender indicates women have lower publication productivity than men, but only in the academic setting.

A: Total articles	*University*	*Research Institute*
Total number of collaborations	.23**	.10
Marital Status (1=married, 0= not married)	.11	.13
Gender (1=male, 2=female)	-.21**	-.12
Doctoral degree (1=with doctorate, 0=without doctorate)	.36**	.36**
Professional involvement (1=high, 0=low)	.15*	.25**
Email Intensity	.13*	.17*
9. R^2	.48	.35
10. N	168	103
B: Articles in national journals		
Total number of collaborations	.33**	.11
Marital Status (1=married, 0= not married)	.09	.07
Gender (1=male, 2=female)	-.10	-.12
Doctoral degree (1=with doctorate, 0=without doctorate)	.05	.17
Professional involvement (1=high, 0=low)	.10	.23*
Email Intensity	.18*	.14
9. R^2	.25	.18
10. N	168	103
C: Articles in foreign journals		
1	*2*	*3*
Total number of collaborations	.10	.03
Marital Status (1=married, 0= not married)	.13*	.09
Gender (1=male, 2=female)	-.22**	-.12
Doctoral degree (1=with doctorate, 0=without doctorate)	.42**	.43**
Professional involvement (1=high, 0=low)	.10	.15
Email Intensity	.12	.24**
9. R^2	.42	.36
10. N	169	103

Table 4. Regression of publication productivity on total collaboration, email intensity, and background factors

Notes: **p<.01, *p<.05

Professional involvement: Membership in professional association

Email intensity: 0=Not at all; 1= Less than one hour; 2= Between one and five hours; 3= Between five and ten hours; 4= Between ten and twenty hours; 5 = Over twenty hours per week

The models we have seen so far explain combined publication productivity, but do not distinguish between national and foreign productivity. The distinction is important, since publication in foreign journals is more highly valued by research institutions in developing areas. Is there any underlying contextual distinction between national and foreign levels in this collaboration-productivity linkage? Do the respondents strive for international recognition in their own respective disciplines and specializations by publishing regularly in more visible foreign journals rather than in locally produced journals that focus on local and regional topics?

Panels B and C of Table 4 show regression models for the logarithm of national and foreign productivity (publication in national journals and foreign journals respectively). Here we can see a dissimilar pattern. Greater collaboration and email intensity are associated with increased national productivity for university scientists, but not for those employed in research institutes, where professional involvement is the most decisive factor. However, the significance of these factors disappears when we regress foreign productivity on the same set of variables in Panel C. Total collaboration does not determine international productivity for either organizational setting. For university scientists, the most important correlates of foreign productivity are gender, marital status, and doctoral degree. For those in research institutes, accounting for more than one-third of the variation in the model, doctoral degree and email intensity are crucial.

A: Total articles	*University*	*Research Institute*
International collaboration	.08	.15
Marital Status (1=married, 0= not married)	.10	.12
Gender (1=male, 2=female)	-.25**	-.123
Doctoral degree (1=with doctorate, 0=without doctorate)	.33**	.37**
Professional involvement (1=high, 0=low)	.26**	.20*
Email Intensity	.16*	.18*
9. R^2	.41	.38
10. N	128	87
B: Articles in national journals		
International collaboration	.14	.23*
Marital Status (1=married, 0= not married)	.10	.05
Gender (1=male, 2=female)	-.09	-.12
Doctoral degree (1=with doctorate, 0=without doctorate)	.04	.17
Professional involvement (1=high, 0=low)	.15	.18
Email Intensity	.26**	.13
9. R^2	.17	.22
10. N	128	87
C: Articles in foreign journals		
1	*2*	*3*
International collaboration	.04	.12

Marital Status (1=married, 0= not married)	.12	.07
Gender (1=male, 2=female)	-.25**	-.12
Doctoral degree (1=with doctorate, 0=without doctorate)	.37**	.45**
Professional involvement (1=high, 0=low)	.17*	.09
Email Intensity	.10	.26**
9. R^2	.35	.39
10. N	128	87

Table 5. Regression of publication productivity on international collaboration, email intensity, and background factors

Notes: **p<.01, *p<.05

Professional involvement: Membership in professional association

Email intensity: 0=Not at all; 1= Less than one hour; 2= Between one and five hours; 3= Between five and ten hours; 4= Between ten and twenty hours; 5 = Over twenty hours per week

Finally, we turn to the relationship between email intensity, international collaboration, and productivity. Regressing productivity (and its two forms) on international collaboration and email intensity, we find that total productivity of both university and institute scientists is not related to international collaboration but to email intensity (Panel A). Possession of a doctoral degree and high levels of professional involvement are associated with total productivity for scientists in both sectors, but not for female scientists in the university. International collaboration is only associated with national productivity for scientists in research institutes; it is not associated with any model of productivity for academics. While email intensity is weakly associated with total productivity—the sum of national and foreign articles—the models are much clearer when the two kinds of productivity are considered separately. Email intensity is strongly correlated with *national productivity* for university researchers, but with *foreign productivity* for scientists in research institutes. Recurring again is the strong negative correlation between foreign productivity and gender, indicating that male university respondents publish more in foreign journals than do females. In both contexts, doctoral degree is the factor most highly correlated with foreign publication productivity.

