Unseen Science: Representation of BRICs in Global Science

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Abstract— A survey of scientific periodical publications (or venues) from BRIC country practitioners counted more than 15,000 national publications. Data collected from and about Brazil, Russia, India, and China (BRIC countries) show that 495 publications, or about 3%, are listed in the Science Citation Index Expanded© (SCIE©) in 2010. Contrary to our expectation of under-representation overall and coverage limitation of SCIE, the average percentage of SCIE-listed publications for the BRICs is about the same as that for advanced countries. China has the lowest representation of national publications in SCIE at 2% of all publications; Russia has the highest at about 8%. India has about 6% of publications in SCIE; Brazil has about 4%. In other words, SCIE includes about the same percentage of high quality science from these four countries as for North America and Europe, meaning that these countries are not under-represented in SCIE. Moreover, the number of national publications available as outlets suggests that national scientists in these countries have good access to publication venues. Some of the BRIC national publications are difficult to "see" at the global level because of language barriers, diverse publication formats, and lack of digitization. Other national differences represent historical traditions surrounding publication.

Index Terms— global science; BRICs; open access; developing countries; national comparisons

I. Introduction

Scientific publications have been a medium for communicating research results for more than 300 years. The normal mode of growth in the number of scientific publications has been exponential [1]. Growth is proportional to the size of the population and, as Price [1] points out: "the bigger a thing is, the faster it grows". Recent analyses show that the science system continues to grow, stoked by national investments in research and development (R&D) spending and human capital creation. The rapidly developing countries have been the leaders in this growth. For example, according to UNESCO's *2010 Science Report*, since the beginning of the 21st century, developing countries have more than doubled their R&D spending and scientists and engineers are being educated in record numbers [2].

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The expansion of science in rapidly developing countries can be measured by bibliometric data as compiled by the indexing services. The Science Citation Index (a Thomson-Reuters product, previously referred to as ISI) is widely acknowledged to be the authoritative source indexing high quality scientific publications. SCIE is most often used for bibliometric analyses as well as for comparing the quality and productivity of national outputs. Studies using SCIE data have shown the growth in scientific output of the BRIC countries: Brazil, Russia, India, and China [3]. Although not yet members of OECD (Organization for Economic Cooperation and Development), the BRICs are noted for the rapid growth of both their economies and their science systems. The National Science Foundation, using Web of Science data, reports that non-OECD countries increased their representation by three percentage points during the decade 1993 -2003[2]. Among non-OECD countries and economies, five countries in particular—Brazil, China, India, Russia, and Taiwan—produced two-thirds of this increase. China has attracted attention for the exponential increase in the number of scientific articles being introduced into the international scientific system [4][5].

SCIE and other indices are often used to measure the output of elite scientific institutions, to identify breakthroughs and track developments, and to identify highly productive researchers. These data are used as the basis by which one country is ranked against another as "leading" in science. Of the material in SCIE, more than 50 percent of journals are attributed to just three countries: the United States (34 percent); England (19 percent) and the Netherlands (8 percent) reflecting an English-language bias that has been documented [6][7]. Van Leeuwen et al. [9] find a similar English-language bias in journal citations. As of 2010, SCIE/Web of Science (which focuses exclusively on the natural and engineering sciences, excluding social sciences and humanities) covers 7,100 journals across 150 disciplines[3]. In 2008, Thomson-Reuters increased the number of periodicals covered within the Web of Science in part to improve the visibility of under-represented countries[4]. SCIE focuses on tracking high quality,

[2] In 2003, OECD nations produced 584,000 articles which accounted for 84% of the world total; this number was compared to 10 years earlier when OCEC countries accounted for 87% of all articles in 1993, according to NSF [3].

[3] The parent database, Web of Science, includes the SSCI (social science citation index), the JCR (Journal Citation Record) and the AHCI (arts and humanities citation index).

