AD-A092 892 DEPARTMENT OF STATE WASHINGTON DC OFFICE OF EXTERNAL--ETC F/6 5/4
CONTRIBUTIONS TO INDUSTRIAL DEVELOPMENT OF SCIENCE AND TECHNOLO--ETC(U)
SEP 79 G E SCHWEITZER, F A LONG, R HUGHES

UNCLASSIFIED FAR-3004 NL

1 of 1
AD
A092892

END
DATE
FILMED
1 81
DTIC

① LEVEL II

FAR 30004

AD-A092892

Contributions to Industrial Development of Science and Technology Institutions in Malaysia, Nigeria, and Colombia and Opportunities for Bilateral Cooperation (A Cross-Country Comparative Analysis)

G. E. Schweitzer and F. A. Long

September 1979

Final Report to U.S. Department of State

The Program on Science, Technology, and Society
Cornell University
Ithaca, New York 14853

(6) CONTRIBUTIONS TO INDUSTRIAL DEVELOPMENT
OF SCIENCE AND TECHNOLOGY INSTITUTIONS
IN MALAYSIA, NIGERIA, AND COLOMBIA
AND
OPPORTUNITIES FOR BILATERAL COOPERATION
(A Cross-Country Comparative Analysis).

Prepared by

12)

10) G. E. Schweitzer, Senior Research Fellow
F. A. Long, ~~Henry Luce~~ Professor of Science and Society

9) Final rept.

With Contributions by

Robert Hughes, Professor of Chemistry
Peter Auer, Professor of Mechanical Engineering
Julian Smith, Professor of Chemical Engineering
Robert Von Berg, Professor of Chemical Engineering
Robert Finn, Professor of Chemical Engineering
Matthew Drosdoff, Professor of Agronomy
David King, Graduate Student Research Assistant
Theodore Bergh, Graduate Student Research Assistant
Penny Pinsky, Graduate Student Research Assistant

18) FAR

11) Sep 79

19)

Program on Science, Technology, and Society
Cornell University

September 1979

This study was funded by the Department of State under Contract No. 1751-300350. However, views and conclusions contained in the study should not be interpreted as representing the official opinion or policy of the United States Government.

403 232

PREFACE

This report presents the highlights of recently completed studies of the contributions to industrial development of science and technology institutions in Malaysia, Nigeria, and Colombia and of the opportunities for bilateral co-operation between these institutions and U.S. organizations. Common problems encountered in the three countries and innovative approaches in addressing such problems have been of special interest. The details of the country studies are presented in three companion reports. A fifth report describes the methodology that was developed for analyzing science and technology capabilities within the countries.

The country studies, which provide the basis for this report, were carried out by teams of senior scientists and engineers from Cornell University. In addition to their strong technical backgrounds, the team members have had considerable experience in analyzing the many economic, organizational, and other factors influencing the role of science and technology institutions. Each team spent three weeks in the country and several additional months analyzing available documentation. This effort, while brief, was adequate to reach a few firmly based conclusions concerning institutional developments.

The country studies concentrated on the institutions which carry out the functions identified in Figure 1. Primary attention was directed to science and technology activities which support -- directly or indirectly -- manufacturing activities, development of the physical infrastructure essential to industrialization, and assessment and use of the nation's natural resource base. In the agricultural area, this report generally does not address activities related to food crops but does consider some activities related to the development, processing, and use of non-food crops.

Figure 1

FUNCTIONS OF THE SCIENCE AND TECHNOLOGY INFRASTRUCTURE

	Education & Training	Adaptation, Development & Research	S & T Services
PUBLIC & PRIVATE SECTOR ACTIVITIES	Scientists and Engineers Teachers Technicians Skilled Labor Managers	Technology Choices Engineering Facilitation Design and Modification Development and Demonstration Basic and Applied Research	Information Extension Patents Testing and Quality Control Maintenance and Repair
INTERNATIONAL ASPECTS	Overseas Training Expatriate Instructors	Technology Transfer International Research Networks	Expatriate Advisors International Services

Special appreciation is expressed for the assistance during the country visits provided by the Malaysian Ministry of Science, Technology, and Environment, the Nigerian National Science and Technology Development Agency, and the Colombian Foundation for Scientific Research. Also, officials of many other agencies, staffs of educational and research institutions, private sector entrepreneurs, and others have gave generously of their time in assisting the study teams. Finally, officials of the Department of State and representatives of the U.S. Embassies and Consulates in the countries provided valuable guidance during the study effort.

TABLE OF CONTENTS

Figures:

POLICY AND ORGANIZATIONAL COMMITMENTS TO SCIENCE AND TECHNOLOGY

The Governments of Malaysia, Nigeria, and Colombia have clearly recognized science and technology as important determinants of the rate and direction of industrial development. They are devoting substantial resources to more effective application of science and technology as part of their efforts to increase productivity in all sectors of the economy. They are convinced that science and technology can provide important tools for improving transportation and communication networks and for attaining wiser management of natural resources. Only through technology will many locally manufactured products be able to compete effectively internationally, or even domestically in the absence of high levels of protectionism. Finally, new and innovative uses of technology may offer the best hope for extending services and job opportunities to the rural poor and thereby enabling them to share to a greater degree in the benefits of modernization.

Each of the nations appreciates the importance of continued, substantial reliance on technologies developed throughout the world, and principally in the industrialized countries, as the major pathway to industrial development. At the same time, there is growing awareness of the importance of greatly strengthened indigenous capabilities to select, replicate, and adapt to local conditions those technologies developed abroad which are most suitable for local needs and capabilities. Experience has shown that mistakes in the choice of technology can be costly and are usually difficult to reverse. Meanwhile, a number of local groups are attempting to develop indigenous technolgies -- principally simple technologies for rural applications. While such efforts are an important aspect of development efforts, they cannot substitute for extensive reliance on modern technologies in efforts to meet the pressing needs of rapidly urbanizing populations in each country.

The commitments of the three nations to science and technology are reflected in a variety of organizational, policy, and program measures adopted during the past decade. Science and technology agencies have been established. Technology transfer is regulated in an increasingly systematic manner. Science and technology activities are standard line items in national budgets. Many universities have active research committees and modest research programs. Industrial standards and product specifications are regularly developed. Public expectations have been aroused that technology will lead to shortcuts in the traditionally long and difficult paths to economic prosperity.

The preparations within each Government for the 1979 United Nations Conference on Science and Technology for Development assisted in elevating and broadening attention to important technology policy and program issues. The process of drafting, coordinating, and clearing the country papers for the Conference was an important step in improved understanding of the multifaceted aspects of science and technology. Also, the process involved useful interactions between Government agencies and representatives of the academic and industrial communities.

There is considerable uncertainty as to the meaning of the terms "research and development" and "science and technology" in developing countries. The experience of the industrialized countries is only partially relevant in this regard. Activities in the three countries reflect a heavy emphasis on "adaptation", "technology", and "services". Indeed, the Director of a central laboratory of a Colombian company urged that "research" not be used to characterize his activities lest management terminate his financial support. Similar sentiments are encountered throughout the universities where even basic science courses are frequently tilted toward practical applications.

Each country has a national science and technology agency as shown in Figure 2. Each of these agencies would like to be able to exert greater influence on major national policies affecting or affected by technological developments. In Malaysia, the Ministry of Science, Technology, and Environment has direct access to the Deputy Prime Minister but does not have the staff capabilities or stature to challenge effectively the recommendations of other agencies. In Colombia, the Foundation for Scientific Research (COLCIENCIAS) has strong analytical capabilities in many areas. However, COLCIENCIAS is subordinate to the Ministry of Education which has limited interests in industrial development. With regard to influencing budgets, the Nigerian National Science and Technology Development Agency (NSTDA) has responsibility for 22 research institutes while COLCIENCIAS has no line responsibility for research activities. The Malaysian Ministry has responsibility for two important facilities. Both NSTDA and COLCIENCIAS have small extramural research programs, carried out principally at the universities.

