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Original Article

A Coauthorship Network as an Indicator for Scientific Collaboration: A Case Study for the School of Biology and Biotechnology, National University of Mongolia

Bazartseren Boldgiv

Department of Ecology, School of Biology and Biotechnology, National University of Mongolia, Ulaanbaatar 210646, Mongolia, e-mail: boldgiv@num.edu.mn

Abstract

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Correspondence:
boldgiv@num.edu.mn

This case study analyzes coauthorship collaboration, or lack thereof, among individual faculty members and departments in the School of Biology and Biotechnology of the National University of Mongolia. I found that publication rates and coauthorship networks in impact-factor journals between 2008 and 2012 (as of October 31, 2012) are highly variable among the eight biology departments we studied, both within and among departments. Even in the best cases, publication rates and coauthorship networks were not sufficient. We call such insufficient coauthorship collaboration among different departments as (non)network of coauthorship. The size of departments and observed coauthorship networks (both connectance and linkage density) appear to positively, although insignificantly, affect not only the total number of publications, but also the publication rate per faculty per year. We suggest that this kind of analysis can be important for administration of academic institutions, for improving the scientific outputs of academic entities by facilitating collaborative efforts and for rationalizing organizational structures and merit-based promotion systems for more productive and efficient academic operations.

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Introduction

One of the first indicators of performance by a research institution or an individual scientist as such is the number of publications in professional scientific journals with high-ranking impact factors by these academic entities. Previously, we have analyzed the scientific outcome by Mongolian researchers in various fields of science (Boldgiv *et al.*, 2004). By analyzing publications by Mongolian scientists indexed in the Institute for Scientific Information's (ISI) database for the period of 1979-2002, we found that the total number of publications had increased for the period studied, mainly owing to growing international collaborations. In terms of quality of publications of Mongolian scientists, indicated by the number of times cited, some fields of science showed positive trends (medicine and biology), whereas other fields declined in terms of relative

citation impacts (mathematics and physics). Here, we narrow the focus of an analysis to determine, at the institutional level, whether there are sufficient coauthorship networks in the form of joint peer-reviewed international journal publications, focusing on publications listed in the Thomson Reuters' Web of Knowledge database. For this analysis, we use our own institution, the School of Biology and Biotechnology (SBB) at the National University of Mongolia (NUM), as a case study.

Scientists are increasingly challenged to develop more effective methods for working across disciplines (Jakobsen *et al.*, 2004) for various reasons. Institutional and financial incentives for developing more interdisciplinary research programs are beginning to be enforced within the academic community in Mongolia. On one hand, these incentives encourage collaboration among scientists, not only within the same field of science, but also across scientific disciplines. On the other hand, there is always an issue of whether or not a significant contribution is made by all collaborators to qualify them as coauthors in the final scientific outcome (see Boldgiv & Bayartogtokh, 2011).

Coauthorship is a partial indicator of collaboration (Katz & Martin, 1997; Bozeman & Corley, 2004). It has been long recognized that the coauthorship of journal publications provides insights into the patterns of collaboration and the structure of collaboration networks reveal many interesting features within an academic community (Newman, 2004b). Growth of collaboration has been observed everywhere, not just in science, but also in business, health care, public works and education. Volatile environments, rapidly advancing technologies, distribution of resources, increasingly compartmentalized and specialized knowledge, and globally-shared infrastructure are among the factors that are forcing collaboration more attractive to researchers, resulting in increasing level of coauthorship. Collaboration in research varies in purpose, organizational structure, team composition, and duration. In "supplementary collaboration", researchers divide tasks among distinctively qualified specialists and make separate contributions to a shared project, whereas in "complementary collaboration", researchers with similar interests and qualifications work closely on all aspects of a joint effort (Smart & Bayer, 1986). In either case, evaluating individual contributions to collaborative research output and allocating credits are difficult, although an increasing number of journals is asking for and reporting about specific contributions of coauthors. In case of irresponsible coauthorship, there are ways to detect coauthorship hitchhiking (Boldgiv & Bayartogtokh, 2011), but it is not always possible. Yet, one thing is clear: research collaboration produces more scientific outcome.

