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Science in the Developing World: Foreign Aid and National Policies at a Crossroad

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While recognizing that the relations between science, technology and development are far more complex than we thought 30 years ago and that neither science nor technology is a shortcut to development, it is argued that the building up of a national research capacity should be considered as a priority for every nation in the world. After a brief historical review of the development of science in the developing world this article discusses the professional and social status of scientists, the conditions under which research is conducted and characterizes the scientific production in developing countries (DCs). Recent changes of the foreign aid policies and institutions are also reviewed. In the conclusion, it is stressed that better concerted cooperation between foreign aid managers and national policy-makers is needed to find innovative ways to back the emergence and the reproduction of endogenous scientific communities in the developing world. More and more problems, e.g. environmental deterioration, are becoming a growing concern for all nations of the world. The solution to these problems will require mobilization of the world around reinforced collaborative efforts.

SCIENCE IN THE SERVICE OF DEVELOPMENT: UTOPIA OR REALITY?

The importance of science and technology in combatting underdevelopment was recognized rather late. It wasn't until the end of the 1940s and the beginning of the 1950s that we first heard about the concept of "underdevelopment" (1) and documents first mentioned the possible role of science and technology (S&T) in fighting it. The concepts underdevelopment and Third World appeared within a year or two of the creation of UNESCO which was almost established without the "S". Science was added to its mandate almost per chance at the very last moment (2). The euphoria of the 1950s and 1960s and the hope implied in the prospect of science in the service of development was soon replaced by disillusion which grew stronger and stronger as the economic crisis and unemployment struck the industrialized countries (ICs) in the 1970s and many developing countries (DCs) were gradually relegated to the wings of the international economic scene. It wasn't until the beginning of the 1980s that a new wave of optimism and mystifying utopia emanated from new scientific developments in the fields of micro-electronics, new materials, and biotechnology.

Research on the "science of science" over the last 20 years enables us to better understand factors that contribute to technical change and technological innovation. We now recognize that there is no more of a direct linear relationship between basic research, applied research, technological development and, finally, economic growth, than between the quantity of research a country conducts and the efficiency of its research system. In other words, investing in research and development (R&D) activities, forming research teams, building universities and laboratories with sophisticated equipment and libraries will not guarantee miraculous scientific discoveries or activate a development machine. Relations between science, technology and development are complicated, and neither science nor technology is a shortcut to development. Further, developing science is a lengthy undertaking. Even under conditions more favorable than those currently prevailing in most of the developing countries, it took more than 50 years for countries like the USA and Japan to be able to compete with the European countries.

The last decades have also made it increasingly clear how risky it was to attempt to reduce the DCs to an integrated entity. The formation of the world economic system has widened the gap between the "least-developed countries" (LDCs), the "intermediary countries" (Int.Cs), and the "newly industrialized countries" (NICs). The promise borne by the new technologies, especially biotechnologies, may widen this gap. The NICs have reached a fair level of scientific research, industrial capacity and domestic sales which justifies their hope to better capitalize on new scientific development and technology (4, 5) while the LDCs have unproductive, inadequate, scientific research systems and lack an industrial base, qualified personnel and capital. The opportunities and powers that science bestows on those who know "how and why" widens the gulf, not only between the developed countries and the DCs, but also between the DCs themselves.

Should we conclude that most LDCs do not have the conditions required for building up a national research capacity? It is true that because of their size and available resources, there are very few LDCs that will be able to contribute to the production of scientific knowledge and of new technologies. This inspired Salomon (6) to make a distinction between controlling production and controlling the use of scientific knowledge and technological change. Even people who do not see the need for each country to have its own scientific community recognize the vital importance for each country to have access to technology. But the question is whether technology can be successfully transferred without a minimum of scientific expertise at the receiving end. The answer is obviously no. Much of the knowledge and technology conceived in the ICs cannot be applied directly in the DCs. There are always problems connected to knowledge appropriation and technology transfer, which can only be solved through on-site science, in other words, on-site scientists. Another justification that seems of prime importance is related to the fact that all modern nations need to have their own higher education system, and it is impossible to conceive of higher education without teachers who are actively involved in research. We could find a whole series of arguments to justify promoting science and technology in the DCs, but this is not the subject at hand. We feel that we are going far enough by concluding simply that the nations which staunchly chose to embark on experimental science now number among the richest, and the DCs have every right to seek their share; they do not want to be left in the wings of the scientific revolution that is now being acted on the scene before them.