Figure 2
NATIONAL AGENCIES FOR SCIENCE AND TECHNOLOGY

	Ministry of Science, Technology & Environment (MALAYSIA)	National Science and Technology Development Agency (NIGERIA)	Foundation for Scientific Research (COLOMBIA)
Parent *Organization*	Office of Prime *Minister*	Federal Executive *Council*	Ministry of Education
Laboratories	Ind. Stds & Res. Inst. Analytical Chemistry Lab.	22 Research Institutes	None
Extramural Research Program	None	New and very small	Well established but small
Impact on Budgets of Other Agencies	Little	Little	Little
Coordination	Council under Deputy Prime Minister has some impact	Large number of committees with some impact	Informal consultations reasonably effective
Analyses & Studies	Very few	Occasional symposia	Many studies
Role in preparing for UNCSTD	Lead role	Lead role	Lead role
Staff for policy and program direction	10	35	75

The linkages between these science and technology agencies and other Governmental departments are uneven and highly dependent on the interests and experience of the personalities involved. In general, the linkages with the ministries and financial institutions concerned with industrial development are weak. Similarly, and somewhat surprisingly, the linkages with the educational planners are also weak, except in the area of funding of university research. In short, for these countries, the concept of science and technology as an exlicit area of concern is relatively new. As might be expected, the older agencies seldom have the time or inclination for effectively involving the new agency in issues that have traditionally been the exclusive domain of the older agencies.

Thus, at least at the operating level, there are separate and, at times even inconsistent, policies for education, for industrial development, and for science and technology. Effective meshing of these policies is a challenge facing each country.

Two areas where the new science and technology agencies and the institutions reporting to the agencies will probably become more involved in important decisions are technology transfer and environmental pollution. For example, COLCIENCIAS has recently become a participant in Government deliberations on specific technology transfer proposals, and industrial ministries in Malaysia and Nigeria are considering methods for drawing on the technical resources of research institutes reporting to the science and technology agencies in this area. In each country older agencies are having increasing difficulties in addressing the technical aspects of environmental pollution, and scientific organizations are strengthening their environmental assessment capabilities.

A limited number of scientific and technical institutions currently provide much of the backbone of each nation's science and technology capability in the physical, engineering, and related sciences. They include: a few strong university departments in undergraduate science and engineering; several Government or quasi-Government research institutes in the field of agro-industry; national petroleum organizations with rapidly growing geology and engineering staffs; and quality control and testing capabilities dispersed throughout the Government, universities, and private sector. In Colombia and Malaysia, several locally owned engineering consulting firms have strong design capabilities in civil and electrical engineering. Also, in Colombia, many private manufacturing firms have well established design engineering departments. In addition, in each country there is a continuing growth in the technical departments of line agencies with operational responsibilities (e.g., Public Works, Communications, Power).

The pages that follow compare and contrast activities involving these and other institutions which comprise the science and technology infrastructures in the three countries. Also, some of the innovative approaches that these nations have developed and important capabilities that have been neglected are identified. As indicated in Figure 3, the countries differ markedly as to their levels of development and their political and cultural settings. Nevertheless, there is considerable similarity in many of the problems encountered by such nations which have historically relied on the industrialized nations for their modern technologies and for the advanced training of their political and technical leaders.

FIGURE 3

SELECTED POLITICAL, ECONOMIC, AND CULTURAL FACTORS

INFLUENCING S & T ACTIVITIES

	MALAYSIA	NIGERIA	COLOMBIA
Domestic Political Commitments	Improve Malay participation in economy	Indigenize companies and institutions	Strengthen small entrepreneurs
Regional Political Commitments	Support ASEAN Regional S & T Institutions	West African Economic integration largely on paper	Andean Pact commitment on trade and technology transfer policies
Balance of Payments Situation	Excellent	Good	Very Good
Inflation	Not a major concern	Very serious	Serious
Reliance on External Aid	Several programs of World Bank, U.K., and Japan	Increasing programs of World Bank; traditional reliance on many agencies	Variety of World Bank and IADB loans
Energy Endowments	Promising oil and gas	Considerable oil	Good coal & hydro; some oil
Mineral Resources	Tin; maybe other ores	Not yet well developed	Good resources but often inaccessible
Road Transportation	Good roads connect major cities	Spotty road network	Difficult mountain roads
Communications	Generally good	Poor	Good
Brain Drain	Minor problem, but growing among Chinese population	Significant problem	Increasing emigration to Venezuela
Student Attitudes	No visible problems but Chinese increasingly discontent	Occasional demonstrations	Frequent demonstrations at public universities
Language	Substituting Malay for English at all levels	English emphasis	English emphasis declining
Attitude toward education	Highly cherished	Highly cherished	Highly cherished
Attitude toward manual skill	Historical dependence on Chinese	Associated with low status	Well accepted

DEVELOPMENT OF TECHNICAL MANPOWER: PROBLEMS, OPPORTUNITIES, AND INNOVATIONS

Expansion of Educational Opportunities

Increased educational opportunity at all levels, and particularly opportunity for rural youth, is a high priority in each country. Science and engineering are generally recognized as study areas of substantial national importance and attract considerable interest from parents and students. Still, a large proportion of the student population prefers other courses as (a) offering earlier opportunities for management positions (e.g., law, business administration); (b) reflecting important cultural values (e.g., medicine, Islamic studies); or (c) being more appropriate in view of weak secondary school preparation in science and mathematics.

In recent years the number of universities has increased dramatically. Lower level institutions, including technical and vocational schools, have multiplied at an even faster rate. Also important in developing technical cadres are a wide variety of informal courses and on-the-job training programs sponsored by both Government and industry. Figure 4 compares the principal educational opportunities in science and technology in the three countries.

FIGURE 4

EDUCATIONAL STRUCTURE IN SCIENCE AND ENGINEERING

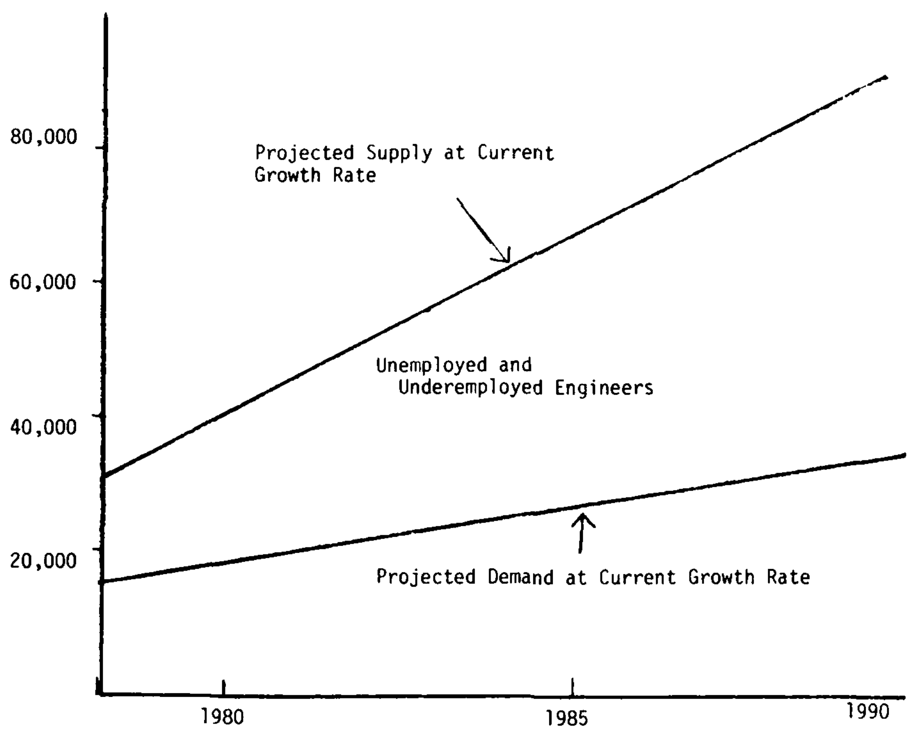
	MALAYSIA	NIGERIA	COLOMBIA
Universities Undergraduate	Public Several well-established; several new	Public Several well-established; several new	Public & Private Many well-established; many new
Graduate	in early stages of development		
Post-secondary Technological Institutes	Two polytechnical schools	18 polytechnical institutes patterned after UK	Many 3-year programs
High Schools with science emphasis	Several strong schools	Some private	Many private
Vocational Schools	Established by three different agencies	Attempting to develop system	More than 100
Government agency training facilities	Well developed	Being developed	Not very important
Government programs for on-the-job training	Not well developed; MARA beginning programs	Industrial experience for engineering students	SENA apprenticeship programs at all firms
Industrial training programs			
Multinational Corporations	Well developed at all levels in many firms		
Local industry	Traditional Chinese approach to learning by doing	Poor	Some are well developed

Almost all developing countries have difficulties in matching the supply of and demand for scientists and engineers. In the three countries, there is an overall excess of trained scientists and engineers although there are spot shortages in some disciplines in each country. As shown in Figure 5 , the situation with engineers in Colombia, for example, is growing worse as the rate of university expansion outpaces industrial growth.