[4] http://community.thomsonreuters.com/t5/Citation-Impact-Center/Web-of-Science-Coverage-Expansion/ba-p/10663 contains a description of the changes to the SCI data [accessed May 2011].

innovative science, thus a selective number of high quality periodicals were added.

This article reports on research to answer the questions: What is the extent of "unseen science" in developing countries? What is the coverage limitation of indexing services with regards to developing countries? The questions arose during the process of compiling The Royal Society's 2011 report: *Knowledge, Networks and Nations* for which one of us was an advisor. That report used data provided by Elsevier, drawing upon the Scopus[5] database, backed up by data from SCIE and other sources. These data were compiled to characterize the global science system by comparing national strengths and international collaborations. The advisory committee asked about the coverage limitations for developing and poor countries, particularly asking whether high quality science is unaccounted for in nation-to-nation comparisons. The assumption among the advisors was that developing countries are not well represented in existing indices and that much of their scientific output remains unseen.

II. DATA AND SOURCES

To illuminate the extent of unseen science, we searched the literature for similar efforts to answer this question. This turned up a sparse literature, notable mostly for asking the same question about under representation. W.W. Gibbs [9] pointed out the low rate of citations to the work of developing country scientists in the Science Citation Index (SCIE) and suggested that lack of visibility may account for part of the under representation. Shrum [10] noted that "if all one is doing is examining science in the low income countries by using these databases, then you will get a massively biased view of what is going on" in developing countries. Cetto, Alonso-Gamboa, and Gonzalez [11] noted similar lack of representation for Ibero-American publications in SCIE, while Jin and Leydesdorff [5] reported similarly on Chinese publications. We were unable to find a publication that addressed the specific question we were asking.

Early in the process, the hope was to survey all developing countries. This goal proved to be ambitious. As the search process developed, it became clear that the four countries dubbed "BRICs" -- Brazil, Russia, India, and China (grouped as such because they have shown similar levels of rapid economic growth) have begun compiling their own lists of national periodicals. The decision was made to focus on these countries and to use this survey as a model for future efforts to collect lists from other countries.

The following steps were taken to obtain data:

1) We contacted Thomson-Reuters and Elsevier, but neither of these companies keeps a list of national publications outside their databases.

2) We collected information on national publications in developing countries from international experts.

3) Then we contacted bibliometricians who have published on national scientific output, as well as people in different countries who have collected relevant data. These efforts turned up pieces of data that we collected into lists.

4) Members of the Interacademy Council of Science were asked to provide input, and some members sent in suggestions, but this did not prove to be a rigorous method of collecting the needed information.

5) Personal contacts (see acknowledgements) also elicited pointers to databases, as well as some lists that are not available electronically.

6) A search query was placed on several listservers and responses gathered, and databases were tapped to gather any relevant journals lists or names of contemporary journals.

7) We also searched Ulrich's Periodical database, and databases within each of three countries to compile a single list of scientific publications for each country (see Table 1 for a list of databases).

Table 1 lists the databases tapped to collect lists of journals, periodicals, bulletins, or newsletters. Access to the databases listed in Table 1 alone could not recreate the lists used for our final analysis, since experts knowledgeable about publications in these countries provided some additional names. The lists are available from the corresponding author.

Once the lists of all publication names were compiled, they were translated into English (where necessary) using human experts and Google Translate[6]. The lists can be assumed to have variable reliability: we did not independently confirm the existence of each journal/periodical title. Furthermore, no effort is made to characterize the quality of the publications whose numbers are included in this survey, nor did we characterize or otherwise collect information on the frequency of publication event. (Indications are that publication frequency varies considerably from weekly, to monthly and quarterly, to annual and even biennial publications.) Similarly, there is no indication whether these publications are peer reviewed or whether they represent good quality research or analysis. Moreover, the fields of science remain unspecified at this time. Further research is needed to characterize these additional features.