SCIENCE DEVELOPMENT IN THE DCs: VERY YOUNG NATIONAL RESEARCH SYSTEMS

While modern science was born in Italy at the turn of the 16th century, the first tangible signs of its penetration only appeared in the 18th and even more so in the 19th century in Latin America and in Asia, and at the turn of the 20th century in Africa. Its birth is often co-related with that of the universities, e.g. in Latin America where there were 23 universities by the end of the 18th century (7, 8). The British colonizers opened the first universities of Asia in 1857 in Calcutta, Madras and Bombay (9). The University of Cairo was founded in 1908 (10). The first universities of Black Africa are much younger. It was only in 1948 that the first courses were given at University College in Ibadan, Nigeria, and the first graduates received their science degrees in 1950 (11). Officially, the University of Dakar, the oldest university in French-speaking Black Africa, was established in 1957.

A comparative study recently conducted in three countries (Costa Rica, Senegal and Thailand) showed the various steps in the development process (12, 13). The primary conclusion that can be drawn from the study is that the systems are very young. The first embryonic research institutes only date back to the end of the 19th century and, most of them were created during the first half of the 20th. It was only in the 1960s and especially in the 1970s that national scientific communities truly developed and the institution-building process took root. The national research systems experienced exceptionally acute growing pains that they were able to control, more or less, during the 1970s. Referring to the European models, these countries designed various services to mold scientific policy as institutions were being developed until finally, some time between 1979 and 1986 they created ministries specifically for scientific and technical research (14).

The Student Population Boom of the 1970s

Regardless of when the universities in the three countries studied were established, the student body was small and graduates few in number until the end of the 1960s; growth was considerable during the decade thereafter particularly in Costa Rica and in Thailand where many new establishments of higher learning were started (Fig. 1). The student boom and the large graduation classes combined with the economic crisis and the short budget led to a new phenomenon: intellectuals without jobs.

A Scientific Potential Concentrated in Universities and Focussed on Agriculture, Social Sciences and Health

Let us not forget that we are dealing with small scientific communities that were estimated, in the early 1980s, at 800–1000 scientists in Costa Rica (15) and in Senegal (12) and just over 5000 in Thailand (16). Furthermore, the number of fulltime equivalent (FTE) research scientists as a percentage of the population as a whole is very small (Thailand 0.06, Senegal 0.08, and Costa Rica 0.17) compared to the industrialized countries (ICs). Thus, there are approximately 20 times fewer FTE researchers per 1000 inhabitants in Costa Rica than in France, and 30 times fewer than in the USA.

More than half of the FTE scientific potential is to be found in the universities (56% in Senegal, 58% in Costa Rica) (Fig. 2). University scientists are also the best trained and have the most and highest degrees. The distribution within the different type of institutions also illustrated the weakness of private research in Costa Rica and in Thailand, and its virtual nonexistence in Senegal. The demand for highly qualified scientific personnel in the private sector is very limited. A clear understanding of the gap between Costa Rica, Senegal and Thailand on the one hand and the ICs on the other can be found in a figure for the OECD countries where, on the whole, 50% of the R&D resources are used in the private sector, mainly for industrial research, (60% in some NICs of Asia).

A breakdown of scientists available in the main fields of research (Fig. 3) shows concentration in three major fields: agriculture, social sciences and health. Agriculture is by far the leading field (from 33% of the FTE scientists in Thailand to 40% in Senegal). The social sciences are in second place in all three countries (between 20–25%) followed not far behind by health in Costa Rica and in Thailand (17).

Figure 1. Students as a percentage of the total population between 1960 and 1986.

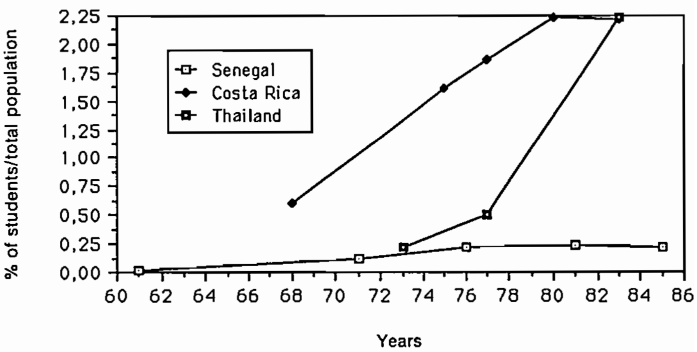


Figure 2. Distribution of full-time equivalent FTE scientists within institutions.