The overly qualified workforces disperse in many directions, including emigration, teaching in secondary schools, shifting to careers in administration, and working as overpriced technicians. Good students from the better schools find engineering jobs, and it is clear that many engineering graduates are not prepared to function as engineers even if jobs were available. However, in science even the best graduates have increasing difficulties in finding suitable employment.

Figure 5

Supply of and Demand for Engineers in Colombia



Source: SER Research Institute, Bogota, June 1979

While the manpower supply and demand problems have been recognized at the highest levels of all three Governments, none of the countries has yet developed strong manpower planning capabilities. The absence of good data on the likely demand handicaps the reaching of rational decisions by university administrators as to annual intake quotas in various disciplines. Also, students have little guidance as to the job opportunities associated with career choices.

In Nigeria and Malaysia the responsibility for manpower assessment is assigned to the planning agencies which seems appropriate. In Colombia there is no clear assignment of responsibility. In any event these activities should receive a higher priority, and results of surveys and estimates should be widely distributed both to educational institutions and to prospective students.

University Training

The rapid expansion of the university systems has been accompanied by a decline in the overall quality of the undergraduate educations that are offered, particularly, but not solely, at many of the new universities. The new universities usually do not have either the staffs or the facilities to offer high quality programs, and the qualifications of many of the entering students are low in view of limited educational opportunities at the secondary school level. Contributing to the decline in standards in science and engineering is an erosion of the English language capabilities of students entering the universities, hindering effective use of English textbooks which are important in each country. While it is unlikely that these trends will be reversed in the foreseeable future, each country should retain a few undergraduate departments of excellence which can serve as models of achievement for the entire system while also catering to the most talented youth of the country.

Many of the undergraduate courses in science and engineering offered at the well established universities in each of the countries compare favorably with similar courses at U.S. universities. However, new engineers in developing countries are faced with many problems which are not encountered in industrialized countries. For example, there may be limited opportunity for learning on the job from senior scientists or engineers. A specialist in one technical discipline is frequently called upon to solve problems in other disciplines. Support by technicians and modern equipment, such as computers, may not be available; and reliable power, water, and other services which are common in the advanced countries often present serious problems. This suggests the need for enrichment of the traditional university curricula. For example, special emphasis in problem solving, in design work, and in technology adaptation might be more fully incorporated into the curricula.

Each of the countries is currently developing limited graduate programs in science and engineering, with principal emphasis on courses at the M.S. level. This development will undoubtedly entail sizeable investments in facilities as well as a sustained commitment to a high level of faculty qualifications. These capabilities should be developed slowly and selectively, given the limited absorptive capacity of these countries for specialists with advanced degrees. Clearly, in some disciplines continued reliance on graduate training abroad will be far less expensive than establishment of new graduate programs at home for some time. The centers of excellence concept is particularly appropriate in the area of graduate education to provide effective critical masses of faculty members with common interests. Also, there is some interest in establishing multi-disciplinary graduate centers to address a variety of development concerns such as environmental and energy problems. While this trend seems healthy, care should be taken to insure that such centers do not undercut the viability of graduate departments structured along discipline lines which for the near future require careful nurturing.

Two major problems inhibiting university development are the heavy course loads for instructors and the rapid turnover of faculty, particularly in engineering departments which regularly lose good staff to industry. In a sense, both of these problems can be traced to the over-expansion of the university systems which in turn have limited budgets. In the absence of funds, additional staff cannot be hired nor pay levels made more competitive.

Training at Overseas Universities and Colleges

Each country relies heavily on overseas training of scientists and engineers at the undergraduate and graduate levels. For example, almost one half of Malaysian university students are studying abroad. During 1979, an estimated 18,000 Nigerians, 3,000 Colombians, and 2,000 Malaysians were studying in the United States.

Students from Colombia are quite sophisticated in selecting appropriate U.S. institutions for such training. There is extensive knowledge throughout the country as to the capabilities of many U.S. institutions. In Malaysia, which has historically sent students principally to Commonwealth countries, knowledge of U.S. institutions is far more limited. The Malaysian American Commission for Educational Exchanges, supported by the International Communications Agency and staffed largely with volunteers, provides a very valuable service in disseminating information on the strengths of U.S. universities and colleges. Many Nigerians are not particular as to which U.S. institutions they enter although some seek out the best universities. The Nigerian Government does not distinguish between degrees from the very best U.S. universities and marginal schools, and many Nigerian students believe that they can transfer after entry into the United States if they are not satisfied with their choices of colleges. However, inappropriate choices of universities and colleges are becoming of greater concern as some U.S. institutions in financial difficulty expand student recruitment efforts in the developing countries.

Some of the students at U.S. institutions have scholarships from their Governments, and a few receive direct assistance from the institutions. The bulk of the students are privately financed. Scholarship students frequently post financial bonds with their Governments which helps insure their return home. Many Nigerians attempt to remain in the United States for many reasons, including lack of enthusiasm for one year of mandatory service in the Youth Corps and employment uncertainties at home. Brain drain to the United States does not seem to be a major problem among Malaysian and Colombian students at present. However, the lack of accurate and readily available data on the emigration of scientists and engineers further complicates efforts to match the supply of and demand for specialists.

Technical and Vocational Training

Post-secondary polytechnical institutes are in place in each of the countries. However, in Colombia and Nigeria the role of these schools, established to train "technologists", is not clear. In Nigeria and Colombia both students and faculty are unhappy that the institutions do not offer degrees. The concept of providing training to fill the gap between technician and engineer has not worked out in practice in these two countries, and this entire approach to education needs careful reevaluation. In Malaysia, the polytechnical institutes are less ambitious and simply provide a somewhat higher grade of technician than is produced in the vocational schools.

Vocational schools of all types exist throughout the three countries. There is great difficulty in retaining qualified staff at these schools in view of higher paying salaries in industry. The pupils are often lacking in ability and motivation, and the available equipment is sometimes antiquated and even inoperative. Further, the organization and administration of these schools in confused by the multiplicity of local (city, state), national (Ministry of Education, Ministry of Labor), and international (UNESCO, ILO) agencies involved. Thus, the sharp criticism by industry of the lack of effectiveness of these schools is not surprising. Nevertheless, the three Governments have made firm commitments to providing such training as a stepping stone to industrial employment. In many cases this approach may be the only hope of disadvantaged segments of the population to enter the mainstream of economic development. Upgrading the vocational systems will not be easy. Cost/benefit analyses may argue against significant additional investments. However, the importance of these schools to the countries may best be measured in political and social terms.

A number of line agencies in Malaysia and Nigeria (e.g., power, communications, and public works) operate training schools with both long and short term courses for their employees, particularly their technicians. These institutions have frequently been established with the assistance of external agencies and are reasonably well stocked with equipment comparable to the equipment that is encountered on the job. In terms of job preparation and of upgrading skills, they offer a sharp contrast in effectiveness to the vocational schools which are usually preparing students for unspecified jobs.

Each country has also been concerned with preparation of skilled workers through on-the-job training and other types of informal preparation. The SENA program in Colombia is by far the most highly developed approach and has achieved considerable success. This program is financed by a two percent tax on all payrolls. Two important components of the SENA program are (a) the specialized job training centers located throughout the country which emphasize highly specialized skills (e.g., aviation mechanics), and (b) the apprenticeship program whereby each company is obliged to accept as five percent of the workforce SENA apprentices for periods of two years. Colombian entrepreneurs in general give the program high marks in terms of preparing workers for industrial employment. In Nigeria, considerable effort has been devoted to providing on-the-job training opportunities for engineering students, using an industrial tax to help finance the program. While the concept seems very sound, there have been difficulties encouraging entrepreneurs to provide meaningful work assignments for the students. Malaysia has also tried to encourage on-the-job training for engineering students.

Most of the multinational companies with significant manufacturing operations in these countries have well developed training programs, often patterned after similar types of programs in the home country. Programs for promising executives and for newly employed engineers sometimes include training abroad. Most skilled workers are provided extensive training upon joining the firms. Once trained, these workers are in high demand. In Nigeria, for example, a trade certificate from Volkswagen is much more highly prized as a stepping stone to higher salaries than is a trade certificate from a technical school or from the Government. One multinational company in Malaysia trains instructors for the Government vocational schools as well as for the company, but in general the companies concentrate their efforts exclusively on their own employees.

