Understanding Factors Influencing the Effect of Scientific Collaboration on Productivity in a Developing Country: Kenya

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ABSTRACT
Increased productivity has been cited as one of the benefits of scientific collaboration. While some studies have identified a positive relationship between collaboration and publication productivity, others have found a negative or no clear relationship between the two. A number of factors determine the relationship established, ranging from the context under which research is carried out that shapes the scientists' collaboration and productivity behaviors and practices, to the methods and measures used. Few studies have examined the factors underlying the said relationship, more so in studies of developing areas. In this article we present the empirical findings of a study seeking to establish the relationship between collaboration and productivity of academic scientists in Kenya, including factors determining the established relationship. The study uses mixed methods research design employing self reported measures of collaboration and productivity. The study establishes a significant, though weak relationship between collaboration and publication productivity for academic scientists in Kenyan Universities. We find that factors affecting level of collaboration, including disciplinary area, academic qualification, and the national and institutional context within which research is done have an effect on productivity of academic scientists. The results presented serve to enhance our understanding of factors determining scientist's productivity, and methods best suited to investigate collaboration and productivity in developing areas.

Keywords
Scientific collaboration, productivity, developing areas

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INTRODUCTION

An increasing trend in collaborative research has been observed over the years (Beaver 2001). Gibbons et al. (1994) attributes this increase to a shift in knowledge production process from Mode 1 to Mode 2, whose main focus is on the context of application, irrespective of disciplinary and institutional boundaries. In contrast, Mode 1 is highly institutionalized and mainly organized around disciplinary areas (Gibbons et al., 1994). Funding bodies are increasingly aligning their research policies in favor of collaborative research (Gibbons et al., 1994; Smith & Katz, 2000; Lee & Bozeman, 2005; Becher & Trowler, 2001), based on an underlying belief in its benefits. Such benefits include use for diverse range of skills, expertise, and access to resources and special equipment not locally available (Beaver, 2001; Katz & Martin, 1997). In addition, personal gains are realised such as increased visibility and recognition, and intellectual companionship (Beaver, 2001; Melin, 2000; Crane, 1972), and higher productivity (Beaver, 2001; Sooryamoorthy & Shrum, 2007; Lee & Bozeman, 2005).

Our main interest is in the effects of collaboration on productivity. While some past studies show a positive association, others find no clear relationship between the two (Lee & Bozeman 2005; Duque et al, 2005; Ynalvez & Shrum, 2010). Literature shows that publication productivity of developing world scientists is quite low as compared to that of the developed world. For example, while Lee & Bozeman (2005) found that an American scientist published an average of 18.9 articles over a five year period, Duque et al (2005) in a study focusing on developing country scientists found that they published an average of 4.5 articles over a similar period. Variations have also been noted between countries within developing regions e.g. Duque et al (2005) found that an Indian scientist published an average of 7 articles while a Kenyan scientist published an average of 2.5 articles over a five year period. This could be attributed to the varying research environments between regions, between countries or even institutions within the same region. While research environments in much of the developed world are

characterized by an abundance of resources and supporting infrastructure, the same does not apply to much of the developing world (Luo & Olson, 2008; Duque et al., 2005). It is therefore important to understand the conditions accounting for the productivity levels of researchers within a particular context.

Literature shows bibliometric measures as the most commonly used indicators of collaboration and productivity. However, the use of publications in international databases as a measure of collaboration and productivity has been criticized in past studies (Katz & Martin, 1997; Shrum & Beggs, 1997; Duque et al., 2005; Lee & Bozeman, 2005). This especially applies to studies of developing areas which prioritize local needs such as poverty, food security and disease control. Such research may result in much of the output being published locally rather than in international journals (Ynalvez & Shrum, 2010; Harle, 2010). In these regions, it's important to consider other measures that would improve accuracy of the data captured. In assessing the relationship between the two, it is important to clarify the form of collaboration and productivity being looked at. The term collaborator may have different meanings to different people, groups and settings, and this meaning needs to be clarified by defining a criterion of what constitutes collaboration. Noting that publications are not the only output emanating from scientific research, it is also important to consider other forms of output, especially in developing countries where much output is in form of reports and working papers, referred to as 'grey literature' by Gitau et al (2010).