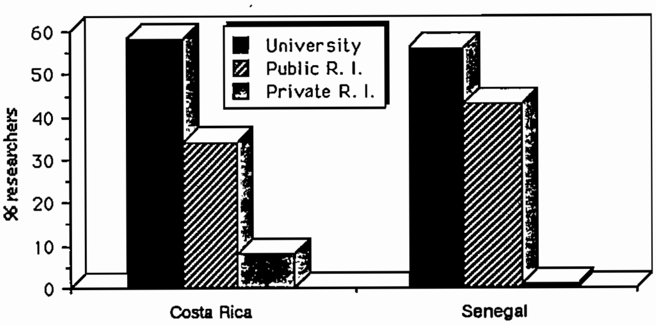
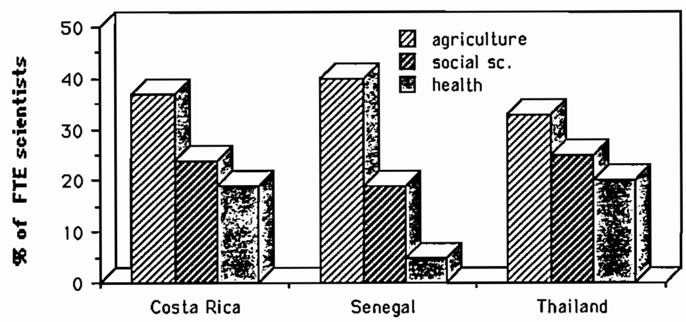


Figure 3. Distribution of full-time equivalent FTE scientists in the major fields of science.



The number of scientists in engineering is low in all three countries. Industrial research is virtually nonexistent in Senegal and plays a very minor role in Thailand and Costa Rica.

Let us look at the DC scientists who compose the emerging national scientific communities to better understand their professional and social status and their working conditions.

SCIENTISTS AND THEIR ENVIRONMENT IN DEVELOPING COUNTRIES (18–20)

The scientists of the DC national communities find themselves at the heart of a dilemma between their decision to participate in solving local problems and their attraction to models and reference systems more or less imposed by the international scientific community. They are highly dependent on countries in the center and on the international scientific community. Outside sources are often relied upon for education and training, institution building, research financing, etc. To a large extent, DC scientists use international scientific literature as their reference, choose research topics on the basis of essentially the same criteria as their colleagues in the center, and tend to select the same equipment that they grew accustomed to during their PhD studies in the IC laboratories.

But importing equipment manufactured in the north into the DCs of the south even with clear instruction manuals, is not enough to ensure equal quality service (21). Similarly, scientists who studied in the north often discover that the subject of their thesis, their course curricula, knowledge and experience are not directly applicable upon return to their home country. It is becoming increasingly clear that placing major international criteria on scientific communities of the periphery, especially in the DCs, will not guarantee the latter's integration into the international scientific community. It may, to the contrary, detract from the relevance of research to local needs and problems.

Education: At Home or Abroad?

Although the proportion of doctorate degrees conferred in the DCs has been constantly increasing since the beginning of the 1970s, research scientists, especially the most active ones, still rely heavily on foreign education (22). A student who has the choice between studying at home or abroad will generally choose the latter. Besides the economic benefits that accompany a stay in an IC, a diploma obtained there is usually rated higher than a diploma from a DC. Among the countries that train DC students to the doctorate level, three stand out on the international scene: the United States, Great Britain and France (23).

Research training is too heavily reliant on foreign facilities and countries, and training abroad does not satisfy the needs of the DC scientists. It would be more realistic, efficient and, in time, productive to allocate the considerable sums of money now being used to train DC scentists (24) to reinforce and establish doctorate programs leading to a PhD in priority fields within the national universities. Doctorate programs could also be organized on a regional basis. Strengthening national academia would contribute to improving the structure of DC scientific communities thanks to added input from both the national scientific potential and the student body. This implies that the countries in the Northern Hemisphere would have to remodel their education aid policy, but obviously does not mean cancelling all opportunities for doctoral or post-doctoral education abroad in certain very highly specialized or marginal fields.