Some of the larger locally owned companies in Colombia and Malaysia also have well developed training programs for their employees; frequently they combine in-plant training with opportunities for additional formal schooling. Local firms in Nigeria and the smaller firms in Malaysia and Colombia rely principally on one-on-one instruction on the production line to help develop the needed skills for specific jobs.

The Governments of the three countries pay little attention to the training programs of private sector industrial firms aside from the specific on-the job training programs required for engineering students in Nigeria and for apprentices in Colombia. Given the mobility of the workforces, particularly engineers and, to a lesser extent, skilled workers, the training programs of industry are no less important than the formal education system in preparing manpower needed for accelerated industrial growth. Yet, there is little interaction between the educational planners and the operators of industrial training programs. Of course, there are a few exceptions to this traditional gap. For example, at one of the polytechnical institutes in Malaysia, an aptitude test developed by a multinational company is now routinely used to screen out applicants who clearly do not have the aptitudes for successful vocational careers.

CHOOSING, ADAPTING, AND DEVELOPING TECHNOLOGIES

Technology Choices

During the early 1970s the strengthening of the institutional capabilities of the developing countries to carry out research and development activities was a principal objective of specialists in the field of science, technology, and development. However, based on recent experiences in Malaysia, Nigeria, and Colombia, as well as in other countries, an even higher priority should be given to a related but somewhat different objective, namely, the strengthening of indigenous capabilities to assess, select, replicate, and adapt technologies, particularly technologies developed abroad. Such a change in objectives implies a change in orientation of technical activities from narrowly based searches for breakthroughs to broadly based programs to utilize earlier developments more effectively.

Only rarely will institutions in these and similar countries have the capability to develop "new" products or manufacturing processes which can compete effectively with processes and products developed in the industrialized countries. At the same time, choices of foreign technologies are being made every day, and there are many opportunities for modifying such technologies to the local environment -- to utilize local materials, to withstand tropical conditions, to take advantage of inexpensive labor, and to modify products to meet the tastes of local consumers. Indeed, technology development for most industrial operations in these countries can be described as a continuing process of many minor modifications and occasional major modifications of production technologies imported from abroad.

FIGURE 6

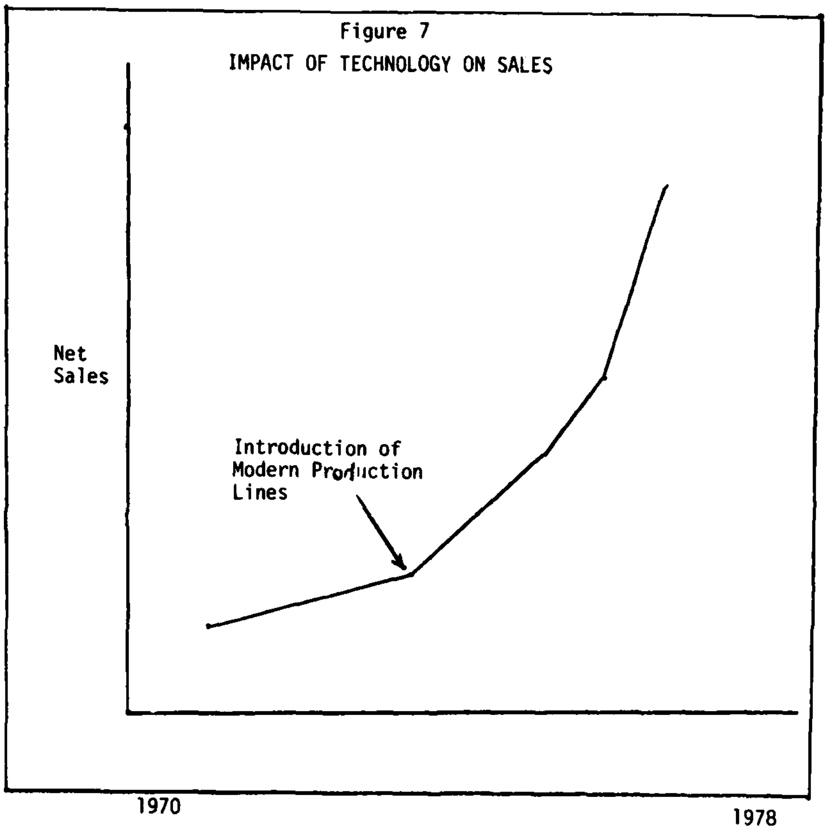
APPROACHES TO REGULATING TECHNOLOGY TRANSFER

	MALAYSIA	NIGERIA	COLOMBIA
Responsible Agencies	Min. of Industry/ MIDA	Min. of Industry/ Bank/Min. of Fin.	Bank/Royalties Committee/INCOMEX/ Planning Dept.
Policy	Continue to encourage under terms more favorable to local companies	Reduce dependency	Expand technology transfer under appropriate terms
Involvement of S&T Community in Government Reviews	Minimum	Minimum	COLCIENCIAS is on committees
Government Capability to Assess Foreign Technology	Limited	Poor	Improving
Capability of local industry to assess technology	Fairly good	Poor	Fairly good
Special concerns	Competition from other Asian countries in attracting MNCs	Excessive costs and maintenance of turnkey facilities	Andean Pact requirements

Significant technological decisions for industry almost always involve entrepreneurs. As suggested in Figure 6, they often also involve Government agencies, particularly if foreign technologies are a consideration. Obviously, credit and market factors and the capabilities and intentions of competitors influence decisions of entrepreneurs. Also playing an often decisive role in such decisions are the engineering staffs of the firms and their knowledge and understanding of the technological options available at home and abroad. Figure 7 presents an example of benefits derived from a wise selection of technology based on recommendations of such an engineering staff. Many bankrupt companies and much idle equipment attest to the problems associated with poor choices of technology.

Figure 7

IMPACT OF TECHNOLOGY ON SALES



Source: 1978 Annual Report, Noel S.A., Medellin, Colombia

Each country relies to some extent on Government research and analysis organizations to advise Government agencies and to assist small industries in their technological choices. To this end, some years ago Colombia organized industrial associations (e.g., plastics, metallurgy), but they have not been very influential in affecting technological decisions. Colombia is now experimenting with public/private research institutions in sugar and forestry and is considering a similar approach in textiles. While such institutions can help disseminate information and can assist Governments in reacting to proposals, the principal assessments must be quite specific and carried out on behalf of the companies that will invest in the technologies. Thus, it is the capabilities of the companies themselves -- either in-house capabilities or capabilities that are acquired on contract on a short term basis -- that are the key to improved selection of technologies.

Innovation Within Industrial Firms

Considerable technological innovation takes place within local industrial firms in each country. (As indicated in Figure 8 , the Governments have taken a number of steps to stimulate such innovations. However, much of the innovation has little relationship to these measures.) For example, a recent survey of 100 Colombian manufacturing firms indicates an average expenditure of 0.5 percent of sales on engineering design, adaptation, and modification activities. Reportedly, these expenditures correlate well with subsequent increases in productivity. The engineering replication activities that characterize the operations of Chinese entrepreneurs in Malaysia frequently involve a series of minor technical adjustments to compensate for peculiarities of the local scene. Even in Nigeria, entrepreneurs agree that substantial innovation is essential to cope with the uncertain power and water supplies and to adjust to the lack of spare parts and repair services.

Figure 8

STIMULATION OF INNOVATION, ADAPTATION, AND INCREASED PRODUCTIVITY

	Malaysia	Nigeria	Colombia
General Policy	Upgrade competitiveness of Malay firms	Reduce international dependence	Reduce protectionism to force higher level of competitiveness
Financial Incentives	Pioneer industries Loan forgiveness for Malay firms	Pioneer industries Tax deductions for R&D Cash prizes for R&D	Low interest technology loans for small industry
Limitations on Technological Dependence	Restrict areas for MNCs	Import Restrictions Required use of local materials Required use of locally made components	Required use of locally made components Tariff protection
Government Services	Certification of product quality Use of Government test facilities Extension programs	Certification of product quality Extension programs	Use of Government & university test facilities Extension programs
Activities of Government Research Institutes	Assistance to small landowners in agro-business	Assistance to food & brick industries	Assistance to food industry

Of particular importance in considering the technological capabilities in each country are the technology adaptation activities of local engineering consulting firms. The civil engineers, in particular, must develop their designs to fit local soil conditions underlying structural foundations, to employ building materials obtained locally, and to minimize maintenance requirements. Examples of such activities are found in each country.

In Colombia, there are about a dozen development laboratories owned by local industrialists. These laboratories serve several purposes, including quality control services and assessments of technologies developed elsewhere, in addition to searching for improved products and processes. Comparable laboratories have not been established in Nigeria or Malaysia.