Based on data from 248 academic scientists in Kenya, our research examines the relationship between collaboration and productivity, while presenting an analysis of the factors affecting the two. A previous study by Duque et al (2005) sought to establish the relationship for scientists in various sectors in Kenya, Ghana and state of Kerala in India. However, our research differs from theirs in terms of the sampled population, measures and methods used in the following ways: Firstly, while theirs involved a general population of scientists in both universities and research institutes over the three regions, our research is an intensive study of a purposefully selected sample of academic scientists in Kenya, focusing on their collaboration characteristics and how they affect their productivity. Secondly, there are important differences in the definition of collaboration and measures used. They define collaboration as any form of contact with someone in another organization, excluding those in the same organization, out of the assumption that inter organizational collaboration is more important than intra for the developing world (Duque et al., 2005; p.767). This definition may be important in identifying professional networks, but not necessarily collaboration networks. Having any form of contact with someone in another organization doesn't mean it's for scientific knowledge production endeavor. Past studies show that distance plays an important role in the initiation and process of collaborative research, with many collaborative projects involving those who are co located. Their exclusion of ties internal to an organization or department may fall short of identifying the actual level of collaboration, and could affect the results of an assessment of the relationship between collaboration and productivity. Furthermore, their measure of productivity does not exclude publications co authored with colleagues, causing an imbalance between their two measures. Thirdly, while their measures of Email use are examined not within the context of collaborative research, but on general use, ours measures incorporate more forms of ICT usage within this particular context. A general view of use may point to the ICT awareness of the community, but understanding their actual effect on collaborative research requires an assessment of their use within this context. Therefore ours is a study focused more specifically on the collaboration process, to understand the factors shaping this process and their effects on productivity, within the specific context of academic scientists in Kenya.

We define collaboration as an interaction between two or more individuals in a research project, whether locally or remotely, working closely together to achieve a common goal(s). The individuals can be within or across departments, universities or organizations, or even international. Productivity is looked at as the total tangible outputs of research, including publications, reports, manuals and innovations over time. However, the comparisons and correlations mainly involve publication productivity measures, to allow comparison of results in previous studies and for ease of quantification. Self reported measures of collaboration and productivity are employed. The study uses mixed methods in an endeavor to get a general view as well as derive a deeper meaning of the established relationship. Using data derived from our survey, we provide collaboration and productivity profiles of the scientists studied, then examine the relationship between the two and present a discussion of the factors shaping this relationship. The results presented serve to enhance our understanding of factors determining collaboration and productivity levels of scientists in developing countries, contributing to the existing debate on the relationship between collaboration and productivity, specifically in developing areas. The study renders support for self-reported measures while advocating for those that would capture all forms of collaboration and outputs, with significant implications for future studies in the area. The study also presents implications for policy makers in making informed decisions and policies that go towards improving productivity level of academic scientists.

Defining and Measuring Collaboration and Productivity

Smith & Katz (2000) note that collaboration in research can be looked at from various levels, be it the national level, organizational level or individual level. They identified three levels of collaboration: formal agreements between

organizations/institutions or even nations; semi formal collaboration between teams out to solve particular problems; and interpersonal collaboration of individuals brought together by need and ability to work together (Smith & Katz, 2000, p. 13). In reference to the classification above, our research investigates research collaboration at the boundary of team and interpersonal collaboration, with the major focus on the individual. An individual is the basic unit of a collaboration and as Bozeman & Corley (2004) put it, 'many of the factors governing individual scientists collaboration choices remain very much within control of the individual, especially when the researcher works in an academic institution' (p. 600), thus the importance of looking at this level.

The meaning assigned to the term collaborator differs between individuals, groups and settings. Laudel (2002) defines a criterion of collaborator typology based on the role played by a partner, whether in provision of a service, special equipment, or transmission of know- how. On the other hand, Katz & Martin (1997) define a criterion based on the contribution of an individual to the project, based on the actual input to the various tasks over the project phases. The criteria defining a collaborator in a study may have different effects on the results of an assessment of collaboration and productivity. While some studies exclude local ties in their measures of collaboration (Duque et al., 2005; Ynalvez & Shrum, 2010), their consideration in assessing collaboration at the individual level is important. Past studies show that distance and spatial proximity play a significant role in initiation and execution of projects at the individual level (Kraut et al, 1988; Bozeman & Corley, 2004; Cummings & Kiesler, 2005; Lee & Bozeman, 2005; Olson & Olson, 2000). Bozeman & Corley (2004), in their study of American scientists proved that 'most researchers are not particularly cosmopolitan in their selection of collaborators' (p. 613). A study by Kraut et al (1988) shows that most people collaborate with those physically closer to them. Local ties are common in research collaborations and should be considered in studies seeking to establish collaboration levels.

Co authorship is a commonly used measure of collaboration and productivity. Duque et al (2005) attributes this to ease of obtaining data and analysis. However, he notes the inappropriateness of using it as both an indicator and outcome of the same activity. This may especially be inappropriate for studies in developing world due to their avenues of disseminating research (Shrum & Beggs, 1997). Also cautioning against use of bibliometric analysis of co authorship to identify research collaboration are Van Raan (2005), Katz & Martin (1997), and Lee & Bozeman (2005), due to the fact that not all collaborations result in publications. Ynalvez & shrum (2010) also cautions against use of curriculum vita, especially in cases where they are not regularly updated posing a limitation in the information given, as was the case with the Filipino scientists they studied. Depending on research environment context and the kind of data sought, one would need to weigh the pros and cons of the different measures used in collaboration and productivity studies in making a decision on the most appropriate.