Although Mongolia is one of the science and technology-lagging countries in the world (according to the Academy of Science for the Developing World, http://twas.org), there is an ever-increasing demand by the society from scientists and engineers, who are charged with generating and disbursing knowledge and technology, as the country's economy and investment in research grow. Organized infrastructures for modern science were established in the country with the foundation of two major scientific institutions, namely the National University of Mongolia in 1942 and the Mongolian Academy of Sciences in 1961. The modern science has been practiced ever since in the country. Still, it should be noted that the publication rate per individual scientist is not sufficient, on average, nowhere near the level to be competitive on the international level. The old adage of "publish-or-perish" is widely recognized in the country's scientific community. However, the policy of recognition, promotion and reward is not sufficiently merit-based, which does not translate into incentive for efficient scientific activities.

We used the Web of Knowledge database of the Institute for Scientific Information (ISI) for this study to quantify rate and collaboration pattern in scientific articles published by our faculty members in journals with impact factors by Journal Citation Report. ISI, established in 1960 and presently a part of the Thomson Reuters Corporation maintains the largest current database on international publications from all fields of science, which can be accessed from the Internet (http://apps.isiknowledge.com; http://thomsonreuters.com/products_services/science). It contains almost forty million international scientific publications and about 8,500 peer-reviewed journals, and once every week, somewhere between twenty and seventy thousand new references are added (Christoffersen *et al*., 2009). By subscribing to a time-limited service of Thomson Reuters' Web of Knowledge database (the subscription provides access to publications indexed in the Web of Knowledge database from

2008 to present), NUM has taken an important step to make evaluation of faculty performance more objective.

Specifically, in this study we analyze publications in peer-reviewed international scientific journals that are listed in the Web of Knowledge database by faculty members belonging to eight different departments of the SBB, NUM to examine (1) how well each department performs in terms of research output; (2) if there is sufficient collaborative effort among faculties in different subdisciplines by looking at the coauthorship networks within and among departments; and (3) what relevance it may have in scientific administration.

Materials and Methods

In this paper, we use the time-limited subscription to services of the Thomson Reuters' Web of Knowledge database for mining publications in journals only with impact factors listed in the Journal Citation Report out of many different types of scientific outputs because reliable sources of information for other types of research output are yet to be compiled for the university. This service provides an access to peer-reviewed publications indexed for the period from 2008 to present, which makes the list somewhat limited. We use a search string "National University of Mongolia (Natl Univ Mongolia)" for the address field search from this database on October 31, 2012. It is possible that faculty members may have used different address in their publications if they were visiting different institutions during this period. In such cases, however, one can successfully argue that these publications are not NUM publications and therefore, they can be disregarded as NUM publications. Resulting publications were checked manually to sort out publications by SBB (NUM) faculty members. We excluded SBB publications from analyses if full-time faculty members were not involved as authors in the publications (that is, publications by SBB students, postdoctoral fellows and other research associates were excluded). Although we realize that this list may not be exhaustive list of international peer-reviewed publications because there are so many journals that are not listed in the Web of Knowledge database due to various reasons, we still refer to it as a reliable and objective source of data. We do not attempt to analyze quality of authorship or quality of papers. Instead, we focus on the number of publications and coauthorship collaborations evident in the publications in journals with impact factors. We did not include papers published in this journal (*Mongolian Journal of Biological Sciences*, ISSN 1684-3908) in our analyses because it is yet to earn its first impact factor from the Journal Citation Report. The number of faculty within each department has been relatively stable over the years and the number of faculty in each department listed in the official roster at the beginning of academic year 2011-2012 was used for analysis. Publication rate of each department was determined on per faculty, per year basis for the peer-reviewed journal publications for the five years. We also calculated the following simple measures of coauthorship networks:

1. *Coauthorship connectance* is used to describe how many actual links within (among individual members) and among departments are present. It was calculated the same way as the connectance of ecological food webs (Morin, 1999):

$$c=L/([N(N\text{-}1)/2])$$

where, L is the number of coauthorship links that exist and N is the number of entities (individuals faculty or departments).