Research Scientists in Search of Statutes and Status

Research scientists in DCs strive for proper professional status; draft texts have often been prepared and stored away in anticipation of better times prestige. Doctors and lawyers and other professionals of that level with at most the same amount of education as the research scientists are not only better paid but also enjoy a much higher social status. The low wages explain why many of them supplement their income by working overtime on side jobs that include anything and everything, e.g. working as a consultant, a teacher or even a taxi driver, etc.

Thus, the strategies adopted by the scientists are the result of negotiations carried out in a socioeconomic, cultural, and political environment that is not always very conducive to scientific perspectives and societal recognition of research science as a profession. Up to the present, science in the DCs, especially in Africa, has been essentially controlled by government. The first step for the newly independent countries was to build up the state and its institutions. Education was given top priority in order to train civil servants. Careers have however often been constructed without considering diploma qualifications. Success in the power struggle has been given more importance than professional specialization.

Because of this situation it has often been difficult to develop research science as a profession, or even as a vocation. As a career, it is not very appealing, and urgently needs status. But isn't the problem being viewed backwards? The absence of status is an indication that the profession has not really distinguished itself in society, and that professional standards and representations do not "gel" properly.

Practicing Research

The conditions described above affect the way research is practiced. Time devoted to research depends on a number of factors. One of them is the nature of the researcher's home institution. Obviously, the researchers with the heaviest teaching load work in universities. This is the case for the majority of DC scientists. In a comparison of our DC-scientist population with their American colleagues (25, 26) we found that American university researchers on average spent less time teaching (27% as against 37%) than their colleagues in the Third World, and, above all, more time doing research (57% as against 34%). The differences are much less significant for researchers working in research institutes, although American researchers again spend more time (77%) doing research in these institutions than do their Third World colleagues. As for the size of their research budget, the differences are of another magnitude. While American researchers in government research institutes have an average annual budget of USD 209 000 and their university colleagues have USD 68 000, we found that researchers in DCs on the average only dispose of USD 5600 plus. Even if we deal with estimates given by researchers, who very often do not know the precise total of their budgets, the differences observed are such that they require no further comment.

Other disparities also bring out the fact that DC scientists are at a significant disadvantage compared to their colleagues in scientifically more-advanced countries. Lack of equipment, vehicles, technicians, and scientific documentation are among the most frequently observed and described. Another disadvantage which is, to my mind, even more critical and at the very center of the scientific enterprise is communication. Many DC scientists suffer from a feeling of isolation especially when they just return from studying abroad and are trying to fit into the scientific community at home. Moravcik (27) describes how difficult, and in some cases impossible, it is for DC scientists to communicate with their peers and colleagues by drawing a comparison with birds whose wings have been clipped. The feeling of isolation is probably heightened by the fact that these scientists have been trained in a large variety of universities located throughout the ICs. Furthermore, during this early period when the young national scientific communities are just "taking off", the scientists often have to cope with being the only specialists in their field within their institution, or even within their country. All the authors, however, agree that science cannot exist without communication, and that a colleague's criticism is vital to progress in any scientific endeavor. Here again the DC scientists are enduring a handicap little known to their colleagues in the ICs. Other handicaps relate to visibility and the recognition of their scientific production.

SCIENTIFIC PRODUCTION: NOT VERY VISIBLE

Given the abovementioned handicaps, it is not surprising that the DC scientific production and its impacts are slight. The DCs are credited with approximately 5% of the world's scientific production. But DC science is seldom reflected in the international databases and is kept off the international science scene (28). International databases, and particularly that of the Institute for Scientific Information (ISI), are very selective and only screen the world's most popular scientific journals, the ones that publish the most frequently cited articles. Thus, the Science Citation Index (SCI), developed by ISI, focuses on what has become known as "mainstream science", the most internationally visible science published in some 4000 scientific journals. Since we know that there are about 70 000 scientific journals in the world, we see how selective the ISI database is; less that 2% of the scientific journals selected come from the DCs.