Determinants of the Relationship between Collaboration and Productivity

Though there exists a general assumption that collaboration increases research productivity, some studies have found no clear relationship between the two. The previously described study by Duque et al (2005) realized that though Kenyan scientists were most collaborative, they were least productive, though noting the differences in publication productivity levels between academic scientists and those in research institutes. Kerala was most productive in terms of number of publications reported by respondents, yet was least collaborative. The relationship is not only unclear for studies in developing areas. Lee & Bozeman (2005), in their study of university researchers associated with the National Science Foundation in the US, used two measures of publication productivity, normal count and fractional count. They found while the former resulted in a positive relationship between collaboration and productivity, the relation was not clear using the latter. This therefore shows that the assumption that collaborative research leads to increased productivity does not hold at all times.

Some of the factors identified in literature as determining productivity rate of scientists include disciplinary field or specialist area (Lee & Bozeman, 2005; Melin, 2000); availability and amount of funding ((Lee & Bozeman, 2005; Bozeman & Corley 2004); research work connections and size of professional networks (Ynalvez & shrum 2010; Hara et al, 2003, Bozeman & Corley, 2004; Luo & Olson, 2008); having a PhD and location of graduate training (Ynalvez & shrum, 2010, Luo & Olson, 2008). Lee & Bozeman (2005) found that scientists were more productive at a certain age, and number of years into PhD. The motive for collaboration partially determines the processes involved and outcomes. While a service motive may end when the two parties fulfill their part of the bargain, a collaboration based on intellectual gains may realize much more than just delivering on the project mandate. Lee & Bozeman (2005) found that having complimentary skills 'had a strong impact on productivity', while the mentor and nationalist motive was not significantly related to productivity (p. 691). Duque et al (2005) found academic scientists to be more productive than their non academic counterparts, which Dimitrina & Koku (2009) attribute to point of interest and motive. While those in academics care much about peer reviewed publications which are considered important for advancement in their research careers, non academic scientists are more interested in other outputs such as manuals, reports and innovations.

Past studies have found a positive impact of ICTs on collaboration and productivity. By incorporating the use of ICT into their collaborations, scientists stand to gain from a

reduction in organizational and communicational problems (Walsh & Maloney, 2007; Cummings & Kiesler, 2005) and extension of their networks (Walsh & Bayma, 1996; Ynalvez & Shrum, 2010). However, Duque et al (2005), like Walsh & Bayma (1996), note the importance of looking closely at the local context when analyzing the effects of ICT and the Internet on collaboration and productivity. He gives the scenario of his study, that though Indian scientists, had greatest access to the Internet among the three regions studied, they were least collaborative, though most productive. This gives the indication that the relationship between Internet use, collaboration and productivity is not always linear. Integration of ICT into research work in developing countries is faced with various problems including poor Internet access, and the costs associated with the requirement for intensive exchange in collaboration may override their benefits in relation to collaboration and productivity (Duque et al, 2005).

The national and institutional context within which research is done is expected to have adverse effects on productivity level of scientists. The environments differ for scientists in developed and developing countries. Shrum & Beggs (1997) observe that the heavy reliance of research systems on financial support from outside the country presents special problems for researchers, as they may not be in full control of the kind of research done. In a similar view, Ynalvez & Shrum (2010) observe that structures of funding bodies, coupled with scarcity of resources may result in more problems that affect productivity. They note that the Filipino scientists they studied still collaborate despite the problems, in order to derive other external benefits such as supplementary income from daily allowances. However, the range and nature of problems faced impact their productivity in one way or the other.

A study of literature has identified a number of factors affecting collaboration and productivity. We explore the effects of some of these factors on collaboration and productivity of academic scientists in Kenyan universities. The following section presents details of the sampling strategies and measures used in the survey.

DATA AND METHODS

Sample

The data in this study is derived from a mixed methods survey targeting academic members of staff in four major Kenyan universities, in four disciplines, Agriculture, Engineering, Public Health and Computing. The Field of Science classification in the Frascati Manual was adapted for selection of the disciplines under study, to reflect diversities in various disciplinary areas. Included was at least one discipline under each of the major fields of classification, with the exception of humanities, since focus is on scientific collaboration and productivity. Selection within the broader fields was based on significance of research to the country and nature of the discipline. A preliminary online survey on university websites identified the universities to be sampled for the study based on establishment of the fields under study. Practical constraints within each selection, in terms of the size of the target population (estimated through the preliminary online survey) and the availability and accessibility of the data and participants were considered in coming up with the final selection. Further sampling within the selected disciplines and universities was found unnecessary due to the need for an intensive focus on this community to understand in details their collaboration and productivity practices.

An online survey targeting 450 members of the academic research community yielded a 15.5% response rate. A follow up was done through hand delivered questionnaires, yielding a further 36% responses, thus a total 51.5% response rate for the quantitative survey. The quantitative survey was supplemented by qualitative interviews with a few purposefully selected individuals across the four institutions. Fifteen interviews were conducted, at least three interviews per discipline, and one with an official from the main research funding arm of the government, the National Council for Science and Technology.