2. *Coauthorship linkage density* refers to the average number of coauthorship links per department and is calculated as (Morin, 1999):

$$\mathrm{d}=L/N$$

where, L and N are as specified above.

3. At the department level, we compute five-year (2008-2012) cumulative *coauthorship interaction strength* among the eight departments by using the same approach as Newman (2001a, b; 2004a, b):

$$w_{ij}=\sum_{k}\frac{\delta_i^k\,\delta_j^k}{(n_k\text{ - }1)}$$

where, w_{ij} is the five-year cumulative interaction strength among departments i and j; δ_i^k is 1 if department i was a coauthor of department j on paper k with n coauthors and zero otherwise.

We also look at the percentage of journal papers with international collaborators and percentage of single-author papers for each department. We

also looked for patterns to determine what factors contribute to departmental scientific output (journal article publications).

Results

The School of Biology and Biotechnology has eight departments, namely (in alphabetical order) departments of Biochemistry and Bioorganic Chemistry, Biophysics and Bioinformatics, Botany, Ecology, Forestry, Molecular Biology and Genetics, Microbiology, and Zoology. Each department has had anywhere between 3 to 7 full-time faculty during the period of 2008-2012 (Table 1).

At the departmental level, rate of publication in international, impact-factor journals was variable. Publication rate per individual per unit time (year) was variable: from zero to 0.486 (Table 1). Coauthorship connectance among faculties within department was also variable, although it was evident that most departments showed no collaboration on their impact-factor journal publications. Faculty members within Departments of Ecology, Forestry, and Biophysics and Bioinformatics showed some collaborative efforts for the specified period (Table 1, Fig. 1). Among departments with internal collaboration, the coauthorship linkage density was highest for the Department of Ecology. It should be emphasized that both the coauthorship connectance and linkage density are still one fifth of maximum possible value even for the most collaborative department.

Another pattern that is evident here is that the most of journal publications by biology faculty in the eight departments have been done in collaboration with international scientists and organizations in the time period covered in this study. On average, 97.48 per cent of all papers published by biology departments in peer-reviewed international journals with impact factors (or 94.8 per cent of all papers) have been prepared within the framework of international collaboration. Interestingly, percentage of single-author papers is non-existent for almost all departments, except only the Department of Zoology had single-author papers (17.65% of impact-factor papers by this department) for the time period. Other six departments produced exclusively collaborative papers for the period studied).

At the departmental level, coauthorship connectance among departments appears to be non-existent (Fig. 1). Only one coauthorship link existed among the eight departments (out of 28 possible links), with the number of links per department did not extend beyond a single publication. The coauthorship interaction strength was weak, with coauthorship interaction between Department of Biophysics and Bioinformatics and Department of Ecology was the only across-departmental collaboration (w_{ij} = 0.5). If the

Table 1. A summary of peer-reviewed international journal publications listed in the Web of Knowledge database by departments of SBB, NUM for the period from 2008 to present. Coauthorship collaboration, or lack thereof, among faculties within departments is indicated by connectance and linkage density per faculty.