Activities of Multinational Corporations

The expenditures by a few multinational firms operating in the petroleum, gas, and mineral fields for exploration and development activities in the three countries dwarf other expenditures within the countries for research and development. These activities employ large numbers of local scientists and engineers. Given these strong capabilities, attention should be directed to how such activities can be coupled more closely to local universities and research institutions with interests in related fields. As an example of a small step in this direction, Exxon has contracts with universities in Malaysia and Colombia to assess the environmental and social impacts of some of their development activities.

Figure 3

ILLUSTRATIVE ACTIVITIES OF MNCs IN EDUCATION, ADAPTATION, AND RESEARCH

Malaysia	
Improving yields of rubber plantations	(Guthrie)
Development of reforestation techniques	(Weyerhauser)
Field testing of new pesticide formulations	(Dow)
University research grants on ecological impacts of oil spills	(Exxon)
Local flavors added to toothpaste and cosmetics	(Colgate-Palmolive)
Development of specialized electronic circuitry	(Motorola)
Training of teachers of vocational schools	(Sime Darby)
Nigeria	
Optimizing tire performance in tropical conditions	(Dunlop)
Use of local raw materials in soap	(Lever)
Adapting product line of adhesives to tropical environment	(3 M)
Producing intermediate technologies/treadle machines	(Singer)
Fellowships for undergraduate engineering education abroad	(McDermott)
Advanced engineering training programs abroad	(ITT)
Training of underwater divers	(Mobil)
Apprenticeship training and certification	(VW)
Colombia	
Technical assistance to upgrade supplier capabilities for producing high quality components	(Chrysler)
Adaptations on plastics applications	(Dow)
University research grant on sociological impact of coal development	(Exxon)
Leadership in developing national product standards for electrical equipment	(GE)
Establishment of non-profit systems analysis group	(IBM)

As indicated in Figure 9 , there are a number of examples of adaptive research, education, and related activities carried out by multinational companies in the three countries. Most of the adaptive activities of multinational companies relates to the use of local raw materials, to modifying products to tropical conditions, and to adjusting products to local consumer tastes. An exception is the Motorola laboratory in Penang. Using the highly skilled Chinese engineers, this laboratory develops special purpose electronic circuitry in direct competition with Motorola's main R & D laboratory in Ft. Lauderdale.

Role of Government Research Institutes

There have been unrealistic expectations that Government research institutes could develop processes or products for adoption by manufacturers in the private sector. While there are a few success stories, there are many more examples of unwanted research results in each of the three countries. The multinational companies, in particular, have far greater technical resources available and have the advantage of being in a position to integrate their research efforts with long term financing and marketing strategies. The Government institutes may have opportunities to carry out programs of technological adaptation in response to requests from Government agencies which are in a position to utilize effectively the results of such adaptations -- for example, in public sector enterprises or through Government procurement (e.g., building materials). However, with few exceptions, the most effective adaptation and innovation will be by technology groups which are directly linked to enterprises, public or private.

At the same time, Government research institutes have a broad potential for supporting industrialization in a number of other ways, particularly in the area of agro-business. They can provide the Government with an important capability to keep abreast on a world-wide basis of technical developments in specific product lines that influence critical export opportunities. The worldwide information network of the Rubber Research Institute in Malaysia is an example of such a capability. The technical capability of research institutes can provide important insights concerning the country's natural resources. Surveys and mapping of the nation's resources are particularly important in this respect. They can provide advice on applications for licensing agreements. They can promulgate standards of performance for certain products which provide reassurance for foreign importers as to quality of exports and help insure the quality of products on the domestic market. They can provide low cost testing and analytical services. Finally, they can serve as repositories of information and material samples concerning resources in specific areas of the country.

Most Government research institutes have a special responsibility to provide technical assistance to small farmers or small entrepreneurs. Usually, to this end, they sponsor seminars, demonstrate available technologies, provide information on operational problems, and try to modify available technologies to the capabilities of the potential users.

The weak linkages between Government industrial research institutes and the private sector have been documented in detail by UNIDO. Entrepreneurial and promotional zeal does not seem to be a principal interest of research managers in the three countries. With a guaranteed Governmental budget, aggressive seeking out of industrial needs and interests and promoting of research results among potential users do not command priority.

Directors of Government research institutes in Malaysia and Nigeria continually complain that private industry lures away their best people to higher-paying jobs. It is time to stop complaining and to recognize that these institutes serve an important educational function in preparing scientists and engineers to work in the private sector.

Two responses to the problem of turnover of technical staff seem in order. First, personnel recruitment policies of the institutes should take into account likely turnover rates, and over-hiring should become standard practice in an effort to reduce the problem of staff vacancies. Secondly, research programs should generally be of limited duration with many intermediate outputs required. Thus, the likelihood of reaping the benefits of the work of key researchers who are vulnerable to industrial recruiting would be enhanced.

Another aspect of the educational potential of Government research institutes is the unrealized opportunity in many cases for mutually beneficial interactions between these institutes and the universities. Often such interactions are thwarted by the distances between facilities and scientists working on related problems. Co-location can often be a key to effective collaborative endeavors within a country. It is usually unrealistic to relocate existing facilities to bring their activities closer together. However, in determining the location of future facilities, considerable importance should be given to the intangible benefits of co-location of research and educational activities as well as the tangible savings resulting from the sharing of expensive equipment, libraries, and other resources.

Judged against the criteria set forth above, the Government institutes in the three countries are reasonably effective. They can be strengthened in many ways as they seek to service their main customers in Government agencies and small industry. However, major new products or processes will seldom originate in these institutes.

Research at the Universities

University research has had little direct impact on economic development in the three countries. This is not surprising in view of the newness of most research endeavors, the limited support that has been provided, the competing demands on the time of the researchers, and the traditional isolation of university activities from activities of production organizations. With regard to indirect impact, some of the established programs are enriching educational activities, sharpening awareness of the technical problems and opportunities in the countries, and encouraging highly talented specialists to pursue their careers in their home countries. A strengthening of university research activities, together with improved coupling of these activities with related efforts of other organizations, should clearly benefit the development of each country.

Universities in these countries cannot realistically aspire to having programs of research carried out at a competitive international level in the basic sciences. However, on a selective basis, they should strive for research programs of very high quality in those "derivative" scientific areas closely related to their geographic and resource positions, e.g., oceanography, atmospheric sciences, geology, ecology, forestry. Research carried out at an international level of excellence in such fields will in turn help orient work in the basic sciences in the most productive directions as well, e.g., physics and chemistry of the oceans, biology of natural products.

There are growing numbers of faculty members, and particularly faculty members trained abroad, who are deeply interested in conducting research in order to stay abreast of developments in their fields of specialization. Other faculty members desire to carry out research which will help solve local problems in areas such as solar energy, environmental pollution, and intermediate technology.

Meanwhile, within the three Governments, there is growing interest in using the technical resources of the universities in addressing near-term development problems. However, university research should not be expected to develop new technologies for industrial applications, even though such success stories occasionally emerge. More often, university research can help point the way to improved technological approaches, can clarify technical problems, and can stimulate broad interest in opportunities for more effective use of science and technology.

The research grants that have been provided to universities by the Nigerian and Colombian Governments in recent years have been very important in catalyzing considerable research talent to address interesting problems. However, by any standards, the overall funds are pitifully small. In Colombia the individual grants are often in the range of $3,000 - $4,000, hardly large enough to encourage serious sustained research efforts. A fewer number of larger grants, perhaps in the $20,000 - $30,000 range, seems preferable in terms of likely impact on specific problems.

The gap is wide between the universities and the industrial sectors in the three countries. Even in Colombia, where many industrialists are also part-time instructors, serious institutional interactions are not commonplace. Still, there are a few examples of collaboration on research projects, particularly in Colombia. Specifically, several multinational companies have provided expensive research equipment to the Santander Industrial University. A large local firm has contracted with the University of Antioquia to develop pollution abatement programs. A recent development in Nigeria calls for an Advisory Council on Technology to be established at the University of Ibadan with representation by industrialists.

TECHNICAL SERVICES TO SUPPORT SCIENTIFIC AND INDUSTRIAL ACTIVITIES

The Range of Technical Services

Each of the three Governments supports a variety of activities designed to increase the productivity and efficiency of local industry and, in a more general way, foster scientific and technological endeavors. These activities are carried out through specialized Government units, through research institutes, and through public universities. They include information services, industrial extension programs, analytical and testing services, development and certification of industrial and product standards, and arrangements for patents.