Measures used

The level of collaboration is generally measured by a question on whether or not one is / has been involved in any collaborative research project over a period of ten years. The degree of involvement in collaboration is measured through self reported number of collaborative projects one had been involved in (both current and past – over a period of ten years). The participants were asked to provide information on up to three major or significant research projects, including details of collaborators and their institutional affiliations, used in building a collaboration network. This is important in understanding the form of their collaborations and their effect on productivity.

Considering the arguments presented in literature for or against the various methods of researching collaboration and productivity, we settled for self reported measures. We agree with Lee & Bozeman (2005) and Duque et al (2005) that self reported measures allows one to capture collaborations that do not involve publication productivity. However, we acknowledge that self reported measures may bring in bias in reporting as the respondent decides what is or is not a significant collaboration. A guideline was given on what is referred to as collaborative research in the study for clarification. The motivation for collaboration and type and magnitude of problems experienced within the collaborations are some of the determinants identified in literature as impacting on the level and form of collaboration, and ultimately productivity. Data on motivation for collaboration was captured in a question asking the respondents to indicate how important each of the given motives was in criteria of choice of a collaborator. Similarly, the respondents were asked to indicate the extent to which each of a list of 17 problem areas was problematic for them.

It's been argued out in literature that publications may not be the only output from a collaborative research study (Van Raan, 2005; Lee & Bozeman 2005), more so in developing areas whereby the kind of research done is perhaps with organizations outside the academia whose major interest is not in publications (Dimitrina & Koku, 2009; Harle, 2010). Productivity is therefore measured through self reported number of publications and other forms of research outputs within the projects listed. We use control variables derived from previous research on collaboration and research productivity, including disciplinary area, institutional affiliation, ICT use, gender, age, academic qualification, region of study and motivation for collaboration.

FINDINGS

Descriptive statistics

Table 1 presents a summary of means and percentages of factors that may influence collaboration and productivity. Majority of respondents are involved in collaborative research (65%), with an average number of 1.8 projects. Majority are male (79%), mainly between 31 – 60 years of age, and have an advanced degree, with PhD (55%), Masters (39.6%) and others (5.3%). 52% obtained their advanced degree in a developed country, the most common training location being Europe (30.3%). Majority (63.4%) use the Internet up to 10 hours in a week, and the most commonly used form of ICT within research collaborations is Email. Video calls, instant messaging services and web forums are rarely used. Majority have access to the basic ICTs, with over 80% having access to a computer or laptop at work or at home, mobile phone and Internet connection at work place. However, indicated as constituting major problems in use of Internet were sites and material that require payment for use (80%), Internet down time (75.8%) and time taken to connect to the Internet (60.3%). The respondents report an average of 7.45 publications in the past 10 years of which 4.6 are coauthored. Publication productivity is positively skewed, consistent with the distribution in Ynalvez & Shrum (2010). Of importance in motivation for and selection of collaborators are sharing a common goal (97.3%), diverse skills (92.7%), funding (87.2) and strong work ethics (84.7%), while friendship (25.7%) and nationality (12.2) are of less importance.

47.8% of respondents indicate publications as their form of output, 36.6% reports, 11.8% products and 19.3% others. Percentages for each form of output within the various categories are presented in columns 6 – 9 in Table 1.

Collaboration

As evident in Table 1, majority of respondents are involved in collaborative research. However, a One Way ANOVA test reveals significant differences in the means of number of current or past research projects between disciplinary areas, academic qualification and region where advanced degree was attained. Differences across institutions, age and gender categories were non-significant. Chi square tests of association to establish the significance of a number of factors relevant to determining involvement in a collaboration identified in literature were significant for disciplinary area (χ^2= 28.01, p<.001); nature of the area of specialization (χ^2 = 6.01, p < .05); academic qualification (χ^2= 57.54, p<.001); publication productivity (χ^2 =68.78, p<.001); region where highest degree was attained (χ^2= 7.01, p < .01); use of email for both local contact (χ^2 = 61.87, p < .001) and remote contact (χ^2 = 99.70, p < .001); and use of VOIP for remote contact (χ^2 = 12.48, p < .001). The tests were not significant for institutional affiliation, age, gender and other forms of web technologies (i.e. web forums and chat).

Table 3 columns 3 presents the results of modeling the above factors using logistic regression to determine their effect in predicting involvement in collaboration. The results indicate that disciplinary area, academic qualification, email use and publication productivity are most significant predictors of involvement in collaboration. The Cox & Snell R^2 for this model is 0.470, meaning the included predictor variables account for 47% of the dependent variable, which is involvement in collaboration. Included is the Wald statistic (in brackets), indicating the unique contribution of each predictor in determining the outcome. The greater the value the more the weight of the predictor variable. In this case, it is greatest for Email use (34.60), followed by academic qualification (12.09), discipline (10.37), and publications (4.29).