Departments	Number of faculty[1]	Publication rate[2]	Coauthorship connectance[3]	Coauthorship linkage density[4]	% papers with foreign collaborators	% single-author papers
Biochemistry	7	0.257	0.000	0.000 (3.0)	100.00	0.00
Biophysics	6	0.167	0.100	0.200 (2.0)	100.00	0.00
Botany	7	0.200	0.000	0.000 (3.0)	100.00	0.00
Ecology	5	0.480	0.200	0.400 (2.0)	100.00	0.00
Forestry	4	0.350	0.167	0.250 (1.5)	100.00	0.00
Genetics	4	0.100	0.000	0.000 (1.5)	100.00	0.00
Microbiology	3	0.000	-	- (1.0)	-	-
Zoology	7	0.486	0.000	0.000 (3.0)	82.35	17.65
Average	5.375	0.255	0.062	0.121	97.48	2.52
Standard error	0.565	0.062	0.031	0.058	2.36	2.36

Remarks: [1]The number of faculty has been relatively stable and was taken as in the official roster at the beginning of academic year 2011-2012. [2]Publication rate is the number of papers in peer-reviewed, impact-factor journals per faculty per year for five years. [3]Maximum possible value of coauthorship connectance is 1.0. [4]Maximum possible linkage density values for each department are given in parentheses.

analyses were not limited to Thomson Reuters' impact factor journals, there are more coauthorship interactions among departments in publications in other international peer-reviewed journals, which are not indexed in Web of Knowledge database (data not shown).

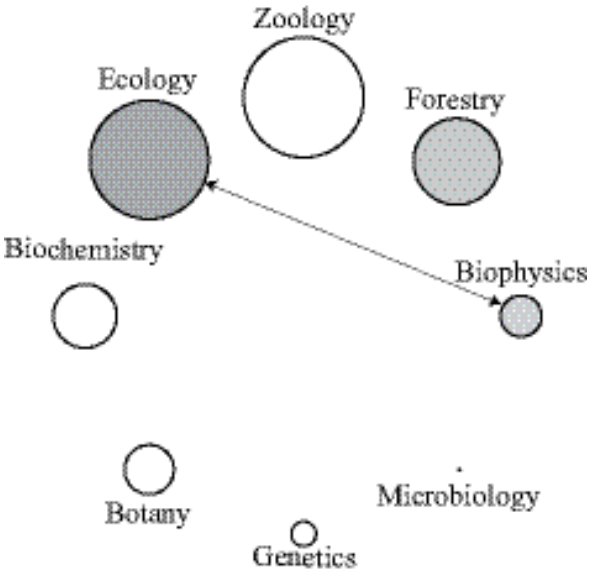

Figure 1. A network of coauthorship interaction among eight biology departments of NUM. The arrow indicates the only interaction that exist among the departments. Relative size of circles indicates the publication rate for the specified period by each department, whereas the shade of circles shows the coauthorship connectance among individual faculty members within each department. (The darker the shade, the more collaborative individual faculty members are within a department. Open circles means that there was no coauthorship collaboration among faculty members within a department.) See Table 1 for actual numbers.

The number of faculty members in each department had understandably positive, but only marginally insignificant impact on the total number of publications ($r = 0.66$, $P = 0.076$; Fig. 2A). Disturbingly, however, the number of faculty members also retained the positive trend with standardized departmental rates of publication, i.e., the number of publications per faculty per year for the period included in this study ($r = 0.43$, $P = 0.288$; Fig. 2B). Experience of faculties (indicated by the number of years of professional career) did not have any effect on research outcome, although there was an insignificant tendency of mid-career faculty members having more publication outcome (data not shown).

Discussion

As pointed out, it is a challenge to evaluate individual contributions to collaborative research output and allocate appropriate credits to individuals. One glaring case of irresponsible coauthorship is what we termed the coauthorship hitchhiking (Boldgiv & Bayartogtokh, 2011), which can sometimes be detected. In this study, we only looked at coauthorship networks as an indicator of collaborative scientific efforts, or lack thereof, within and among department. This in turn can provide useful insights into