Once translated, the resulting lists for Brazil, Russia, and India were cleaned to take out obvious mistakes, duplicates, and unrelated materials. (In the case of China, a single list was provided with categories previously delineated. We used the list provided by officials at the *China Scientific and Technical Papers and Citations Database (CSTPCD)* without additional cleaning.) The cleaning process involved judgments about the relevance of titles to this survey. Judgments were based on the

[5] Coverage in *Scopus* goes back to 1966 for bibliographic records and abstracts and 1996 for citations. As of October 2006, there were over 28 million records in the database from over 15,000 "peer-reviewed" titles, including coverage of 500 Open Access journals, 700 conference proceedings, 600 trade publications, and 125 book series (Elsevier, 2006). Subject areas covered in *Scopus* include: Chemistry, Physics, Mathematics, and Engineering (4,500 titles), Life and Health Sciences (5,900 titles, including 100% Medline coverage), Arts and Humanities, Social Sciences, Psychology, and Economics (2,700 titles), Biological, Agricultural, and Environmental Sciences (2,500 titles), and General Sciences (50 titles).

[6] Google Translate worked very well compared to the human translators; human translators sometimes did not know the technical term in English, while technical terms did not pose a problem for GT.

titles alone: we did not have full knowledge of the contents of the publications. Decisions were made in favor of keeping publications on the list if the nature of the material was unspecified. As a result of the choice of this methodology, there is likely to be some over counting. Except for the case of China (which was already sorted and counted), the lists also were cleaned to remove periodicals whose subjects do not appear in SCIE (e.g., architecture, finance, hospital administration) although, again, the decisions made were subjective, and questionable entries were left in the list[7].

Others have sought to characterize the coverage limitations of SCIE for fields of science. Meho and Yang [12] explored this question in the wake of the rise of many other publication outlets, including databases and citation analyses tools that are emerging on the Internet [12][8]. In their review of the literature, Meho and Yang found two studies which counted the number of journals cited in high quality papers but not listed in SCIE: the two studies they reviewed had 26% and 23% of journals. It is important not to over-interpret this finding with respect to the question we are asking because the sample sizes were very small, but Meho and Yang's review could suggest that about 25 percent of quality journals are not listed in SCIE.

A review of 2,836,490 references within Thomson-Reuter's Journal Citation Report (2008) produced a list of 299,888 journals or venues not listed in SCIE. (Of this number, a random sample found that about 14% of these citations were to publications that are not journals; these were mainly books and theses.) This suggests that 257,904 venues are not included in SCIE (note that this number includes social sciences but excludes arts and humanities). Comparing the number of source journals in SCIE (8209 in 2008) and the number of non-source references (257,904 in 2008) an estimate can be derived that about 3 percent of all scientific and technical publications are included in SCIE.

TABLE 1.

www.scielo.br	Brazil
www.periodicos.capes.gov.br/portugues/index.jsp	Brazil
www.latindex.unam.mx	Brazil
www.maik.ru	Russia
www.elibrary.ru	Russia
www.indianjournals.com/ijor.aspx	India
www.uni-mysore.ac.in/assets/faculty	India
www.nistads.res.in/indiasnt2008/t5output/t5out5.htm	India
www.nstmis-dst.org/dip/index.asp	India

[7] As an example, the Brazilian list retains "Bulletin CDAPH" but omits the "Bulletin of Prosecutors [Full Text] electronic journal".

[8] Meho and Yang [12] find that using citation data from *Scopus* significantly alters the relative ranking of those scholars that appear in the middle of the rankings (although at the top, SCI and Scopus are the same). Using *Google Scholar* stands out in its coverage of conference proceedings as well as international, non-English language journals.

III. FINDINGS

Of the four countries surveyed, 15,000 science or engineering publications were identified and counted in our survey. Of this number, 445 journals from these countries were included in SCIE in 2010. This suggests that SCIE includes close to 3 percent of journals from these countries, which is about the same percentage share as the number of journals and publications from other sources, based on the review of the Journal Citation Report citations counts cited above. This finding suggests that national science and engineering publication venues from the BRIC countries are not underrepresented in SCIE. National science may be "unseen" in some cases, but lack of representation within SCIE is not the obstacle to that visibility.