Problems experienced in research could have an adverse effect on the level of collaboration and productivity. A question asking the respondents to indicate the extent to which each of the 17 listed problems areas[1], applied to them was used to capture the magnitude of the problems in research collaborations, on a scale ranging from 1=major problem to 4=not a problem and 5 = not applicable. Indicated by majority of respondents as major problem or problem are ease of getting funding (76%), amount of funding (79.1%), availability and access to special equipment (67.8%) and availability of time to commit to research (58.4%). A factor analysis of the 17 problem areas extracted three problem dimensions: problems of socio cultural nature; problems of management and control and problems of availability of resources. A correlation of the factor scores associated with each problem dimension with number of collaborative projects and productivity was significant for the third factor dimension, availability of resources (r = .149, p = .05).

[1] Listed problem areas were Availability and access to special equipment, Ease of getting funding, Amount of funding, Administration of the funding, Availability of skilled personnel, Defining roles, Coordination of member's activities, Timely delivery of results, Diverse disciplinary training of collaborators, Cultural differences, Resolving conflicts, Scientific competition, Information security, Authorship inclusion and order, Selection of a publication forum, Leadership and control, Availability of time to commit to research

Variable		Collaboration		Productivity				
	% Response	Mean of Current projects	Mean of Past projects	Mean Publications	% publications	% Reports	% innovations	% others
Involved in collaboration (1=Yes, 0=No)	65	1.80	2.43	7.45	47.8	36.6	11.8	19.3
Discipline	**N = 248**				**N =77**	**N=59**	**N=19**	**N=31**
Agriculture	27.5	2.38	3.13	11.57	45.5	43.1	42.1	58.1
Engineering	49.4	1.50	2.00	5.97	35.0	39.6	36.8	22.5
Public Health	13.0	1.14	1.67	5.37	13.0	12.1	-	19.4
Computing	10.0	1.62	2.62	6.09	6.5	5.2	21.1	-
Institutional Affiliation	**N = 248**				**N=78**	**N = 59**	**N = 19**	**N = 31**
UON	31.1	1.72	3.42	9.12	32.1	32.2	21.1	54.8
JKUAT	41.5	2.02	2.11	7.02	41.0	28.8	68.4	29.0
KU	10.5	1.65	1.94	6.69	14.1	16.9	5.3	6.5
MU	16.9	1.56	1.74	5.97	12.8	22.0	5.3	9.7
Age	**N = 228**				**N = 77**	**N = 58**	**N = 18**	**N = 31**
25 - 30	7.5	1.71	1.69	2.0	3.9	6.9	5.6	3.2
31 - 40	28.9	1.75	2.75	5.41	23.4	20.7	22.2	9.7
41 - 50	30.7	1.82	2.35	9.67	40.3	39.7	44.4	51.6
51 - 60	25.4	2.05	3.00	8.78	23.4	27.6	27.8	29.0
Over 60	7.5	1.27	3.10	7.38	9.1	5.2	-	6.5
Gender	**N=248**				**N=78**	**N = 59**	**N = 19**	**N = 31**
Male	79	1.89	2.47	7.76	83.3	79.7	89.5	74.2
Female	21	1.38	2.23	5.66	16.7	20.3	10.5	25.8
Educational Background:	**N=225**				**N= 76**	**N =58**	**N = 18**	**N = 31**
Has a PhD (1=Yes, 0=No)	55	1.98	2.72	10.93	76.3	82.8	77.8	12.9
No PhD	45	1.39	1.79	3.14	23.7	17.2	22.2	87.1
Trained in developing country =1	48	1.50	2.13	5.78	43.3	49	26.7	50
Trained in Developed country = 0	52	2.12	2.66	8.65	56.7	51	73.3	50
Frequency of Use of Internet	**N=235**				**N= 78**	**N = 59**	**N = 19**	**N = 31**
0 – 5 hrs	32.3	1.83	2.13	6.28	28.2	20.3	26.3	25.8
6 – 10 hrs	31.1	1.86	2.98	8.51	28.2	35.6	52.6	38.7
11 – 20 hrs	20.4	1.75	2.19	7.67	25.6	25.4	15.8	19.4
More than 20 hrs	14.5	1.95	2.23	8.40	16.7	18.6	5.3	12.9
Don't use ICT	1.7	0.00	1.33	2.50	1.3	-	-	3.2
ICT type of use within collaboration	**N = 161**				**N=78**	**N = 59**	**N = 19**	**N = 31**
Use Email	87.5	1.88	2.47	8.97	94.9	93.2	94.7	90.3
Don't use email	12.5	1.00	2.00	4.19	5.1	6.8	5.3	9.7
Use VOIP	13.1	2.14	2.05	9.65	17.9	16.9	15.8	12.9
Don't use VOIP	86.9	1.74	2.49	7.24	82.1	83.1	84.2	87.1
Use Web forums	3.8	1.83	1.83	6.00	3.8	6.8	0	6.5
Don't use web forums	96.2	1.80	2.45	7.50	96.2	93.2	100	93.5