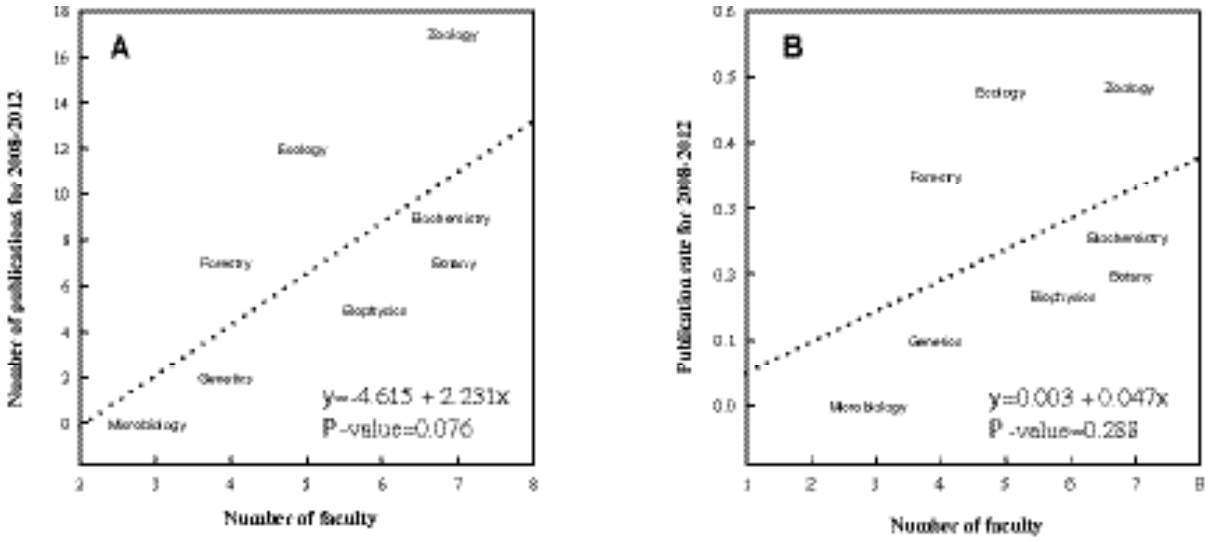

Figure 2. Relationships (A) between the number of faculty in each department and total number of publications and (B) between the number of faculty in each department and rate of publication per faculty per year. The best-fit line is indicated by the dotted line, which is marginally insignificant for (A) and not significant (B), although the trends are still evident.

interesting structures and dynamics of an academic institution (Newman, 2004b). Here we did not attempt to analyze individual contributions of faculty members and quality of each publication. With most of the publications produced by the faculty being joint publications with international researchers and organizations and only a few single-author publications (5.2% of all publications), the next step for merit-based promotion should be an attempt to weigh out contributions of individual faculty to published scientific papers. Quality of publications was also not figured into analysis this time. There are a number of ways to make such analyses, which we do not attempt here.

The fact that most of the journal papers by our faculty are joint collaborative efforts with international scientists (94.8% of all our publications) may also mean that there is limited funding for research is available within country, and that we have to rely on outside sources. This is certainly the case, when current government-funded grant size in biology per year is considered.

Publication rate, although highly variable among departments, is still very low. However, it should be emphasized that NUM produces a significant part of Mongolia's scientific output and the SBB has recently become one of the most productive faculty within NUM. This can be seen not only from annual academic year reports of the university, but also from the fact that SBB publications (i.e., publications by SBB faculty members, students, and research associates combined) make up about 47% of all NUM publications for the period included in this study. This should be judged against the fact that SBB is only one of 14 constituent schools of NUM.

Coauthorship connectance and linkage densities are also variable among departments, but yet nowhere near the maximum possible values. Coauthorship network, as an indicator of collaborative effort, within and among departments is very limited among our faculty members. With majority of the departments have no coauthorship collaboration within and with only a few single-author journal publications, it is of no surprise that the size of our eight departments (3 to 7) is too small to be effective units. It is clear from this analysis of scientific output, even without considering academic curricula. Another interesting pattern is that the publication rate standardized per faculty per year appears to increase with the size of the department, although this trend is statistically insignificant (Figure 2B). This also suggests that we have too many, too small departments to be effective academic units. It is possible that too much compartmentalization does not foster collaborative mentality. This is not only the case of our organization. Insufficient collaboration within and among scientific entities, highly compartmentalized organizational structure, inefficient power hierarchy and irrational recognition system are typical in academic institutions across the country.

