USE OF PUBLICATION LISTS TO STUDY SCIENTIFIC PRODUCTION AND STRATEGIES OF SCIENTISTS IN DEVELOPING COUNTRIES

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ABSTRACT

A bibliometric study using the lists of publications and work of 207 scientists working in Asia, Latin America and Africa was conducted. A certain number of authored and co-authored articles published in scientific journals and bulletins, conference papers, books, chapters of books, reports were taken into consideration to measure the total scientific output. Local vs. international production was also determined by scientific fields, geographic areas, sexe and language of publication. Co-authorship studies were also used to particularly measure the degree of collaboration and dependance of Developing Countries'(DC) scientists on foreign co-authors. An analysis of the references used (age, origins) was also made. Conclusions drawn concern the comparatively specific nature of science produced by DC's researcher. Partly given the importance of the scientific production published in local journals, the inadequacy of international databases to study DC science is confirmed. Most of the DC scientists publish in both national and international journals. They often cite their colleagues from the developed countries but their own work being less "visible" is seldom cited.

RESUME

Une étude bibliométrique utilisant les listes des travaux et publications de 213 chercheurs travaillant en Asie, en Amérique Latine et en Afrique a été effectuée. La production scientifique totale de ces chercheurs a été mesurée en prenant en compte le nombre d'articles en tant qu'auteur et co-auteur publiés dans des journaux scientifiques et bulletins, les contributions à des conférences, les livres et chapitres de livres ainsi que les rapports. La répartition de leur production entre science locale et internationale a également été déterminée par domaines scientifiques et géographiques, par sexe et langue de publication. La qualité des co-auteurs a également été examinée pour déterminer en particulier le degré de collaboration et de dépendance des chercheurs des Pays en Développement (PED) par rapport aux chercheurs étrangers. Les conclusions mettent en évidence les caractéristiques spécifiques de la production scientifique des chercheurs des PED. Compte tenu de la relative importance de la production scientifique publiée dans les journaux locaux, l'inadéquation des bases de données internationales pour étudier la science des PED est confirmée. La plupart des chercheurs des PED publient à la fois

dans des revues nationales et internationales. Ils citent beaucoup les travaux de leurs collègues des pays développés, mais leurs propres travaux étant moins "visibles" sont rarement cités.

INTRODUCTION

To measure the relative scientific output from the Developing Countries (DC) most authors have so far been using international databases, especially the one from the Institute for Scientific Information (ISI) in the United States (Garfield 1983, Frame et al. 1977, Blickenstaff and Moravcsik 1982). The work done by Davis (1983) in 36 sub-Saharan African countries for the period 1970-1979 is interesting because it concerns a relatively homogeneous group of countries. The scientific output of groups of countries (Arunalachalam and Markanday 1981; Krauskopf, Pessot and Vicuna, 1986) and individual countries (Krauskopf and Pessot 1983, Martinez-Palomo and Arechiga 1979, Morel and Morel 1978) has also been analysed using ISI and other international databases. These studies provide interesting information on the position of the various countries on the mainstream science supplier list and their impact on world science, but the description of how science is constructed in these countries, the researchers' scientific strategy, and their participation in national and international science is incomplete and often inaccurate.

We propose to use a different approach. This paper examines the scientific written output of 207 African, Asian and Latin American scientists who have been awarded one or several research grant(s) from the International Foundation for Science (IFS) in the agricultural and biological sciences and related technology. These scientists are working in 54 countries (23 African, 13 Latino American and 18 Asian Countries). Their scientific written output represents close to 5000 references produced during the 70's and the early 80's. The most significant individual feature of the population stems from the fact that the researchers who constitute it are the products of an internationally directed selection procedure. In other words, we could hypothesize that they are among the best researchers in DCs.