Table 1. Collaboration and productivity profile of respondents

This implies that a decrease in the problem of availability of resources (in this case ease of getting funding, amount of funding and availability and access to special equipment and facilities) leads to an increase in collaboration. However, the results are not significant for publication productivity. There is a negative, though weak (hence non significant) correlation between factor score dimension 1 (socio cultural problems) and 2 (management and control) and number of research projects and productivity, meaning those in more research projects experience more problems of each kind. The data on problems identified above was supported extensively in the qualitative survey. In addition, the respondents in the qualitative interviews also reported substantial problems in lack of institutional support including the many bureaucratic processes that slow down collaborations such as in disbursement of funds. Bureaucracies were also cited in the process of sharing equipment. One of the participants in the interviews in university X indicated that it takes a long process of approvals to bring in a collaborator who is not a member of X to share the facilities at X, making him prefer to collaborate with those outside the university where there are less stringent rules.

Though there is no much variation in level of collaboration based on frequency of using the Internet, considerable differences are observed in the number of collaborations between those who diversify their use of the Internet and those who do not. This is evident in Table 1 under ICT type of use within collaboration, consistent with the findings by Ynalvez & Shrum (2010). Use of email is significantly correlated with both increase in collaboration ($r = .196$, $p < .05$) and productivity ($r = .365$, $p < .001$). A correlation of the factor scores produced by the factor analysis of problems in a collaboration described above and frequency of use of the Internet was significant for factor score 2 (management and control) and frequency of using the Internet ($r = .231$, $p < .01$). This is an indication that frequent use of the Internet significantly reduces problems of management and control.

Productivity

The mean publication rate for an academic scientist over a 10 year period is 7.45. However, the mean publication levels vary across disciplines, with Agriculture having the highest at 11.57 over the ten year period, as compared to public health at 5.37. Agriculture too has a relatively higher

Motivation for collaboration	% Response	Mean Current projects	Mean of Past projects	Mean of Publications
Common goal - important	97.3	1.87	2.44	9.60
Common goal less important	2.7	2.0	2.25	8.67
Special skills important	92.7	1.86	2.49	10.0
Special skills less important	7.3	1.89	2.13	7.75
Sharing equipment important	78.9	1.86	2.26	9.32
Sharing equipment less important	21.1	1.72	3.05	12.20
Mentorship important	67.1	1.7	2.15	8.07
Mentorship not important	22.9	2.05	2.06	11.50
Funding important	87.2	1.79	2.44	9.77
Funding not important	12.8	2.3	2.3	9.4
Strong work ethics important	84.7	1.85	2.54	9.43
Strong work ethics not important	15.3	1.59	2.12	11.80
Strong reputation important	75.5	1.90	2.43	10.00
Strong reputation less important	24.5	1.81	2.78	9.01
Institutional affiliation important	77.5	1.92	2.44	8.5
Institutional affiliation not important	22.5	2.02	2.24	12.8
Friendship important	25.7	1.86	2.72	9.83
Friendship not important	74.3	1.78	2.31	9.38

Table 2. Publication and productivity profiles based on motive for collaboration

percentage of other outputs, as evident in Table 1 columns 7 - 9. Most productive age group in all forms of output is 41 – 50, closely followed by 51 – 60. Those over 60 have the lowest mean number of current research projects, though the highest number of past projects, an indication they were more productive in their 50s. This is consistent with Lee & Bozeman (2005) finding that research activity peaks at a certain age then falls. Significant differences are observed in productivity levels in all forms of output between those with a PhD and those without, also reflected in the region of study. Those who studied in a developed country reflect a higher mean number of publications as well as innovations as compared to those who studied in a developing country, as reflected in Table 1.

No significant differences are observed in productivity based on frequency of using the Internet. However, using email and VOIP for communication and coordination purposes has considerable effect on publication productivity as evident in Table 1. The Motive for collaboration has been found to affect productivity levels of scientists (Melin, 2000). Consistent with Lee & Bozeman (2005) findings, those who consider mentorship an important motive for collaboration have considerably lower rates of productivity levels. Projects centered on supervision of students were excluded in the definition of collaboration, possibly accounting for the lower number of collaborative projects indicated by those considering mentorship an important motive, as evident in Table 2. Considerable differences are observed in the mean number of publications for those who consider special skills, sharing equipment, strong work ethics and institutional affiliation important as compared to those who do not. While those who consider sharing skills as an important motive have higher rate of publication productivity, those who collaborate to share equipment have lower rates of publication productivity. Those who consider institutional affiliation not important also reflect higher rates of productivity.

Having given an analysis of the factors influencing collaboration and productivity separately, we further asses the relationship between the two using a number of control variables identified in literature and discussed above in the following section.