In sum, controlling for education, professional involvement, and gender, *neither total collaboration nor international collaboration is consistently associated with productivity*. More significant than collaboration is the degree to which the respondent employs email, which is associated with productivity across both sectors. This finding is consistent with previous studies (Cummings & Kiesler, 2003; Oldham, 2005; Sonnenwald, forthcoming 2007), but with an important qualification: For university scientists, email intensity has no impact on the foreign publication productivity that is generally regarded as most valuable by university administrators and Ministries of Education.

Discussion

We examined the linkages among Internet use, scientific collaboration, and productivity of scientists working in two institutional settings (universities and research institutes) in the most highly developed research system in sub-Saharan Africa. Beginning with the question of collaboration, including international collaboration that is a constituent component of e-science and its connection with productivity, we analyzed whether the use of the Internet was associated with collaboration and the productivity of researchers. Our data are cross-sectional, and we cannot claim that a statistically significant association between two variables is causal in nature. We stress the need for future panel studies of this issue; this study can only be viewed as a first, preliminary assessment of the issue.

However, cross-sectional data analysis can have causal implications. The absence of an association in bivariate or multi-variate analysis does cast doubt on the theories that postulate causal relationship. Measuring collaboration in terms of both the number of collaborative research projects and their location, this study provides a preliminary look at the collaborative behavior of scientists in South Africa. To summarize the important findings, we have seen that:

(1) Academics engage in less collaboration than scientists in research institutes, but their collaborations are more likely to be international.
(2) Internet use, as measured by the time spent on email, is positively associated with collaboration. However, it is associated with *international* collaboration only for university scientists.
(3) Collaboration is not generally related to publication productivity, except for two specific cases of the total productivity and national productivity of scientists in universities. There is no evidence in our South Africa data that academics benefit in terms of publications from international collaboration.
(4) In the South African context, scientists who use email intensively are typically more productive, with one important exception. Email intensity is not associated with greater foreign productivity for academic scientists, even when collaborative behavior is controlled.

We note that there is a consistent negative association, often significant, of gender with both collaboration and productivity. This negative association is more visible in the university context than in government institutes, and suggests the presence of barriers, discrimination, or other factors that cause women to lag behind their male counterparts in an important sector of knowledge production. We note in particular that this negative effect is greater for *international collaborations and for foreign productivity* than for total collaborations and national productivity. This finding is consistent with recent work on South India focusing on restrictions of physical mobility that limit international opportunities for women (Palackal, Anderson, Miller, & Shrum, 2006; Miller, Sooryamoorthy, Anderson, Palackal, & Shrum, 2006. (ok) While gender was not originally a focus of our analysis here, this emergent finding is clearly a matter of great concern in this transforming phase of South Africa.

In sum, these data indicate the importance of email use, particularly the intensity of email use in a context where email access is universal. While there is still substantial variation in access to ICTs within the scientific communities of other sub-Saharan African countries, virtually all scientific personnel in the province of KwaZulu-Natal, South Africa, are provided with Internet access. Given that uniformity, our analysis focused on the intensity of Internet use, and our results show that more hours spent using email on a weekly basis is associated with generally higher levels of collaboration and greater productivity. Certain control variables including gender, professional involvement, and doctoral degree also proved significant, but with institutional variations. For academics, professional involvement and doctoral degree have considerable effects on collaboration, while only gender is significant for the collaborative behavior of scientists in institutes. University scientists are engaged in more international collaboration than their counterparts in research institutes. But while their national productivity is related to the intensity of email use, their foreign productivity is not associated with either collaboration or Internet use. More significant for foreign productivity are the "traditional" factors of doctoral degree, professional involvement, and gender. Non-academic scientists do seem to benefit from higher levels of email intensity in their foreign productivity, but their international collaborations are few.

As compared with studies of OECD countries, studies of developing areas must address publication productivity from the twin angles of national and foreign output. We employed separate measures to overcome the problem of treating all publications as similar, when international work is more highly valued in the developing context. We then examined the relationship between collaboration and productivity, controlling for relevant predictors, in the two institutional settings of university departments and government research institutes. While there are methodological and analytical similarities with the study by Duque, et al. (2005), South Africa is quite different from Kenya and Ghana, with a population of researchers that does not reflect the ethnic composition of the country, and research facilities—including Internet access—that far exceed them. (please remove the words "that far exceed them." The sentence ends at "Internet access."