1. Local science and mainstream science

Although there is no database that is anywhere near complete, the DCs were recently credited with approximately 5% of the world's scientific production. Many databases are highly specialized. This is not the case for ISI which covers some 4500 journals from very diverse fields of science. But ISI is very selective and only screens the world's most popular scientific journals, the ones that publish the most frequently cited articles. Its Science Citation Index (SCI), developed by the ISI mapmakers, mainly focuses on what has become known as

"mainstream science", the most internationally visible science carried in 3100 scientific journals. Considering that there are not far from 70 000 scientific journals in the world (Turner 1984), the ISI database is really selective. Thus ISI represents about 6.5% of the scientific journals published throughout the world. Bibliometric work is often based on ISI data. Therefore, even if it covers the mainstream, it only bears on a small proportion of the world's science. Further, the DC scientific reviews are rated as "backwood cousins" in the ISI database which includes hardly more than 2% of them. French publications, together with all the other publications that are not in English, are at a disadvantage. The scanty number of DC journals, per country and per discipline, to be found in the ISI database illustrates how severely DC science is underrepresented.

The question of adequately representing science produced in the DCs in international databases was the main point at issue at a 1985 conference organised at ISI, in Philadelphia. The title of the final conference report, "Strengthening the Coverage of Third World Science" pointed to a glaring gap (Moravcsik 1986). It is difficult to define the precise amount of DC science omitted from the international databases, especially at ISI. The final conference report noted that "the workshop participants estimated that only about half of the scientific output of the third world which meets international standards of excellence is included in the SCI" (Moravcsik 1986, p. 3). ISI explains that DC scientific production published in national journals is not included in the SCI for reasons of quality. The national scientific journals are accused of not passing articles through a screening committee and publishing poor and even dubious quality work[1] (Packer and Murdoch 1974). This criticism is often addressed to India, the Third World's leading producer of science...by Indian scientists themselves (Arunachalam 1979a, 1979b, Arunachalam and Manorama 1988). The explanation often goes back to a cultural tradition that virtually bans criticism, especially in Asia. "No one wants to hurt the other. Politeness, a virtue of drawing room conversation, is extended to mean that no one criticises the other. In such an atmosphere, genuine criticism of someone's work is taken as a personal insult and leads to sentimental and emotional reactions, rather than rational defense" (Arunachalam 1979a, p. 8).

The work published in DC scientific journals is not excluded from international science and more specifically from the SCI for reasons of quality alone. The citation criterion, which is the basis of the system, works against scientific communities at the periphery because, as we will see in greater detail below, much of the work is published in local reviews only circulated within the

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[1]The editorial practise of certain mainstream journals, including some of the leading ones, is not always very selective. Packer and Murdoch asserted that during the 1963-1973 period, The Bulletin of Entomological Society of America, by principle, and insofar as possible, printed all the articles it received. During that decade only 4% of the articles submitted submitted to the Journal of 'Economic Entomology', The 'Annals of the Entomological Society of America' and 'Environmental Entomology' were rejected.

country. The scientists of these communities are caught in an especially vicious circle, because even when their findings are published in highly influential, prestigious scientific journals in the centre, they are, all told, far less often cited than writings by their colleagues from the centre, (Arunachalam and Garg 1985) which explains the very ambivalent feelings of scientific communities in the periphery concerning the significance of citation. Recent work on referencing within the Brazilian scientific community showed that, "citation patterns are significantly influenced by factors 'external' to the scientific realm and, thus, reflect neither simply the quality, influence, nor even the impact of the research work referred to" (Vehlo 1986). Brazilian scientists feel that the place of publication strongly influences the number of times a publication is cited. This was borne out by S. M. Lawani (1977) who showed that out of a representative sample of 100 entomology articles written by Nigerian authors, articles published in foreign journals were cited 1.74 times more often than articles published in local scientific journals[2].

Actually as J. D. Frame so correctly said, it all depends on what you are trying to assess. "If the purpose of the bibliometric indicators is to help in the building of a national scientific inventory, telling us what kind of research is being performed at different institutions, then coverage of local as well as mainstream publications would seem important. On the other hand, if one is primarily interested in investigating third world contributions to world science, then publication counts taken from a restrictive journal set would seem most appropriate" (Frame 1985, p. 121).

There is also a marked tendancy to assign research scientists of the peripheral scientific communities to two distinct categories; scientists who "really count", in other words are known to the international scientific community since they publish overseas in influential international journals and, the others, whose "local" science lacks originality and, at best, is published in low circulation local journals (Arunachalam, 1988).