The relationship between collaboration and publication productivity

A Spearman's rank correlation between the number of collaborative research projects and number of publications in the last ten years was significant, with a correlation coefficient $r = 0.418$, at $p < 0.001$. The coefficient of determination, r^2 equals 17.47%, meaning that only 17.47% of the variance in publications is related to number of collaborative projects. This indicates a relatively weak though significant correlation, meaning other factors also determine the collaboration levels.

Using multiple regression analysis, we model the effect of a number of variables in predicting publication productivity. Table 3 column 2 presents the standardized regression coefficients and significance levels for a model (1) that explains more than a quarter of the variance in productivity, an improvement over a model with only number of collaborations as the predictor variable. This model shows that academic qualifications, number of collaborative projects and disciplinary field (Agriculture) as most significant predictors of publication productivity. Though email use is positively associated with publication productivity ($r = 0.365$, $p = 0.001$), fitting it into our model gives non significant results, probably an indication that email is still a preferred mode of communication by those who don't publish much. Age and gender differences, frequency of using the Internet and region where highest degree was attained are non significant in predicting productivity when fitted into this model.

DISCUSSION

The results indicate that collaboration levels among academic scientists in Kenya are relatively high with 65% of those studied indicating involvement in collaborative research. However, despite the high level of collaboration, publication productivity levels as compared to developed countries are relatively low. For example, while Lee & Bozeman (2005) established productivity of American Scientists to be approximately 3.8 articles per year, Kenyan academic scientists publish a mean of 0.75 articles per year, much similar to Duque et al (2005) approximation of 0.5 articles per year for Kenyan scientists. With majority of respondents involved in collaborative research, the question is why this does not translate to high level of publication productivity?

Dependent variable Independent variable	Model 1	Model 2
Discipline		(10.37)*
Agriculture	.214**	.765
Engineering	-.074	-1.087
Health Science	-.062	.389
Personal and professional characteristics		
Age	.050	(2.50)
Gender	-.087	-1.25(3.15)
Academic Qualification	.395***	2.05 (12.09)**
Region of study	-.034	-.403
ICT Use		
Frequency of use of internet	-.020	(1.69)
Email use	.098	2.90 (34.60)***
Choice of collaborator		
Personal characteristics	-.109	
Sharing of knowledge and resources	-.010	
Shared vision	-.006	
Collaboration	.193*	
Publications		.122 (4.29)*
constant	3.89	-.520(.176)
R^2	0.341	0.470

P<.05*, P<.01**, P<.001***. In brackets is the Wald statistic

Table 3. Multiple Regression results for publication productivity (Model 1) and Binary Logistic Regression results for collaboration (Model 2)

There is a significant relationship between collaboration and productivity for academic scientists in Kenya. This is consistent with the findings of the study by Duque et al (2005), in which though the relationship was non-significant for the general scientific population in Kenya, it was significant for academic scientists when estimated by sector. However, the differences in measures of collaboration between our study and Duque et al (2005) as discussed earlier should be noted.

This study has established significant disciplinary differences in levels of collaboration and productivity, consistent with the findings by Lee & Bozeman (2005). Agriculture has the highest level of collaboration as well as productivity, and enjoys a significant amount of donor funding and support as reflected in the number of funded projects. This could be attributed to the importance of agricultural research to the country in an endeavor to secure food security in a country where food shortages in times of inconsistent weather conditions result in national disaster, thus attracting much support. Some participants expressed a feeling of neglect for some disciplines in funding issues. One participant in the interview from Engineering lamented that '*Engineering projects are rarely funded around here...we are supposed to be consumers of technology, not producers'*, though another participant from Agriculture disagreed, blaming their lack of funding on inability to write competitive proposals. If the argument of the Engineer is valid, then that is an indication that more attention needs to be given to other fields in terms of provision of equipment and funding so that the other fields can be as productive.

Those with a PhD qualification have significantly higher levels of collaboration and productivity, consistent with the findings by Duque et al (2005) and Ynalvez & Shrum (2010), with slightly more than half of them having trained in a developed country. It is expected that this, in addition to gaining scientific and research skills gives them an opportunity to build and extend their networks, with significant effects on their research life (Ynalvez & Shrum, 2010; Luo & Olson, 2008) Having trained in developed countries where publication productivity is viewed as an important part of the research career may translate the same to their view of publishing, possibly leading to the observed higher levels of publication productivity in this group.

This study shows collaborative research as being faced with major problems that could affect productivity level of academic scientists. Top on the list of problems is access to funding and special equipment. There is much reliance on donor support, with the results of the survey showing 65% of the projects respondents are involved in as being funded by international bodies and organizations. A study of the links existing between the researchers reveals that a number of academic scientists are collaborating with those in research institutes and international organizations, probably shaped by the funding patterns. We agree with the argument presented by Duque et al (2005) and Dimitrina & Koku (2009) that those outside the academia possibly have less interest in publications, and major output from such projects are in form of reports, manual and products. Once the outlined outcomes are delivered, many of the scientists may not be bothered with the extra effort and time that goes into publications. Therefore the much collaboration outside academia may be lowering publication productivity of academic scientists.