As always, the historical particularities of the South African context must be taken into account. In the post-apartheid era, international aid and interest have flowed into the country, and the scientific and educational sectors have been beneficiaries. For the most part, our respondents were extensively collaborative in their research, and the value has taken deep roots in the South African academic and research community. Collaboration, as we became increasingly aware during our face-to-face interviews, is now viewed as an opportunity and a means for researchers to establish an international reputation in their own respective fields of specialization. We noted that our respondents are openly receptive to the world of collaborative opportunities outside the country and are motivated by the benefits of collaboration for their professional careers. On the other side, the rich diversity of the flora, fauna, and the unique geographical features along with the new political situation have attracted international scholars, who have approached South African scientists to gather and share huge quantities of untapped data. In this contemporary era, the most conspicuous factor in international collaboration is the Internet, which has emerged as the primary means of project communication and coordination.

The system currently in place in universities and regional and national research institutes of South Africa nurtures publication potential through certain structural mechanisms that are thought to lead to increased productivity. Not only is publication productivity an accepted standard for career advancement, but also for government funding to tertiary institutions, based on the calculation of publications in SAPSE (South African Post Secondary Education) approved journals. It is therefore not surprising that productivity figures position South Africa above other African countries like Ghana and Kenya. It is easy to conclude that collaboration and email use have a positive impact on publication productivity, particularly on the international journals that are the main targets of government and university interest. The fact that research is such an important activity for academics despite their teaching and administrative responsibilities shows the value they place on research for knowledge production and career development in South Africa. Yet our findings cast serious doubt on the idea that either collaboration or Internet use has a uniformly positive impact on productivity. For university scientists in South Africa, new ICTs are indeed important for international collaboration, but there is little evidence in these data that either has any large impact on their foreign productivity.

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Notes

1. See Sonnenwald (forthcoming 2007) for a review of studies of collaboration.
2. In this study we did not consider private sector research.
3. There are eleven "traditional" universities in the country. We did not examine universities of technology offering practically-oriented degrees and diplomas in technical fields or comprehensive universities offering a combination of qualifications.
4. For purposes of sampling, and because staff size is often similar, we consider a university department as an organization in the same sense as a research institute, most of which are under a common administrative body. University departments included in our study have both teaching and research responsibilities (40% each of their time). It is not possible to calculate a response rate in the conventional sense. Although a percentage figure could be generated, we are reluctant to do so because it is uninterpretable. It is better to note that only three respondents refused to be interviewed, and another one dropped out midway through the interview. We defined the population of eligible respondents as those individuals who were physically present during the data collection interval at their institutions. Individuals who are on study leave, seconded to other areas, and so forth were not considered eligible members of the population.
5. Lee and Bozeman (2005) used the "collaboration cosmopolitanism" scale to indicate the extent to which researchers tended to be more or less "cosmopolitan" (collaborating with those outside the proximate work environment) on a scale ranging from 0-5, with 0 being the least cosmopolitan and 5 the most. The scale is calculated by multiplying the fraction of their time each participant spent working with a type of collaborator by the cosmopolitan rank of that variable.
6. Other collaborations typically examined in the literature are similar in the sense that participants are co-located (Sonnenwald, forthcoming 2007).
7. The indicator "access to email" that was often used in prior studies of East and West Africa is useless in the present context. Only two of 275 respondents reported they had no access to email.
8. More than half of the population in the country (52.2%, Census 2001) (now added under StatsSA) is female, and women's participation in other domains of public life is quite evident, but not so in these two sectors of teaching and research.
9. We began with the dimensions that were significant in studies of other countries, adding and subtracting factors listed in Table 2. For the final models we selected those variables with consistent effects.
10. Only professional status is statistically significant at the .05 level.

11. We asked a series of questions about the respondent's productivity over the last five years (papers at state or national workshops, international conferences, reports either published or otherwise, bulletins for extension, articles in foreign journals, articles in national journals, chapters in books, and so forth). In the present analysis we focus only on published journal articles in national and foreign journals.
12. A key issue in the measurement of publication productivity is the use of "normal" or "fractional" counts. In the former method, all publications are counted equally regardless of the number of co-authors. In the latter, the number of publications is divided by the number of co-authors in an attempt to correct for the partial contributions implied by the division of labour in multi-authored papers. Lee and Bozeman (2005), using CV data on publications, find that (1) the correlation between normal and fractional count productivity is extremely high (.928), and (2) the association between normal count productivity and collaboration (.209) is even stronger than between fractional count productivity and collaboration (.147). Thus, the absence of a measure of fractional count productivity for our sample of scientists in developing areas is unlikely to be critical.

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About the Authors

R. Sooryamoorthy is Associate Professor in the Sociology Programme at the University of KwaZulu-Natal in South Africa.

Address: Sociology Programme, University of KwaZulu-Natal, Howard College campus, Durban-4041, South Africa

Wesley Shrum is Professor of Sociology at Louisiana State University and Secretary of the Society for Social Studies of Science. Since 1994 he has studied scientific communication in developing areas, with a focus on Kenya, Ghana, and Kerala.
Address: Louisiana State University, Baton Rouge, Louisiana, USA