Several recent studies justify a revision of this exaggerated - but largely held - caricature of science production in the periphery. Arvanitis & Chatelin (1988) Chatelin & Arvanitis, 1988) made a bibliometric study on soil sciences and agriculture which pointed to great differences in the national and individual publication strategies in the DCs, and showed that local science was not synonymous to poor science. It is not for reasons of scientific quality that the vast majority of studies on soils and agriculture are not "mainstream". Many dynamic DC scientists actually partake of the international scientific life but publish most of their findings in national journals. Studying a scientific generation's original work in this field so vital to development brought out the

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[2]In this publication Lawani also provides a per country rundown of the 829 journals that have an above-average impact according to the SCI. The USA is the leader (60% of the titles), followed by Great Britain and the Netherlands. There is only one DC journal (Revista Mexicana de Astronomia, published in Mexico) on the list.

importance of the time needed to develop a scientific thrust. A close look at the history of scientific production at a Mexican biomedical research institute showed that research scientists had changed their publication strategies in the score of years between 1959 and 1979 (Lomnitz, Rees and Cameo, 1987). By 1979 half of their output was published in international journals. Yuthavong, (1986) reporting on Thai scientific institutions, found a strong correlation between the number of articles the scientists from these institutions published in international journals and in the Journal of the Science Society of Thailand[3]. Eisemon and Davis (1988) showed that a sizeable proportion of the more dynamic scientists from four peripheral scientific communities of Asia (South Korea, Taiwan, Malaysia, and Singapore) published both in local and in international journals. They said that "the decision to publish locally is not merely the reflex of a second rate scientist, or the result of rejection elsewhere." It is the result of choice rather than necessity. These four countries have developed important local scientific literature that is not mainstream and, according to these authors, the local science will probably not be eliminated as the scientific communities gain clout in the international scientific community.

All these recent findings substantiate the thesis that the bibliometric indicators, especially the SCI, do not accurately assess the scientific output from the periphery, especially from the DCs and that local science far from being synonym of poor science, is at least as important as international science in the context of a developing country, and should thus be taken into account.

2. Total scientific output: sizeable local production, especially in Asia and in Latin America

In our sample, each scientist is producing on average 0.6 publication per year as sole author, and 0.7 as co-author (Table 1).

Table 1. Production per scientist per year.

Articles in scientific journals	1.3
Conference papers	0.5
Books or chapters in books	0.07
Bulletins and reports	0.3

This is slightly more than half that of American researchers in agricultural sciences, according to Busch and Lacy who reported 0.9 and 1.3 respectively.

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[3] The Journal of the Science Society of Thailand is also indexed in the SCI of the ISI. A weaker correlation was noted between the number of publications appearing in the latter's journal and the number of abstracts presented at the annual symposium of the Science Society of Thailand by the various scientific institutes of Thailand.

Further we have been able to estimate that more than half (55%) of the total scientific production of the scientists was published or available locally. The remaining 45% which was published abroad can be divided into articles published in scientific journals in industrialised countries (37%) and in other developing countries (8%).

These global statistics camouflage significant variations between geographical and scientific areas (cf. Table 2). The field in which the scientists are publishing most (1.6 publications per grantee per year) is Natural Products. This is also the field in which they publish most abroad (1.1 publications per grantee per year). Food Sciences is almost the opposite. There are more local (1.0) publications than foreign (0.4) publications. These results can be traced to the nature of the related research. The fields in which there are the fewest publications, i.e., Forestry (0.7) and Rural Technology (0.8) are probably also the fields with the most practical applications, whose results do not always need to be published.

We have also observed that Asian scientists publish more than African or Latin American scientists (1.5 as against 1 journal article per grantee per year respectively). Further, Asian scientists publish more locally (60%) than African scientists (41%). In Latin America more was published locally (58%) than overseas. (Table 3). These percentages, in comparison with figures for developed countries, are exceptionally high. Scientists in France publish 20% of their scientific production in foreign journals. For West Europe as a whole, the figure is 12%, and for Japan 25% (Garfield 1977, 1978, 1983).

Table 2. Number of journal articles (per scientist per year) by discipline.