Refering to ISI and other international databases, recent studies have provided 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 (29, 30).

India, the uncontested DC science leader, produces five times more mainstream scientific publications than the People's Republic of China (31). Table 2 lists the top 15 producers of mainstream scientific literature in the DCs for 1973 and for the 1981–1985 period. This list changed notably during the reference period. Production in certain 1973 leading countries like Brazil and Nigeria rose sharply. Some countries with small, even very small, scientific output in 1973 started climbing, e.g., Hong Kong, Saudi Arabia, South Korea. Other countries like Iran and Lebanon, in the throes of political and military unrest, lost their standing (32). Most of the countries on the list produced substantially more in the years following 1973 (33), but the per country mainstream scientific production remained small, even in countries at the top of the list like Egypt, Mexico and Nigeria. A comparison with the production of scientific institutions in the OECD countries shows, for example, that a country such as Egypt produces less than the Harvard University Medical School (35).

Studies referring to international databases, moreover, tend either implicity or explicitly, 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. But quality is not the only reason for excluding DC scientific journals from international databases. The citation criterion, which is the basis of the system, works against scientific communities at the periphery, because much of the work is published in local journals that are only circulated within the country. The DC scientists are caught in an especially vicious circle, because even when their findings are published in highly influential, prestigious scientific journals in the center, they are far less often cited than are writings by their colleagues in the center (36). Recent work in 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" (34). The place of publication strongly influences the number of times a publication is cited (38). We also found out that DC scientists often cite colleagues in ICs, but more rarely cite DC scientists, even when their works are published in well-read international journals. This behavior seems to be the result of a rather widespread, although difficult to prove, conviction among DC scientists that quoting works published by colleagues in ICs brings more credit to their own work.

Table 1. Fifteen leading DC science producers, ranked according to number of mainstream publications produced. Source:* (35), Table 4, pp. 507–508; ** (43).

Rank	1973*		1981–1985**	No. of publications (annual averages)
	Country	No. of publications	Country	
1	India	6880	India	10 978
2	Argentina	764	People's Rep. China	2146
3	Egypt	683	Brazil	1498
4	Brazil	573	Argentina	1124
5	Mexico	368	Egypt	1029
6	Chile	356	Nigeria	790
7	Nigeria	280	Mexico	709
8	Venezuela	200	Chile	590
9	Taiwan	186	Taiwan	509
10	Iran	174	Hong Kong	365
11	Malaysia	138	Saudi Arabia	319
12	Kenya	125	South Korea	312
13	Singapore	120	Venezuela	311
14	Thailand	117	Kenya	248
15	Lebanon	114	Singapore	214

To sum up, the international databases need better coverage of science produced in the DCs, and local databases need to be created, and consulted. Databases at this level, accompanied by periodical production and dissemination of documented analytical bulletins would not only serve to improve scientific output in the DCs but would also, in time, enhance south-south and north-south documentation exchange and both the visibility and accessibility of DC scientific production. All these recommendations solicit national research policies and foreign research aid policies, which must fit into a jointly redefined, well-coordinated policy frame. Attention should be given to the main types of foreign policies for scientific cooperation, and how they have changed during the last decade.

FOREIGN AID: FROM ASSISTANCE TO SCIENTIFIC COOPERATION

The main ICs of the north created a wide variety of institutions and mechanisms to handle collaborative undertakings. History and national tradition had a strong influence (39). Certain countries such as France, United Kingdom, the Netherlands, Belgium and Portugal, which have a long history of scientific and technical assistance to DCs, created specialized scientific research institutes for the tropics (40) and have specialized teams of research scientists, differing in size, that have acquired unique field experience. Other countries such as Canada, Sweden and Australia, which do not have a colonial past, set up mainly during the 1970s central institutions specialized in scientific and technical cooperation with the DCs (41). And then some countries such as the US and Germany created an essentially decentralized system in line with their respective political and administrative organization. In other words, depending on the country the system is more or less centralized, favors supporting or implementing research, emphasizes the creation of institutes for tropical research or for assistance to national scientific communities in general, or prefers bi- or multilateral activities, etc.