Consistent with past studies, also highly ranked is the problem of lack of availability of time to commit to research (Harle, 2009). Academic scientists are often burdened with high teaching loads, administrative duties and other obligations. This, coupled with the stresses of trying to cope with the requirements of their collaborations gives creating time for publications low priority. The many bureaucratic processes at the universities were blamed for stifling and slowing down collaborative research projects, affecting the timely delivery of results. Some of the respondents were of the opinion that they should be given a free hand to manage their collaborations, without the strict guidelines imposed by their universities on the process. Universities need to support the collaboration process by creating conducive environments for research, expected to have positive impacts. This could include, for instance, a proposal by one of the participants in relieving those involved in research projects some of their teaching loads so they have more time to do research and publish.

The motive for collaboration has been found to have a moderating effect on collaboration and productivity. Consistent with Lee & Bozeman (2005), this study found those collaborating to share skills as reflecting higher rates of publication productivity. Those who collaborate to share equipment have lower rates. This is an indication that

collaborations purposed at shared intellectual gains are generally more productive than those brought together for material gains. Some will collaborate for the financial gains in funded projects, and once they deliver on the requirements of the projects will not bother on the extras such as publications.

Unlike other studies that have found gender differences in level of collaboration (Ynalvez & Shrum, 2010; Bozeman & Corley, 2004), this study, in consistence with Lee & Bozeman (2005) and Duque et al (2005), finds gender differences not significant in determining collaboration and productivity. Unlike Lee & Bozeman (2005), age is not significant in determining collaboration and productivity, though statistics in Table 1 reflect the most productive age in all forms of output as being 41 – 60 years. Lee & Bozeman (2005) notes that the earlier and later years of one's career may not be as productive also reflected in these findings.

This study finds that Email use has significant effects on collaboration, which can be attributed to its power in alleviating problems of coordination as evident in this study. This is consistent with the findings of Walsh & Maloney (2007), Ynalvez & Shrum (2010) and Cummings & Kiesler (2005). As evident in Table 1, those who use email within their collaborations are twice as productive as those who don't. Diversified use of Internet technologies is reflected by those in more collaborations, in their use of VOIP and web forums. However, majority of respondents mainly use email, citing lack of awareness of other Internet technologies. No significant differences are observed in publication productivity of those using VOIP and web forums and those who do not. This perhaps could be a reflection of the problems facing their use, including the commonly cited unreliable Internet connectivity, resulting in no observable differences.

The findings discussed show the knowledge production process as gradually moving towards the Mode 2 type as presented by Gibbons et al (1994). Search for complimentary skills and resources rank high in motivation for collaboration, as opposed to institutional affiliation, which was also not significant in determining collaboration or productivity. This is could be seen as an indication of the fading disciplinary and institutional boundaries, with much encouragement from government funding policies that are encouraging cross institutional research projects.

CONCLUSIONS

Past studies have found research collaboration and productivity to be highly dependent on the context within which research is done. This context differs between regions, countries and even institutions. It is for this reason that we sought to establish the relationship between collaboration and productivity while seeking to understand factors affecting the two, within a specific context of a developing country, academic scientists in Kenya.

This study thus established a significant relationship between collaboration and publication productivity for the studied group. However, collaboration and productivity levels are much dependent on the disciplinary area, resource availability (including funding, special equipment, Internet availability and time), personal factors such as academic qualification and region of study, motivation for collaboration and institutional processes and support.

Of the many methods used to measure collaboration and productivity, we are in agreement with past studies supporting self reported measures. Consistent with these studies we found that many collaborations do not necessarily result in publications, and other outputs account for a substantial amount of research output. Using co authorship to measure collaboration is an under representation of the actual level of collaboration, and studies in these areas focusing on scientist's productivity need to consider productivity in all forms to give a wholesome picture.

We reemphasize that the major differences in this study and past studies in the region, mainly in reference to Duque et al (2005), is in the sample and measures used. The study focuses intensively on a particular group of scientists, to improve accuracy on establishing collaborative relationships, and uses more inclusive measures of collaboration and productivity. It confirms some of the findings in Duque et al (2005) as discussed. In addition, it explains some of the factors shaping collaboration and productivity of academic scientists in Kenya as discussed above which were not addressed by Duque et al (2005). Unlike past studies in the region, the use and effects of ICT are looked at specifically within the context of collaboration, establishing their effect on reducing coordination and management problems.

Much support is called for, both nationally and institutionally in provision of resources and creation of conducive research environments which are important to the overall productivity of scientists. There is need to prioritize research, and give more attention to other disciplinary areas that seem neglected. Developing policies that go towards alleviating the problems faced in collaborative research will lead to realization of the assumed benefits, more so in this case, increased productivity.

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