Discipline	Published locally	Published abroad	Total
Aquaculture	0.6	0.7	1.3
Animal Production	0.8	0.4	1.2
Crop Science	0.5	0.6	1.1
Forestry	0.4	0.3	0.7
Food Sciences	1.0	0.4	1.4
Natural Products	0.5	1.1	1.6
Rural Technology	0.4	0.4	0.8
Total Mean	0.64	0.66	1.3

It should be made clear that this covers the scientists' total scientific production, not only journal articles which are published in equal proportions in local and foreign journals. When consulting Table 3 one should also remember that there are many more local journals in Asia and in Latin America than in Africa. We have also observed a relatively significant difference in productivity by gender; men publish more than women. This difference is all the more

Science and Natural Products and less active in fields such as Rural Technology where little is published. Women tend to publish more locally than men.

Table 3 . Place of publication per geographical area (%).

Geographical area	Locallly	In another developing country	In an industrialised country
Africa	41	10	49
Latin America	58	9	33
Asia	60	6	34
Total	55	8	37

Research is becoming increasingly collective, and scientists work together not only to bring their research to a successful conclusion but also to be able to publish their results as a joint venture. This holds for scientists who publish about two-thirds of their work with co-authors, as is shown in Table 4. Table 4 establishes that as a general rule the fields in which scientists work together most are the fields in which most is published.

Table 4. Number of publications (including bulletins, books, internal reports, conference papers) per scientist and per year as sole author and as co-author.

Research area	As sole author	As co-author	Total
Aquaculture	0.9	1.3	2.2
Animal Production	0.4	1.6	2.1
Forestry	0.7	1.2	1.9
Food Science	0.9	1.7	2.6
Natural Products	0.4	1.9	2.3
Rural Technology	0.7	0.9	1.6
Total	0.7	1.4	2.1

This confirms earlier findings by Price and Beaver (1966) and by Beaver and Rosen (1978, 1979a, 1979b) who observed that collaborative research enhanced

productivity[4]. Results also show that there is significant difference between disciplines. Fields that have the largest number of authors per publication, such as Natural Products, are fields that require inputs from a variety of disciplines e.g., taxonomy, botany, chemistry, and pharmacology. If the right specialists are not locally available, foreign cooperation is required, which explains the higher number of foreign co-authors per publication (0.53) for a field such as Natural Products (Table 5). Although the difference in average numbers of co-authors in terms of geographical distribution is not significant, we have noted that Asia has the highest number (2.4), followed by Latin America (2.2) and then Africa (2.1).

The mean number of authors per publication gives an interesting indication of the degree of association among researchers who publish, and the origin (local or foreign co-authors) gives an indication of the openness and/or dependence of the researchers. Table 5, for instance, confirms that National Products is the field for which the publication rate is the highest. It is also the field that brings DC scientists and foreign scientists together most. Actually, the more the scientists publish abroad, the more they work with foreign scientists.

Table 5. Average number of authors and co-authors (local and foreign) per publication .

Research area	No. of authors	No. of local authors	No. of foreign co-authors	Total no. of publications per scientist/year
Aquaculture	1.87	0.75	0.12	2.2
Animal Production	2.12	0.98	0.14	2.6
Crop Science	1.95	0.72	0.23	2.1
Forestry	1.98	0.67	0.31	1.9
Food Science	2.12	0.98	0.14	2.6
Natural Products	2.85	1.32	0.53	2.3
Rural Technology	2.20	0.80	0.40	1.6
Total	2.25	0.96	0.29	2.1

Thus we found that there were no researchers who had published more than 12 articles abroad without a foreign co-author. Garfield (1983) has shown that articles by researchers in DCs have a greater impact (on the international scientific community, measured in terms of number of citations per article) when they are

[4]Three reports by Beaver and Rosen published as a series in 'Scientometrics' in 1978 and 1979 are based on a study of collaboration between scientists throughout time since the 17th century. This study showed that collaboration in scientific research was a sign of professionalism within the scientific community and made the scientists more mobile and "visible".

co-authored by researchers from industrialised countries. Here we come up against the dilemma of the strategic scientific choices that researchers in DCs, in common with most researchers in peripheral scientific communities, have to make between participation in mainstream science (the most used, most visible, and most frequently cited science) and the resolution of local problems through "inward looking" research which some call "domestic" or "in-breeding" science.