Many new initiatives have been started since the beginning of the 1970s. These initiatives have been expressed mainly through the creation of new organizations, and an increase in the number of donors and their overall financial contributors. External funding agencies have been paying for increasing parts of DC research budgets. In some countries, the number of donors involved in research financing is such that it is practically impossible to determine the share that comes from the national budget. This erratic growth of foreign aid and the lack of coordination caused serious problems, e.g., the capacity to absorb this aid, the excessive numbers of task forces and individual visits for a variety of aid programs and some small projects, and the impossibility of integrating aid programs into national, technical and financial administrative structures. The more diversified the financing and the greater the number of potential funders, the more time that has to be devoted to receiving and touring representatives of the donor organizations, filling funding applications, organizing fund management along the lines set out in the specific requirement forms and criteria papers of each of the donors, drafting mid-term or final progress reports, participating in evaluation groups, etc. Furthermore, externally funded projects and programs run the potential risk of having to change size, objective, or duration. The donor has the unilateral power to bring them to a halt, through a decision that may be the result of a change of government, governmental policy or economic conditions in the donor country.

Donor organizations providing research aid in DCs only started working on coordinating their efforts in the mid-1970s, partly as a reaction to the economic crisis. The follow-through was that in 1982 a group of donors (BOSTID, USA; GATE, Fed. Rep. of Germany; IFS; NUFFIC, Netherlands; and SAREC, Sweden) upon the initiative of Canada, created IDRIS, the Inter-Agency Development Research Information System, which serves as a database for the group members by compiling descriptions of their respective DC-related activities. In the start-up phase, IDRIS sought to bring together a small number of organizations, but now it is open to new members, and its system is available to outside users, including the DCs. Similar initiatives have been taken by the World Bank, e.g., CGIAR created a donors' club called SPAAR, The Special Program for African Agricultural Research.

In addition to the recent attempts to better coordinate S&T activities, both at the national and international level, and hence to greater internationalization of the policies, we can observe an emerging consensus of the aims and goals of S&T cooperation with the DCs. Until the 1960s, the "north" countries mainly used their own human and financial resources to solve problems in the south without seeking agreement on the choice of countries to help, the target populations or the type of science. Since that era, the priority has shifted to recognition of the development of endogenous scientific and technological capabilities that are in harmony with the social and cultural traditions and the conditions specific to each DC all the while emphasizing the importance of satisfying basic needs (42). Gradually, S&T assistance that more often than not (and this still applies in certain cases) meant "substitution research", is changing into genuine S&T cooperation through a partnership with the national scientific communities of countries of the south.

CONCLUSION

Of the many advantages of having foreign-aid managers and DC policy makers work together, we need only mention greater transparency, better understanding of priorities and prerequisites, and improved functioning. Lack of concertation is detrimental to both the donors, and even more the DCs which would greatly benefit from meeting together to share their attitudes to and uses of aid, to assess advantages and drawbacks and to discuss mechanisms that could be used nationally to obtain the most favorable aid conditions. Among other things, we believe that more coordination in research financing would help maximize and control foreign aid and minimize the risk of national scientists undertaking research of low priority to their home country.

Dependency is not a matter of all or nothing. The immediate solution for DCs is not to attain scientific and technological autonomy comparable to the ICs, but rather to use a certain degree of freedom to determine national R&D priorities in accordance with national socioeconomic goals, to develop a capacity to take autonomous decisions and to master their environment. The implementation of a national science policy is unthinkable without a genuine professional status for the scientists and greater autonomy for their institutions. This will mean, inter alia, redefining higher education policies. Concerning higher education, dependency is incompatible with the creation of an independent scientific tradition and the emergence of a truly autonomous scientific community. It is becoming increasingly urgent to shift the center of gravity of doctorate-level education from the countries of the north to the south. This will require cooperation between the traditional northern host countries (which offer scholarships) and the DCs to establish or strengthen doctorate courses in DC universities (at a national or regional level) in disciplines of national (or regional) priority.

The appropriateness of foreign-aid research priorities agenda also needs to be reviewed. While the strongest emphasis is traditionally put on agricultural and to a lesser extent on medical sciences one can observe that agriculture is playing a decreasing role in successful development strategies. Recently observed growth is due in most cases to industrialization and to the development of services. Accelerated urbanization and environmental deterioration are of growing concern. As science and technology evolve, the pace of resource exploitation speeds up causing the so-called "Environment-Development Crisis". This is a joint DC-IC problem that has to be solved by the DCs and ICs together.