Often overlooked are closely related services provided by the private sector. For example, Chambers of Commerce, trade associations, and professional societies are important mechanisms for information dissemination which sometimes leads to diffusion of technologies within the countries. Private entrepreneurs offer analytical and testing services, almost always at a higher cost, but often with more rapid service than Government facilities. Also, a number of private consulting firms and non-profit organizations are becoming increasingly involved in programs to assist small and medium industry, sometimes financed by the companies and sometimes by external aid agencies.

Undergirding the entire industrial effort must be a service and maintenance capability that can cope with a wide range of imported technologies and a scarcity of spare parts. In Malaysia and Colombia, technicians employed by the Government, by large companies, and by private repair shops are very skilled at keeping equipment running. In Nigeria where modern technology descended on an unprepared economy, the level of activity is very primitive. Consequently, in Nigeria it is more important for universities and research institutes to expand their maintenance staffs than to increase their educational or research activities. It is more important to invest in auxiliary power supplies than in laboratory equipment. Indeed, in the near term, each technical organization in Nigeria will have to fend largely for itself, despite the inefficiencies associated with such an approach.

Information and Extension Services

Every technical institution is seeking better access to useful information. Yet, none of the Governments has developed a satisfactory national approach to information services. Indeed, Malaysia and Nigeria are only beginning to address the issue.

After a decade of experimentation, Colombia has begun sorting out the components of a national approach. A clear distinction is being made among (a) statistical and related information essential for planning at many levels within the public and private sectors, (b) information for educational purposes at both secondary and post-secondary levels, (c) information on selected problems of national importance which require a lead role to be taken by a Government institution (e.g., energy, environment and natural resources), and (d) industrial information. Neither Colombia nor the other two countries has a clear conception as to an appropriate role for Government in the last category.

With regard to major national problems, the Colombian approach couples the lead organizational responsibility for information with the lead responsibility for addressing the substantive problem. A similar approach has evolved in Malaysia where, for example, the Rubber Research Institute, the Forestry Research Institute, and the Mines Research Institute take the lead in providing information services in their areas. In Nigeria, current attention is being given to centralized documentation centers with coupling with the information users uncertain. Information services for the educational sector in Nigeria and Colombia, and to a lesser degree in Malaysia, are hampered by thefts in libraries, usually resulting in policies that books cannot be taken off the premises

Too little attention has been given to the importance of statistical services as an important basis for planning in both the public and private sectors. In Nigeria and Malaysia, there is a striking absence of good data concerning population, employment, and industrial trends. In those cases where such data have been collected, it is often classified or it is reproduced in so few copies that interested parties within and outside Government have no access to the data. Colombia provides a sharp contrast, with many types of statistical data collected and published, not only by the Government, but by private organizations as well.

Individual companies have individual information needs. Their principal interest is in observing operations which they seek to emulate or modify. Usually, written documentation is a poor substitute for direct observation and for demonstrations. Nevertheless, decisions are often made on the basis of documentation, and improved approaches to documentation cannot be totally dismissed. There are, of course, standard texts and manuals that can be helpful for very simple operations, but as operations become more sophisticated, information needs become highly specialized.

Central to effective information systems is the level of development of the printing and publishing industry. In Colombia the industry is well developed, and there are many journals, books, and other publications to disseminate scientific and technical findings within the country. In Nigeria the situation is quite the opposite, with very rudimentary printing services and few books and journals available. In Malaysia publication of technical findings may be delayed for years due to a shortage of English language editors as well as backlogs in the printing sector. Clearly, the design of any information system should be no more advanced than the capabilities of the publishing and printing industry to support the system.

In each country, a variety of organizations are attempting to provide technical assistance to small industry. (See Figure 10.) There is little coordination and, indeed, duplication among some of the efforts. Among the more promising efforts are the programs of (a) the Malaysian Rubber Research Institute to increase productivity of smallholders, (b) the Colombian Popular Finance Corporation to design feasibility studies for small manufacturers, and (c) the University of Ife to advise on accounting and industrial engineering aspects of small industry activity. The results of these efforts have underscored that, while it is often relatively easy to provide loans to small industry, provision of effective technical assistance is far more difficult. The attitude and capability of the entrepreneur are almost always the decisive factors as to the success of such efforts. Unless the purveyors of assistance are perceived as experts with pragmatic business experiences, their advice will probably fall on deaf ears.

Figure 10

EXAMPLES OF PROGRAMS OF ASSISTANCE TO SMALL INDUSTRY

	MALAYSIA	NIGERIA	COLOMBIA
Government Research Institutes	Rubber Research Institute (Rubber) Mines Research Institute (Tin, Mine Safety)	Projects Development Institute (Bricks)	Institute of Industrial Technology (Food)
Universities	________	Ife (various) Nigeria (building materials)	Santander (Mining)
Other	MARA	________	Popular Finance Corporation FISITEC

Universities in each country are attempting to develop programs to provide information and advice to industry. These programs encompass continuing education courses, free advisory services, and testing services for minimal fees. Perhaps the most highly developed program is at the Santander Industrial University in Colombia, where a full-time staff of 35, financed principally by Government and international agencies, is devoted to research and advice directed principally to small local entrepreneurs. However, even with regard to this university, industrial entrepreneurs are skeptical that such activities will be of much help in a direct sense unless they are carried out under contract with the users who insist on the relevance of the activities. In these cases, care must be taken by the universities that they do not become simply job shops for industry, carrying out activities that are totally unrelated to educational endeavors.

Standards and Quality Control

Each country has made impressive progress in the field of standards and product specifications. Each has an institution with growing capabilities in these fields. Many standards are already on the books. While enforcement is spotty, there nevertheless is a good degree of acceptance of the standards and Government procurement provides powerful leverage in this regard. In most cases, standards that have been developed in the United States and the United Kingdom provide the point of departure for developing the local standards. In the construction area, more often than not, the foreign standards are adopted with little modification.

In each country there are examples of multinational corporations working with small suppliers in upgrading the productivity and the quality of the products of their suppliers. These types of relationships are increasing as Governments in countries such as Colombia and Nigeria expand their requirements for components to be manufactured locally. For example, in Colombia Chrysler purchases components from both small and medium industry totalling 35 percent of the value of trucks and automobiles. These components are carefully tested at Chrysler's modern laboratories in Bogota and, indeed, meet the same performance standards demanded in the United States. Some of the component manufacturers buy subcomponents from other suppliers, and a similar type of quality control is imposed. These types of commercial interactions are far more likely to result in an upgrading of technological approaches in the near term than technical advice that may not be linked to the very lifeblood of a small firm's survival.

In Colombia, and to a lesser extent in the other countries, there are examples of locally owned firms playing a similar role to that of the multinationals in setting quality standards for suppliers in different product areas. Also, in several cases in Colombia, large holding companies have been formed with central research and quality control laboratories which influence the technological levels employed in the subsidiary companies.

The Importance of Linkages

The importance of technical services in the industrial sector underscores the impotence of research and development activities carried out in isolation from the overall development thrust of the countries. If science and technology are to impact on economic development, they must be developed in concert with many other activities throughout the economy.

One key to better realization of the potential of science and technology in each country is a strengthening of institutional linkages -- at the level of national planning, in the development of programs, and at the level of the bench scientists. While strengthened linkages cannot solve problems in and of themselves, they can contribute to development in many significant ways.

OPPORTUNITIES FOR BILATERAL COOPERATION

The Changing Pattern of Cooperative Efforts

For the past two decades the U.S. Government and U.S. private foundations have supported a range of cooperative activities in each country. A small portion of these activities have encompassed programs in the physical, engineering, and related sciences. These programs have involved a variety of U.S. organizations, a number of institutions in Colombia, a few institutions in Nigeria, and several institutions in Malaysia. The imprint of this cooperation can be seen at several science and technology institutions in each country -- in well trained technical staffs, an improved appreciation of the capabilities and limitations of technology, and reasonably well organized educational and research programs.

Now, aside from aspects of the Fulbright Program, there are no substantial U.S. Government programs for developing and supporting such cooperative programs. Also, the Ford and Rockefeller Foundations have sharply curtailed their activities. (See Figure 11.) Thus, a conspicuous void has appeared just as many of the science and technology institutions in these countries are reaching a stage where they could begin to carry their share of cooperative programs, both financially and technically. The impact of this void is particularly noticeable in the lack of contact with U.S. institutions involved in applications of science and technology even in the public sector, a decline in awareness of research programs in this country, and a decline in the ability to use English as an entree into the world of science and technology. Visiting American scientists and engineers have become a rare sight at universities and research institutions in these countries, particularly at institutions outside the capital cities, while visiting specialists from other countries have become a more familiar sight.