The overall findings of this survey are shown in Table 2. The first column presents the results from searching for "science" and the country name in Ulrich's Periodical database. As can be seen from the table, Ulrich's was the least productive of the databases searched for this survey. The Web of Science's Science Citation Index produced the numbers of journals in the column with that title. The number in the parenthesis is the percentage of all national publications (by our count) that appears in SCIE. China has the lowest representation at 2% of national publications appearing in SCIE, and Russia has the highest at about 8%. India has about 6% of publications in SCIE, and Brazil has about 4%. The column titled "National Publications" is the count that resulted from our survey.

TABLE 2.

Region or Country	SCIE (percentage of all national publications)	National publications	Number of FTE researchers (2007, UNESCO)	Number of SCIE/national publications for each one researcher
Brazil	102 (.04)	2472	133266	1307/54
Russia	149 (.08)	1901	451213	3028/237
India	105 (.06)	555*	154827	1468/279
China	139 (.02)	6596	1423380	10240/143
All	495	11524	2162686	4369/188
Sources: All searches done Spring 2011	Web of Science 2010	Authors' survey	UNESCO 2010	Author's calculation
		** The government of India reports that there are 998 national publications, but we were unable to produce a list of journal titles with this number.*		

To seek additional insight into possible coverage limitations, the number of scientific publications is compared to the number of national researchers. A column presents the number of full time equivalent (FTE) researchers for each country (data from UNESCO). The number of journals is then divided by the number of researchers to gain insight into the availability of publishing outlets for national researchers. This analysis suggests that the BRIC countries have numbers of national publications similar to scientifically advanced countries. Brazil leads in the number of publication outlets per researcher with one outlet for every 54 practitioners, followed by China with one outlet for every 143 researchers. India has about 155 publication outlets per researcher, and Russia has about one publication for every 237 researchers. These numbers are close to those in the North America and Europe, suggesting that the BRICs have about the same national capacity to publish science and technology as more scientifically advanced countries.

These findings do not negate the possibility of "unseen science" within the BRICs. Indeed, publications in local languages can be difficult to access and even more difficult to read for those not speaking or reading the national language (although, as noted, Google Translate worked well for technical titles). According to the Latindex database—the most authoritative source of information for Spanish and Portuguese publications in Latin America--there are 10,186 Spanish language journals (54%), and 4,201 Portuguese journals (22%) in Latin America. Some of these publications are available online, but most are not digitally available. Only 1.5% of these journals are registered in the Web of Science, and even these are not available in full text online. Brazil, as the only Portuguese speaking country in Latin America, can claim 102 journals in SCIE, see Table 2. Table 3 shows the numbers of Latin American journals in SCIE by country. The SCIE number suggests that only one journal exists for 1307 researchers in Brazil; the national number from our survey there is a more realistic view of 54 periodicals for each one researcher (see Table 2).

TABLE 3.

Country	Number of journals in SCIE©
Brazil	132
Chile	45
Mexico	43
Colombia	23
Argentina	20
Costa Rica	1
Cuba	1
Ecuador	1
Jamaica	1
Peru	1
Venezuela	14
Uruguay	1
Total	283

Similarly, within Russia there are several lists of journals, proceedings, and abstracts for national publications, most of which are in the Russian language, and many of these are not published online. Of these venues, eLibrary.ru claims to be Russia's largest information portal for science, technology, medicine and education publications. It claims to contain abstracts and full texts of more than 13 million scientific articles and publications in Russian, English and other languages. On the platform of eLibrary.ru, the user is offered access to electronic versions of over 2000 Russian scientific and technical journals, including more than 1000 open access journals. Major projects for this Scientific Electronic Library involve creating the Russian Science Citation Index as well as collecting and making available all open access scientific journals. In addition, eLibrary.ru creates portals called the Information Resources in Nanotechnology, Subscribe to the Russian Scientific Journals online, and the International Conference of Science Online. (We found that eLibrary.ru is not consistently online.)