Another activity that requires cooperation is scientific communication. Collaborative efforts are needed to better balance scientific communications in the DCs and to help develop a scientific nucleus with international ramifications. This could include establishing formal and informal networks (based on interpersonal relations between scientists in DCs and ICs), and convening national and regional conferences in the DCs followed by the publication and wide distribution of conference proceedings. Considering how poorly scientific information is circulated in the DCs, seminars and conferences are at present the most effective tool for establishing durable scientific contacts. Other measures might include encouraging researchers from various institutions in DCs and ICs to work together on joint projects, encouraging exchanges of scientists between various types of institutes in DCs and ICs, making national journals more visible, and unpublished documents more readily available by creating a central index system for reference materials.

In most DCs, the first steps of institution building have been completed and significant, although insufficient, human and financial resources are available. Innovative ways should now be found to support the emergence and reproduction of endogenous scientific communities. The International Foundation for Science (IFS) with its program of well-targeted grants for individual scientists has already made a significant contribution. But the issue is also one of institutional and organizational structures. What research system should be adopted and supported, and what organizational procedures should be applied? The main focus should be on the system's functional qualities rather than on quantitative expansion, on indicators of efficiency rather than on resources.

References and Notes

1. President Truman, who coined the word under-development, originally used it in a speech in 1949. The expression "Third World" was first used as an analogy to "Tiers Etat" by Alfred Sauvy in 1952. President Truman's speech was "practically the first document that mentioned that science and technology might be useful in the fight against under-development" (3).
2. King, A. 1974. *Science and Policy: The International Stimulus*. Oxford University Press, London.
3. Rufo, G. 1985. La science, la technologie et le Tiers Monde. *Encyclopœdia Universalis 17, symposium*.
4. Development of endogenous science has not always been the impetus for development in the NICs, in particular in Singapore and South Korea where steady growth has been supported by acquiring techniques and transforming imported resources together with staff training. These countries are trying ever harder to develop their national S&T capabilities, in particular by offering attractive salaries to national scientists working abroad.
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6. Salomon, J.J. 1986. Science technologie et développement: le problème des priorités. *Tiers Monde 28*, 213–222.
7. Very few students were actually educated there. By the end of the 19th century, the 28 Latin American universities had only 150 graduates.
8. Botelho, A.J.J. 1983. *Les Scientifiques et le Pouvoir au Brésil: le Cas de la Société Brésilienne pour le Progrès de la Science (SBPS), 1948–1980.* DEA thesis, STS/CNAM, Paris, 1983, 186 p.
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11. Kolinsky, M. 1985. The growth of Nigerian universities, 1948–1980. *Minerva 23*, 29–61.
12. Gaillard, J. 1989. *Les Chercheurs et l'Émergence de Communautés Scientifiques dans les Pays en Développement (PED)*. PhD thesis, CNAM, Paris, 452 p.
13. These three countries are small (Costa Rica and Senegal) or medium (Thailand) in size. Their per capita income places them high in the category of low-income countries (Senegal) or in the middle of the category of medium-income countries (Thailand and Costa Rica). All three countries are agricultural although the economies of two of them (Costa Rica and Thailand) have been structurally changing as industry accounts for an increasing part of the GNP. Excluding the major scientific powers of the Third World, e.g. China, India and Brazil,and NICs such as the four Asian "dragons", they are representative of many developing countries.
14. The Ministry created in Senegal in 1983 only existed for three years.
15. CONCIT/IDRC. 1982. *Situacion Actual y Caracteristicas de las Actividades de Investigacion en Costa Rica*. San José, 44 p.
16. MOSTE. 1987. *The White Book on Science and Technology in Thailand*. Bangkok. (In Thai). Concerning Thailand see also Gaillard, J. 1990. La communauté scientifique thailandaise: un développement rapide mais une reproduction difficile. *Inter-Mondes 1*, 43–57.
17. The figure for Senegal (4.5%) obtained from a survey carried out by the Ministry of Research in 1981 is most probably too low.
18. This paragraph is mainly based on the results of a questionnaire survey carried out on a population of close to 500 DC scientists who received grants from the International Foundation for Science (IFS).
19. Gaillard, J. 1989. *Les Chercheurs des PED: Origines, Formations, Pratiques de la Recherche et Production Scientifique*. ORSTOM publication, Paris, 220 p.
20. Gaillard, J. *Scientists in the Third World*. The University Press of Kentucky, Lexington, 224 p. (In press).
21. Gaillard, J. and Ouattar, S. 1988. Purchase, use and maintenance of scientific equipment in developing countries. *Interciencia 13*, 65–70.
22. Dependency correlates with degree level. A study of the IFS grantees shows that 75% go abroad for their PhD, 45% for a MSc, and 10% for a BSc.
23. Gaillard, J. 1987. Les chercheurs des pays en développement. *La Recherche, No. 189, June 1987*, 861–870.
24. The cost of scholarship students abroad depends mainly on the country. Excluding registration, tuition fees and travel expenses, the annual cost in