It is worth observing that co-authoring with foreign scientists is most prevalent among scientists who studied, or went on post-doctorate study tours abroad. In most cases, however, these publications are produced in the years immediately following the stay abroad; sustained active collaboration is rare. Other associations develop when a foreign professor is on assignment in the scientist's home laboratory, or when expertise, not locally available, is brought in as part of a programme financed by a foreign institution or subsequent to an international conference.

The choice of language of publication is also central to the scientific strategy. A look at the lists of references consulted in preparing this study confirms the hypothesis that the different linguistic worlds are almost "language-proof", especially between the English and French languages. Spanish- and Portuguese-speakers often cite literature in English; this is rarely the case for French-speakers. And references by English-language scientists are drawn for all intent and purposes exclusively from literature written in English (Table 6). To one degree or another, these four languages dominate the world's scientific literature. In a few Asian countries, science is published in national local languages.

Table 6. Language of publication by linguistic area (%).

Linguistic area	Local	English	French	Spanish & Portuguese	Total
French-speaking countries	1	17	82	-	100
English-speaking countries	8	92	-	-	100
Spanish- & Port. speaking countries	-	36	1	63	100
Total	6	76	8	10	100

The percentages in Table 6 refer to approximately 5000 publications produced by 40 Latin American researchers (mainly Spanish speaking), 29 French-

speaking African researchers and 138 English-speaking researchers. These results confirm the prime importance of English and the resulting subordination of the other languages. Out of 3678 publications by English-speaking scientists, 2 were in French, 1 in German, 4 in Russian and none in either Spanish or Portuguese. On the other hand, more than one-third (36%) of the publications by Latin American and almost one-fifth (17%) by French-speaking scientists were in English. Our case study in Senegal indicated that English was increasingly used in French-speaking countries. The percentage of articles published in English by scientists working in Senegal, for instance, rose from 15% in 1975 to some 30% in the early 1980s (Gaillard, 1989).

The other conclusions that can be drawn concern the relatively significant use (8%) of local languages in certain Asian countries, e.g., Indonesia where more than half (52%) of the scientists' published works appear in Indonesian, Thailand (28% in Thai), and South Korea (18% in Korean). These percentages would be considerably higher if our figures only applied to the language of publication used in the national journals. Eisemon and Davis (1989) reported that over half (57.1%) of the articles in six South Korean journals were published in Korean[5]. Publication strategies differ greatly, depending on both the country and the discipline. Unlike South Korea, in Singapore all the scientific journals are in English.

As a general rule researchers will tend to publish in local languages, in national publications if their subject of research is for direct application. Except, perhaps, for a few Thai scientists, who find it difficult to write in English, the decision to publish in a national language and in a national publication is usually a question of strategy, as can be seen in interviews with scientists who say things like, "I submitted this paper to a local journal because the contents essentially bear on a local problem. This should make it easier for me to make the authorities aware of the problem and help them find the right solutions for our national development." Or, as concerned Korean and Thai, "I published in my national language so that I could use it in teaching." Another scientist said that he had decided to publish in a new local journal to contribute to its development because "...I feel that it is essential for our countries to have good quality scientific publications."

A few scientists admitted that it was "easier" and "faster" to publish in national journals. Using a national language also means reaching readers that do not receive international journals, and, furthermore gaining repute amongst peers and students in the home institutions. Most published both in national and international journals. Only about 20% published exclusively in the national journals; these were mainly young scientists working in agronomic research (Animal Production, Crop Science, Forestry) and Aquaculture. There were no

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[5]The fields covered by these journals, viz., biology, biochemistry, computer sciences, electronics and physics, are however more directly related to international science.

scientists from Natural Products who published exclusively in the national journals.