From eLibrary.ru it is possible to identify 6607 unique publication names, of which 6280 are provided in full text, according to the website. (We did not independently check this fact.) This number includes social sciences and humanities publications as well as some related foreign journals. (For this survey, all the scientific and technological journals were extracted from the eLibrary.ru by scientific subfield to avoid collecting social sciences and humanities publications.) The VINITI library provided us with a list of journals from their library. Like eLibrary.ru, the VINITI list had social sciences, humanities, trade, and civil publications included. After cleaning the list of non-scientific titles (again, favoring inclusion in cases that were not clear), abstracts and proceedings, we compared the VINITI list to the one we harvested from eLibrary.ru, SCIE, and other publishers. The two lists were combined to create a single list of 1901 journals—the number shown in Table 2--which also counts a large number of university scientific bulletins which were retained in the list. The SCIE numbers show about one journal for every 3028 researchers; when national publications are included, the numbers are much healthier at about 237 publications for each one researcher.

The number reported in Table 2 for India is derived from a chapter within the online publication *India, Science and Technology 2008*, an Indian government report, which counts 998 Indian science periodicals (of various disciplines and frequency of publication). Searches we conducted for this survey found three unique websites with lists of Indian periodicals. These websites afforded us the opportunity to identify the technical names of 555 Indian publications. The discrepancy between the 998 and our number may be due to the Indian government counting in the names of some historical journals that have been consolidated into one, or where a journal may have changed names or perhaps ceased publication. Whatever the cause, we were unable to identify the names of roughly 45% of Indian journals counted by the government of India. Thus the unseen science among Indian journals goes beyond the full text to include even the names of all the scientific journals[9]. The number of journals per

[9] Garg et al. [13] note that additional research on their part is expected to turn up even more titles than the 998 they identified. (The Garg et al. article is

researcher is difficult to assess because of the differences in reported and counted numbers. The SCIE number suggests about one journal for every 1468 researchers, while the national number that we were able to count is about one journal for every 279 researchers.

Chinese scientific output has attracted a great deal of attention because the number of scientific papers in SCIE is surpassing the number of papers published by scientists from the United States [14]. Zhou and Leydesdorff [15] found that "China is a large country not only in terms of its scientific publications, but also in the large number of scientific journals it produces." Two institutions have organized Chinese data in a format similar to that of the *Science Citation Index*:

- *China Scientific and Technical Papers and Citations Database (CSTPCD)*, is produced by the Institute of Scientific and Technical Informati143 on of China (ISTIC); and
- *Chinese Science Citation Database (CSCD)*, is produced by the Documentation and Information Centre of the Chinese Academy of Sciences (see Table 1).

CSTPCD provided the list used for this survey. The list shows 6596 journals publishing scientific or technical research results. This number is a significant increase from the 2001 number reported in the literature: that number shows about 4100 journals reported in [4], who used the CSCD list. China's SCIE representation shows about one journal for every 10,240 researchers, while the national number suggests about one journal for every 143 researchers.

IV. Discussion

The finding that BRIC countries are not underrepresented in SCIE was unexpected. The finding relates to the number of publications, not to the citation rate, which has been found by others to be lower for developing countries than for advanced countries (see earlier discussion). Even so, we expected that the BRIC countries would have a lower representation within SCIE, but this is not the case. High quality science from the BRICs appears to be represented at the same level as more advanced countries.

It is important not to confuse quality, visibility, and accessibility when analyzing the findings. Even though BRICs are represented as having quality output, this does not mean that science or technology publications produced in these countries is equally visible and accessible as venues in North America and Europe. Publications in national languages not digitized (and thus inaccessible on Google Scholar) are very difficult to find—or to even know of their existence. Thus much of the output (and even more importantly, the capacity on the ground) can be considered as "unseen" in terms of searchability and accessibility at the global level.