dollars in the mid 80's, ranges from USD 3000 in the USSR to USD 10 800 in Japan. Everything included, a doctorate requiring 4 years of study would cost USD 70 000 in the US which is at least ten times more than it would cost in a DC.

25. For comparison, we used figures obtained by Busch and Lacy (1983) with American researchers working in related fields of research.
26. Busch, L. and Lacy, W.B. 1983. *Science, Agriculture, and the Politics of Research*. Westview, 303 p.
27. Moravcik, M.J. 1976. *Science Development—the Building of Science in Less Developed Countries*. PASITAM, Bloomington, Ind. Second Edition, 285 p.
28. Gaillard, J. 1989. La science du Tiers Monde est-elle visible? *La Recherche, No. 210, May 1989*. 636–640.
29. Chatelin, Y. and Arvanitis, R. 1988. *Le Stratégies Scientifiques et le Développement. Sols et Agricultures des Régions Chaudes*. Paris, ORSTOM, 143 p.
30. Davis, C. and Eisemon, T. 1989. Mainstream and non-mainstream scientific literature in four peripheral Asian scientific communities. *Scientometrics 15*, 215–239.
31. The scientific output of the People's Republic of China was completely ignored in the 1973 SCI base (except for one publication). The powerful emergence of this country at the end of the 1970s was due to three interdependent phenomena, viz., increased contact with Western science, a sharp rise in the number of scientific journals published in the country, and ISI's decision to correct the under- or nonrepresentation of that country in the ISI database.
32. Thailand and Malaysia, which had disappeared from the list of top 15, were 16th and 17th in the 1981–1985 period, with annual average production figures of 188 and 169 publications, respectively.
33. Brazil's progression has been especially remarkable considering the highly local focus of its scientific output in national journals, in Portuguese.
34. Velho, L. 1985. *Science on the Periphery: A Study of the Agricultural Scientific Community in Brazilian Universities*. PhD Thesis, SPRU, University of Sussex, 301 p.
35. Frame, D.J., Narin, F. and Carpentier, M.P. 1977. The distribution of world science. *Social Studies of Science 7*, 501–516.
36. Arunachalam, S. and Garg, K.C. 1985. A small country in a world of big science: a preliminary bibliometric study of science in Singapore. *Scientometrics 8*, 301–313.
37. Velho, L. 1986. The meaning of citation in the context of a scientifically peripheral country. *Scientometrics 9*, 71–89.
38. Lawani, S.M. 1977. Citation analysis and the quality of scientific productivity. *BioScience 23*, 26–31.
39. OECD. 1985. *Scientific and Technological Cooperation with Developing Countries*. Paris.
40. Some of them were created at the end of the 19th century. Amongst the most important and best known are (current names): the Tropical Development Research Institute (TDRI) in the UK, the Institute Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM) in France, the Royal Institute for the Tropics (KIT) in the Netherlands, the Institute for Tropical Scientific Research (LNICT) in Portugal and the Prince Leopold Institute for Tropical Medicine in Antwerp.
41. Canada created the International Development Research Centre (IDRC) in 1970, Sweden created the Swedish Agency for Scientific Cooperation with the DCs (SAREC) in 1975 and Australia created the Australian Centre for International Agricultural Research (ACIAR) in 1981.
42. These principles were strongly restated at the 1979 Conference on Science and Technology in Vienna.

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