An analysis of the references used in articles provides precious information on the scientific output and research practices. We saw, for instance, there was far more intra-linguistic than inter-linguistic transfer. We also obtained information on the relative use of local and international science and the relative age of the work cited in the scientists' publications. Some authors found that scientists from the peripheral countries tended to ignore - or did not have access to - older publications, and thus concluded that the use of more recent references was characteristic of science in these countries (Rabkin and Inhaber 1979) The opposite was also alleged, i.e., that scientists in the peripheral countries cite references that are much older than those cited in articles published in international journals by colleagues from industrialised countries (Aranuchalam and Markanday 1981, Velho 1985, pp. 244-256).

Now let us look at our study population. For purposes of comparison with scientists from developed countries working in similar fields we referred to Lea Velho's thesis (1985, p. 247) to find a sample of articles published by - mainly American - scientists in scientific journals of centre countries. The results (Tables 7, 8, 9 and 10) show that DC scientists generally refer to articles more that 10 years old. Close to half (45%) of the references date back to over 10 years, while for authors from centre countries the figure is under one-third (29%).

Table 7. Breakdown according to age of reference cited, per continent of scientists' work.

Years	Africa	Asia	Lat. Am.	Total DC	Centre countries
0-5	180 (22)	195 (22)	126 (25)	519 (23)	340 (42)
6-10	312 (38)	240 (27)	180 (32)	732 (32)	239 (29)
> 10	327 (39)	456 (51)	240 (42)	1023 (45)	232 (29)
Total	819	891	564	2274	811

N.B. Figures between brackets show rounded percentages of the total.

On the other hand, scientists from centre countries often (42%) use references under five years old, while for DC scientists the figure drops to 23%. Table 7 showed us that there was no great difference between geographical areas for the

three main continents although there was, as has been shown in other studies[6] (Crane 1972) and in Table 8 below, between disciplines.

Table 8. Breakdown of age of reference cited according to scientific discipline.

Discipline	0-5 (%)	6-10 (%)	> 10 (%)	Total
Aquaculture	132 (23)	138 (24)	303 (52)	573
Animal Prod.	42 (17)	96 (38)	114 (45)	252
Crop Science	102 (18)	171 (31)	285 (51)	558
Forestry	51 (26)	75 (37)	75 (37)	201
Food Sciences	48 (21)	108 (47)	75 (32)	231
Nat. Products	144 (31)	144 (31)	171 (38)	459
Total	519 (23)	732 (32)	1023 (45)	2274

The figures indicate that Natural Products, a discipline that draws heavily on organic chemistry and pharmacology, uses the most recent references (31% within the last five years). It is worth remembering that this is the field that generates the most joint publications with foreign researchers. The biological sciences most directly linked to agriculture (Animal Production and Crop Science) and Aquaculture are the disciplines with the most references over ten years old (between 45 and 52%). Thus, biological disciplines, largely based on analytical work, e.g., natural substances and work on mycorrhiza in forestry, tend to use more recent references than the more descriptive research that relies more on experiments with live matter.

As concerns the age controversy with regard to "national vs. international" journals, our results (Table 9) tend to agree with Arunachalam and Markanday (1981). Apparently articles published in national journals cite references that are older that those cited in international journals that belong to mainstream science. A finer analysis would probably reveal significant differences between countries. Eisemon and Davis (1989) showed that one-fifth of the references in articles published in national journals of Malaysia, Thailand, and South Korea dated back

[6]Brown, cited by Crane (1972), found that the percentage of refernces under 10 years old was the highest in publications on physics, lowest in biology and that physiology and chemistry came in between.

to five years ago at most whilst in Singapore nearly one-third of the non-mainstream science references were of that age.

Table 9. Breakdown per age of reference between publications published abroad and nationally.

Years	Abroad (%)	National (%)	Total (%)
0-5	405 (25)	114 (17)	519 (23)
6-10	537 (34)	195 (29)	732 (32)
>10	660 (41)	363 (54)	1023 (45)
Total	1602	672	2274

It is quite clear that articles printed in national reviews are much more readily assimilated by DC scientists than anything found in foreign journals, as Table 10 indicates.

Table 10. Breakdown per age of reference: foreign vs. national.