It is also important to note that this observation about inclusion assumes that SCIE is the major source of global visibility, which may no longer be the case. Google Scholar (GS) and Scopus catalog a greater numbers of publications than SCIE, with Google Scholar being perhaps the most accessible of the three databases. Nevertheless, Google Scholar has significant drawbacks for scholarly purposes compared to SCIE. For example, GS does not collate entries at the journal level. It would be difficult if not impossible to use GS to compare the citation rates of a single author or institution to disciplinary averages, as one can do in SCIE. Moreover, GS often leaves the inquirer at the front page to a subscription site, where, if one does not have a paid subscription, it can cost money to access even a single journal article.

Inclusion in *SCIE* has been debated in terms of national, language, and disciplinary biases. It is important to note that SCIE is a privately-operated resource with no obligation to provide equitable access to any country or political entity. The barrier can be considerable for institutions in developing countries that seek to create scientific output at the level of SCIE since language barriers and local practices may be inconsistent with participation at the global level. SCIE applicants are screened for quality, not representation across the political landscape. For Chinese publications, the barriers may be even more severe—the indexing services acknowledge a bias against including journals published in languages other than those using the Latin alphabet. China's barriers include language, quality, and symbols. Thus it is even more noteworthy that they have been increasing quantity so quickly.

Van Leeuwen *et al*. [8] have argued that the language bias of the coverage in SCIE has consequences for international comparisons of national research performance, but our survey could not support this observation. It would appear that most high quality science produced in the BRICs is included in SCIE; of the entries, a significant number are published in English and all of the venues are abstracted in English. Thus, comparisons drawn from SCIE would have some independent validity. Similarly, it would appear that national comparisons created by the Royal Society in the 2011 report, *Knowledge, Nations, and Networks* can be presumed to provide a reasonable approximation of high quality science and engineering comparisons.

SCIE is important for quality measures, but less important for knowledge diffusion purposes. SCIE is used for quality assessments and rankings. Beyond quality rankings there are other motivations for scientific publication. Among these are to stake a claim in a field [1], to share ideas [16], to establish community [17], and to attract collaborators [18]. The process of creating networks and collaborating in science—sometimes called "the Invisible College"--is another growing feature of the science system [19]. In order to join the network of global collaborators, it is important to have one's scientific work seen by others, to be identifiable as a member of a subfield or community, and to have a presence within the group. This process of becoming a participant in the invisible college has been a central feature of science for centuries; in the 21st century, it may be more important to become participants in the global invisible college, particularly for developing countries that do not have a history of being closely tied into scientific communications [20].

included in the file containing the lists of journals.) Garg et al. report that most of the titles identified for their study are published quarterly (33 percent of titles). Agriculture accounted for the majority of Indian journals, followed by medical science, life sciences, and engineering, according to Garg et al. (Our survey does not parse the lists by fields of science.)

The questions of inclusion of developing countries in a global invisible college go beyond the technical ones attached to numbers, reading of symbols, or the level of quality acceptable at a world-class level. For the purpose of our survey, the language barrier did not pose a particular problem, since Google Translate provided a fair approximation of the content. (Whether Google Translate would be acceptable for scientific purposes is a question worth further study.) The focus of this survey is on the visibility and the incorporation of developing country scientists into the international arena. The latter is partly operationalized as publications in English, but even in national languages, there is representation in SCIE. It would be highly unrealistic to expect more than 2 million researchers in BRIC countries to write in English (Table 2). Even if their work were accessible in their native language--and making the heroic assumption that all these publications are of acceptable quality--the SCIE would need to incorporate thousands of additional titles into their index to make these countries visible. This is clearly an unrealistic goal and beyond the scope of SCIE's mission. Many publications are unseen at the global level because of barriers significantly beyond the role of indexing services.