Collaboration begets more collaboration, which means more scientific outcome results from collaboration. The trend that the publication rate depended positively on the coauthorship connectance and linkage density is an important pattern, although the trend is not statistically significant (data not shown). All these patterns attest that effective, efficient, equal collaborations are crucial in scientific outcomes. Coauthorship is a complex phenomenon and more systematic, detailed studies should be carried out to enhance quality, productivity and efficiency of our work.

Administrators play a key role in collaboration by shaping policies supporting faculty to work together and stimulating collaborative work by offering incentives for collaboration. Their insights and leadership are vital in improving an output any academic organization, where integration of knowledge is a key. In many cases, capacity of individual faculties is competitive, and it is the barriers to academic collaboration, such as cross-disciplinary illiteracy, power hierarchy and organizational boundaries that are detrimental to overall productivity of an academic community. This is the issue that should be addressed by administrators. We hope this case study will provide some beginning ideas on how to improve the effective management of an academic organization for increasing publication output, bettering their merit-based recognition system, rationalizing institutional structure, facilitating collaborative efforts and developing the most efficient organizational structure.

Finally, it should be emphasized that this paper is not about SBB being academically dysfunctional entity. Rather, it is hard to criticize its performance in terms of scientific publications, considering its contribution to NUM publications and considering the level of funding that is provided by the national funding organization.

This is just to point out that there are many areas for improvement based on careful analyses our performances and there are many things to be learned from this and further analyses to become a more productive and more efficient academic community.

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References

Boldgiv, B. & Bayartogtokh, B. 2011. Coauthorship hitchhiking: indicators and effects in scientific development in Mongolia. *Mongolian Journal of Biological Sciences*, 9: 53-58.

Boldgiv, B., Shagdarsuren, O., Terbish, K. & Boldbaatar, B. 2004. Scientific wealth of Mongolia on global scale. *Mongolian Journal of Biological Sciences*, 2: 43-49.

Bozeman, B. & Corley, E. 2004. Scientists' collaboration strategies: implications for scientific and technical human capital. *Research Policy*, 33: 599-616.

Christoffersen, M. L., Almeida, W. de O. & Lycurgo, T. 2009. Sociology of science: are knowledge production and the quest for scientific status two divergent courses?. *História, Ciências, Saúde-Manguinhos*, 16(2): 505-513.

Jakobsen, C. H., Hels, T. & McLaughlin, W. J. 2004. Barriers and facilitators to integration among scientists in transdisciplinary landscape analyses: a cross country comparison. *Forest Policy and Economics*, 6: 15-31.

Katz, J. S. & Martin, P. R. 1997. What is research collaboration? *Research Policy*, 26: 1-18.

Morin, P. J. 1999. *Community Ecology*. Blackwell Science, Inc., Malden, MA.

Newman, M. E. J. 2001a. Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality. *Physical Review E*, 64: 016132.

Newman, M. E. J. 2001b. The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences of the United States of America*, 98: 404-409.

Newman, M. 2004a. Who is the best connected scientist? A study of scientific coauthorship networks. *Complex Networks*, 650: 337-370.

Newman, M. E. J. 2004b. Coauthorship networks and patterns of scientific collaboration. *Proceedings of the National Academy of Sciences of the United States of America*, 101: 5200-5205.

Smart, J. C. & Bayer, A. E. 1986. Author collaboration and impact: a note on citation rates of single- and multiple-authored articles. *Scientometrics*, 10: 297-305.

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