Years	Foreign ref. (%)	National ref. (%)	Total (%)
0-5	243 (14)	276 (56)	519 (23)
6-10	606 (34)	126 (26)	732 (32)
>10	936 (52)	87 (18)	1023 (45)
Total	1785	489	2274

Over half (56%) of the references drawn from national scientific literature date back at most five years, while only about one out of seven references (24%) taken from foreign journals are thus dated. Yet the scientific transfer within or between the DCs is not very great (only 22%). In other words references in publications by DC scientists are mainly (78%) taken from mainstream scientific literature, but with some delay since more than half the references date back to at least a decade ago. Several reasons can be suggested for this situation which is largely due to dysfunctioning of scientific practices in the developing countries.

Since most of the DC scientists, unlike their colleagues in developed countries of the centre, do not belong to what is generally called the "invisible college",

they do not become familiar with their colleagues' work before it is published. Actually their only access to information is tedious bibliographic research, and even this does not always result in the identification of the most relevant reference work. We also found out that only half the scientists had bibliographic catalogues like "Current Contents", and that less than one-third of them had access to bibliographic databanks. The unavailability of bibliographic references was felt with special acuteness in most African countries. This said, during our missions we saw that, except in several African countries, the libraries in DC universities and institutions had relatively recent scientific journals from countries of the centre that institute scientists rarely consulted. Some of these journals looked as if they had never been opened. Many scientists try to subscribe individually to the most relevant international journals, but scanty financial means that are not regularly available makes this difficult.

The fact that DC scientists often cite articles in journals that are over ten years old can also be related to the time between their training period abroad and the publication of their work. Over 75% of our cohort studied abroad, mainly in the U.S., Great Britain, and France. Quite possibly their references are works they learned about during their education abroad. This is an explanation Lea Velho entertains in reference to Brazilian scientists: "the longer the time since the researchers returned to Brazil from graduate training abroad, the older the foreign literature they tend to cite" (Velho, 1985, p. 253).

Turning to total scientific production we see that English-speaking scientists, mainly in Asia, constitute the most published group (2.37 publications per scientist per year), while French-speaking Africans (1.63) and Latin Americans (1.76) form the least published groups. These figures, of course, only provide a partial indication and cannot be used as a decisive measurement of the quality of a research scientist. Other indicators have to be used. For reasons given above we decided not to use the citations method in measuring the impact and the quality of articles published in international reviews. A full-fledged qualitative evaluation would have required the participation of several specialists with a variety of linguistic capacities for each of the disciplines concerned, which was beyond the means of our study.

CONCLUSION

Several conclusions can be drawn from this study concerning the specific nature of science produced by DC researchers, and the construction of science in their countries.

Science produced in DCs is not adequately represented in international databases not exclusively for reasons of quality. While international databases can be used as a source of information of the relative strengths of various countries in mainstream science, they give an incomplete and often inaccurate

picture of total scientific output and how science is constructed in non-mainstream countries.

A look at total scientific production shows that DC scientists often publish (up to 60% in Asia) in national journals, that the leading language is English, a language even used for publishing by close to one-fifth of the French-speaking scientists and over one-third of the Latin American scientists. We also saw that the English-speaking scientists only publish in English or, as is the case in some Asian countries (e.g. Indonesia, Thailand and Korea), often in local languages. Most of the scientists publish in both national and international journals. Although publication strategies differ according to country and to scientific discipline, scientists who decide to publish in a local language or journal most often do so by choice and not by necessity.

DC scientists cite references essentially (78%) from mainstream scientific literature which they seem to receive later than their colleagues in the centre since nearly half the references are over 10 years old, as against 29% of the references cited by scientists from the centre countries. An analysis of the citations indicates that DC scientists use articles from national journals much sooner in time than articles from international journals. Actually citation modes are affected significantly by factors unrelated to science, factors which are social rather than cognitive in nature. Scientists in the DCs need much more time to avail themselves of new scientific data that are pertinent to their research.

In sum, DC scientists often cite their colleagues from the developed countries, but their own work being relatively "invisible" is seldom cited. They often feel caught in a dilemma: either adopt the habit of scientists from developed countries and publish in international journals to become more "visible" and gain international standing, or else seek national recognition by publishing in local journals, and sometimes in local languages, thus being condemned to non-existence or, at best, marginal existence in mainstream science. The general trend is to adopt the two strategies together.

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