One avenue for practitioners whose work is not included in indexing services may be the use of open access websites and repositories. These are increasingly used to present the results of research findings, both before and after the peer review and editing processes. Promoters of open access claim that there are more than 5000 open access journals and more than 1800 institutional open access repositories. (Open access venues are also included in the Web of Science: Thomson-Reuters reports that about 1021 open access journals are included in SCIE, SSCI and AHCI.) The OAISTER search program reportedly will find many articles (free full text) published in open access journals, and, depending on the location of one's search, it may also turn up materials from commercial journals and from institutional repositories[10]. Open access search can recover articles from PLoS, Elsevier, Springer, BioMedCentral for example, as well as from national journals made available from the SciELO, Bioline, MedKnow and other platforms. The Directory of Open Access Journals and the Directory of Open Access Repositories provide a portal to these resources.

A report on the website Directory of Open Access Journals (accessed May 2011) listed the following numbers of open access journals for the BRIC countries in 2010:

- Brazil, 537 open access journals—among the highest number of any country using open access;
- India is listed as having had 284 open access journals;
- China is listed as having 15 (with Taiwan at 14);
- Russia is not listed on the DOAJ country list, although, as noted, eLibrary.ru is creating its own open access content.

This survey did not seek to characterize the open access content, but only to note that developing countries are using open access to achieve visibility for their work. Open access materials published in national journals can be relevant to neighboring countries or those within the region that may have similar problems—perhaps problems that do not rise to the level of global interest. Such local or regional exchange could improve communications, and possibly strengthen (and internationalize) local journals[11]. A search of the DOAJ website for "Brazil" and "soil" found a number of articles that could not be replicated in Google Scholar or Web of Science. A more fulsome test would be needed to understand the coverage of DOAJ compared to other online sources. Nevertheless, anyone conducting a search would need to be aware of the existence of DOAJ in order to take advantage of the local findings.

Open access materials could be useful in disseminating science and in creating visibility for some within the global invisible college. Such materials are not useful for conducting comparisons at the international level because of the difficulty of capturing these data and making them comparable. It may be possible to account for these materials in comparative analyses, but for now, the analysis has not been conducted of what is included, what is missing, and what may be double-counted. Open access also has the downside of not having a peer review process, thus the quality of work published in this way can be questioned, and the work may be disregarded. Additional research is required to fully characterize developing country science, open access, and ways to improve visibility and incorporation of developing countries into the global invisible college.

De Solla Price [1], C.P. Snow [21] and others have suggested that countries or research groups that lag behind the leaders can, in theory, enter the scientific system more easily because they have literature to build upon. Caroline Wagner addressed this question in "The New Invisible College," [20]. With the advent of the Internet, in principle the potential is created to enter the system more easily, although the extent to which this is happening is the subject of debate [22]. The question of whether developing country scientists are able to access scientific publications is one side of the argument, often captured in the "open access" literature discussion[12]. On the other side is the question of whether the lack of visibility of published work from developing countries limits the opportunity for collaboration, since potential collaborators will not know about work going on in developing countries. We know that the system for abstracting, indexing, and sharing scientific publications passively excludes non-English language materials—especially those printed in local, national, and native-language journals or those addressing a local topic. Local knowledge that is not published is even more difficult to access.

A robust global knowledge system will find ways to more broadly incorporate, access, and account for quality knowledge wherever it is being created. Improved visibility of research will increase efficiencies in the system, as people can avoid redundancy by collaborating. This requires a broadening

[10] http://www.oaister.worldcat.org/.

[11] Further to OAIster and Google Scholar as tools to discover open access materials, OpenDOAR's new repository search tool http://www.opendoar.org/search.php . OpenDOAR [*] also has a global list of open access repositories that can be searched using geographic area or subject area.

[12] See, for example, the open directory project, http://www.dmoz.org/Science/Publications/Journals/Free_Online_Journals/

of thought on what constitutes "published literature"—well beyond the research that is abstracted in SCIE and similar venues. As research budgets are squeezed everywhere, collaboration can increase efficiencies by sharing results and then focusing research work on questions or problems whose answers have not yet been discovered. This requires seeing more of the science currently unseen in developing countries.

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