The principal avenue for interactions with U.S. science and technology institutions are associated with the continuing stream of foreign students entering U.S. educational institutions and with the activities in each country of U.S. multinational corporations. However, neither teacher-pupil nor buyer-seller types of relationships can be fairly characterized as cooperative programs.

Increased interactions with appropriate U.S. specialists could be of technical benefit to institutions in the three countries in almost all areas of science and technology. The benefits to the United States would be best measured in long term economic payoff -- by indirectly improving prospects for trade and foreign investment. In general, for the U.S. participants there would be relatively few technical benefits, and participation by high quality specialists would have to be motivated in substantial measure by desires for broadening experiences. In a few areas, such as the earth sciences and the biological sciences, there clearly are interesting research possibilities in each country.

Designing Cooperative Programs

In considering future cooperative programs, the experiences of the past two decades should be taken into account. Unfortunately, there is no memory

FIGURE 11

SELECTED SCIENCE AND TECHNOLOGY ACTIVITIES OF U.S. AGENCIES

	MALAYSIA	NIGERIA	COLOMBIA
AID			
Bilateral	None	Revive agriculture in FY 1980	Small residual
Global/ Regional	ASEAN projects	Occasional projects	Occasional projects (e.g., ATI)
Other	Minimal IESC program Asia Foundation	Reimbursable Services	Successful IESC Program
Peace Corps	Reducing S&T; now basic needs	None	Phasing out
ICA			
Fulbright	Little S&T	Some S&T	Strong S&T
Other	occasional S&T exchanges; distribution of books and publications	occasional S&T exchanges; distribution of books and publications	occasional S&T exchanges; distribution of books and publications
NSF	None	None	Not very active
NTIS	None	None	Active cooperation ended
NBS	None	Active cooperation ended	Active cooperation ended
NASA	LANDSAT Imagery and Training Programs	LANDSAT Imagery and Training Programs	LANDSAT Imagery and Training Programs
Geological Survey	Publications exchange	Publications exchange	Computer techniques for minerals inventory
COMSAT	Cooperation through INTELSAT	Cooperation through INTELSAT	Cooperation through INTELSAT
OSTP	None	Discussion at political level	Under consideration

bank which has recorded the lessons learned, and most experiences will have to be re-created. As a first step, an appropriate evaluation methodology is needed. Then selected projects should be revisited to assess their impact. Care is needed in reviewing past approaches to project evaluation. These have frequently been oriented to assessing the impact of capital assistance programs and may not be suitable for assessing the development of science and technology institutions. Colombia was a test bed for many AID science and technology projects during the 1970s, and a review of projects clustered in that country might be particularly useful.

However, even in the absence of more rigorous review of experiences with specific projects, enough bilateral activities have been observed to reach a few general conclusions. Specifically, collaborative efforts between relatively well developed institutions can often be quite inexpensive -- involving only a few airplane tickets or limited supplemental salaries for sabbatical visits. (Such costs are in sharp contrast to the cost of an AID technician, now estimated to be about $100,000 per year.) Considerable time and patience may be required to build understanding among collaborators. During this formulative period -- usually measured in years -- interruptions in a developing relationship due to political or other factors can easily negate earlier progress. If institutional capabilities do not exist in both countries as the base for collaborative activities, and institution building is required, the time and cost involved increase significantly, and the importance of uninterrupted interactions becomes a paramount concern.

The most fruitful types of collaboration are those that involve significant technical contributions by all participating institutions and individuals. Publication of joint research reports or joint development of products or processes soon after the initiation of a collaborative relationship can provide a very good stimulus not only to the participants but also to the organization providing financial support for the activities.

With regard to funding, there are a number of examples of interesting collaborative programs that foundered because of insufficient financial support. Serious collaborative efforts should not be attempted in the absence of reasonable assurance that financial support would be available if the program develops along constructive lines. The funding should be provided in sufficiently large increments that the collaborators may spend their time working on substantive problems and not simply searching for additional funding.

Cooperation with Universities and Research Institutes in Developing Countries

Traditionally, the universities and the Government research institutes in the three countries have been the focal points for technical assistance efforts. In a few cases they have participated in genuinely cooperative efforts. However, in general, they still view arrangements with institutions in the United States as "assistance" activities even if they assume some financial responsibility. While sharing of the financial burden is an important component of cooperation, an even more important aspect is the sharing of the technical design and carrying out of the programs. Some universities and research institutes are in a position to assume substantial technical responsibilities in cooperative programs but in many cases a mixture of assistance and cooperation will be appropriate for some time.

What is sorely needed in each country is a steady flow of U.S. specialists in various disciplines for both short term and long term visits. While the emphasis should be on those disciplines of most relevance to development needs, an occasional visitor in the more basic sciences would not be out of order. Clearly, the relatively large AID programs of the past will not be established in the more advanced developing countries. However, as has been demonstrated on a limited scale in the Fulbright Program, by the Ford and Rockefeller Foundations, and to a lesser extent in NSF administered programs, carefully selected individual visitors can have an impact. They can prevent research and educational efforts from entering a blind alley. They can call attention to related work that has already been completed or is in progress. They can catalyze ideas and energies at the institutions. They can implant new concepts and stimulate new approaches.

An important complement to the flow of individual scientists would be a few sustained institutional linkages between U.S. universities and counterpart institutions in the three countries. Such linkages can provide opportunities for coupling exchange visits with on-going local research activities -- through repetitive visits and through counterpart research efforts in the United States. This type of collaboration is very valuable in establishing graduate programs which are in their embryonic stages in each country.

Areas that seem particularly attractive for university-to-university linkages are petroleum engineering, environmental studies, and computer sciences. For example, each of the countries is heavily involved in development of petroleum resources, but none has a well developed educational capability in the engineering aspects. Similarly, universities in each country are entering the field of environmental sciences with emphasis on environmental measurement, an activity that brings the universities and industry closer together in focussing on specific pollution sources. Also, computers are playing an increasingly important role in each country.

As noted above, small research grants often go a long way at developing country universities where funds are in short supply. Such grants can support important research and also open opportunities for more effective collaboration with U.S. institutions. Several external organizations (e.g., OAS, IDRC, IADB, International Science Foundation) provide some research funds to universities in these countries which do not involve foreign collaborators. U.S. programs can be particularly valuable if they involve participation of U.S. specialists whose contributions will likely be more important than the financial contributions.

In the three countries, Government research institutes, with a rapid turnover of key personnel, could benefit considerably from experienced visitors from the United States. For example, in the areas of forestry, geology, and marine sciences, U.S. specialists, including recent Government and university retirees, could provide valuable insights concerning the assessment and development of resources. These areas are also of importance to the United States in an age of increasing resource interdependence.

Drawing on the Capabilities of Multinational Corporations

Many U.S. multinational corporations operating in the three countries have strong capabilities in management, problem solving, engineering adaptation, and training -- areas of direct relevance to development needs. Given the extensive potential of the companies to transfer to local institutions a range of important experiences, increased efforts by both the United States and the host countries to encourage greater attention to opportunities for innovation and for closer linkages with local institutions should command considerable priority. The observations in the three countries largely confirmed the soundness of the 1973 recommendations of the National Academy of Sciences in this regard. (See Figure 12 .)

Figure 12

NAS RECOMMENDATIONS FOR ACTIONS BY MNCs - 1973

1. Assign R, D, and E management personnel to selected LDC affiliates.
2. Train selected management personnel in economic and technological development.
3. Provide support from parent company to affiliates in exploring R, D, and E opportunities and linkages with S & T institutions.
4. Expand training programs to include trainees beyond company requirements.
5. Provide career opportunities for graduates of LDC universities that are comparable to opportunities for graduates of U.S. universities.
6. Combine product-design and product-engineering functions in LDCs.
7. Expand search for labor-intensive equipment.
8. Reduce number and variety of product options to ease maintenance problems.
9. Ease performance standards whenever appropriate.
10. Increase use of locally available materials.
11. Eliminate expensive packaging.
12. Increase subcontracting of production processes.
13. Use LDC technical and service capabilities to extent possible.
14. Use LDC universities as service consultants and as contractors for research.
15. Encourage and support local professional societies.
16. Refer interdisciplinary problems to LDC institutions.
17. Provide management internships for personnel from LDC research institutes.
18. Upgrade capabilities of suppliers to meet high standards of quality control and increase plant efficiency.
19. Experiment with pilot projects at LDC institutions and document and distribute results of experiment.
20. Participate in public service activities, in cooperation with universities and government, in areas such as unemployment, urban congestion, and rural stagnation.

There are, of course, many examples of multinational corporations interacting with local science and technology institutions. They are in contact with universities and specialized training programs as they recruit the graduates of these institutions. They interact with various technical organizations of Government as they seek to comply with construction, industrial, product, environmental, and other standards. They provide guidance and assistance to the quality control groups of the suppliers of their raw materials and equipment.

Usually, such interactions are limited in scope and impact on the economy. Two important exceptions in Colombia are (a) the SENA apprenticeship program which requires indefinite apprenticeship training commitments by all companies, and (b) the establishment by IBM of a systems analysis capability at the SER Research Institute, with a commitment to provide support for five years -- a capability now being used to project national manpower needs. In Malaysia, the larger local and multinational firms are joining together with the encouragement of the Government to form a Science Foundation, patterned after the Osaka Foundation in Japan. This Foundation will initially emphasize increasing public understanding of science. At a later date, the industrial contribution will also be used to support research projects of interest both to industry and the nation.

Closer relations between multinational firms and local universities should be relatively easy to develop. Many overtures have been made in the three countries by universities and by firms, and a heightened interest in such ties seems to have emerged. The firms, of course, are motivated to some degree by the increased competition for the best graduates, while the universities recognize the advanced technological skills of the companies. External agencies might consider funding the university component of joint industry-university research projects of interest not only to the company, but also more broadly to the nation. Company involvement might entail provision of facilities and technical support and critical review of methodologies and results. Such collaboration could also involve side-by-side field work by company and university specialists.

Similarly, closer ties between the companies and Government research institures seem to offer the potential for payoff for both parties. For example, the institutes usually have a good appreciation of the availability of local raw materials while the companies often have strong capabilities to adapt processes to utilize such materials. Again external agencies might provide funds, the companies technical support and know-how, and the institutes the research personnel.

Aside from the suppliers and customers of the multinational corporations, local companies have seldom been able to take advantage of the managerial and analytical skills of the multinational companies. A start in this direction is being made now through seminars, training courses, and other activities of the Chambers of Commerce and trade associations within each country. These efforts to pool experiences of both the multinational and local firms deserve strong support.

Finally, in each country, multinational corporations are interested in major Governmental development programs involving expenditures of hundreds of millions of dollars (e.g., Exxon interest in Colombian coal, GE interest in Nigerian aircraft maintenance facilities). If these major development projects were more closely coupled with efforts to upgrade the capabilities of local educational institutions in areas such as engineering and technician training, the experiences of the U.S. companies might be particularly helpful in strengthening such educational and training endeavors.

With regard to the interests of the countries in having "access" for training purposes to industrial facilities in the United States, U.S. universities can play a useful role. Work-study programs have been common for many years at a number of U.S. institutions, and recently some U.S. engineering schools have assisted their new graduates who are not U.S. residents to receive 18-month internships at U.S. companies. Another approach might pair selected U.S. universities with multinational companies on a one-on-one basis to provide training and technical advice in selected fields (e.g., petroleum engineering, mineral beneficiation, food sciences, agricultural engineering, metallurgy). In addition to academic training, the U.S. university would help insure the quality, breadth, and relevance of the program for specialists from a variety of organizations in developing countries while the corporation provides practical exposure to problems encountered in design engineering, operations, and maintenance.

Actions by U.S. Government Agencies

No U.S. Government agency retains a broad perspective of science and technology developments in any of the three countries. Since most of the documentation concerning developments in the countries is only available locally, keeping abreast of developments from afar is difficult. Perhaps of greater concern is the lack of awareness within the Department of State of (a) some of the programs in the countries funded by U.S. agencies, let alone programs funded indirectly through international organizations, and (b) opportunities for low cost programs with significant potential. Some of the existing programs are funded through intermediaries (e.g., International Executive Service Corps, Asia Foundation, Appropriate Technology International), and the Government's involvement becomes blurred. Nevertheless, an awareness of the extent of U.S. involvement and opportunities for future activities would seem highly desirable.

Consideration should be given to assigning full-time Regional Science Attaches in Southeast Asia, West Africa, and the Andean Pact region. If the Institute for Scientific and Technological Cooperation (ISTC) comes into being, the number of U.S. programs will probably increase, thus adding further confusion to U.S. technical interests in the areas. The Attaches might be patterned after the "Billings" model that was so successful in Taiwan, involving a broadly experienced professional with a small budget for travel grants.

ISTC should maintain a low profile until its budgetary resources have reached a level which will enable it to be a significant factor on the international scene. Many studies, surveys, and pilot projects have been carried out, and the three countries are more interested in meaningful action programs. Also, there is considerable skepticism as to the payoff from a "global research program" in areas other than wheat and rice which is currently a centerpiece of ISTC plans.

The International Communications Agency (ICA) is seldom involved in interagency discussions of science, technology, and development. Yet the agency is responsible for several of the most promising programs for strengthening ties between the science and technology communities of the U.S. and the three countries. These programs include the Fulbright Program, leader grants, and the Hubert Humphrey fellows. Also, ICA represents most Embassies in their contacts with universities, provides counseling for students interested in the United States, and distributes a variety of publications concerning U.S. achievements. Clearly, ICA should be brought into the mainstream of U.S. policymaking and programs in this field.

Critical to the upgrading of science and engineering education at the university level is an upgrading of the quality of technical preparation at the secondary school level. As one helpful step, the Peace Corps, which has been retrenching under the "basic needs" philosophy, could show greater flexibility and expand its programs for the teaching of science and mathematics in secondary schools, particularly in Malaysia. The need is acute, and the United States is well equipped to help fill the void.

The SEED program which had been administered by NSF should be revived. This program enabled individual U.S. scientists and engineers to work on development problems in Colombia and other countries. It has been carefully evaluated on several occasions and found to be a very successful low-cost program. The Department of State should take the lead in sorting out whether AID, NSF, or ISTC should assume responsibility, but this success story should not be allowed to die.

Energy is a central concern in each of the three countries, and the potential of the three countries in non-traditional energy sources should receive greater attention in the United States. While U.S. specialists visit these countries from time to time, the Department of Energy has not devoted serious attention to these countries. Solar energy, firewood, and biomass conversion are obviously of interest in each country. Of even greater interest in Colombia are gasohol and coal conversion. Also, each country has or is developing a very limited capability in nuclear research, an area of traditional U.S. influence.

The National Bureau of Standards and the National Technical Information Service have had intermittent interactions with counterpart organizations in Nigeria and Colombia. Occasional visits by U.S. specialists have been helpful to the organizations in these countries and clearly have contributed to a technical orientation toward the United States. A continuation of such visits would seem to be a low cost, highly beneficial undertaking.

A final concern relates to the need for some type of bilateral mechanism for periodically reviewing science and technology relations between the United States and each of the countries. In the case of Nigeria, a Governmental mechanism is in place following the President's visit to Lagos, but this mechanism has not yet resulted in effective interactions between the science and technology communities of the two countries. In Colombia, not since a workshop organized by the National Academy of Sciences ten years ago has there been a structured and effective dialogue between the two communities. In the case of Malaysia, aside from the Rubber Research Institute, the U.S. science and technology community is largely in the dark as to developments in the country.

Two models should be carefully considered by the U.S. Government for promoting cooperative efforts with these countries. In the case of Taiwan, the National Academy of Sciences has served as an effective mechanism for regular interactions between the science and technology communities of the two countries. A more formal inter-Governmental Commission has been established with India. Its Commission on Science and Technology, which is dominated by Government agencies, and its Commission on Education and Culture, which represents the academic community's interests, seem quite successful in developing and implementing effective exchanges.

What Is the Cost?

Some bilateral cooperative programs might be funded by non-Governmental groups in the United States and by developing country Governments. However, most programs of significance will probably require U.S. Government funding.

Drawing on the experience of ICA, the Asia Foundation, and other organizations currently providing support for cooperative programs, a reasonable bilateral program in the physical, engineering, and related sciences could be mounted in each country at a cost of about $500,000 per country per year in addition to currently funded programs. This estimate does not include overhead costs for the U.S. funding agency. Also, it does not include the costs of possible research grants to institutions in the three countries which might be on the order of $25 - $50,000 per grant.

Most of the funds would be for travel and per diem and for partial salary recovery. A small portion would be needed to cover minor equipment and supplies and some overhead.

MED

8