From: J.J.Salomon, F.Sagasti & C.Sachs (eds.) The Uncertain Quest. Science Technology and Development , UNU Press, Tokyo, New York, Paris, 1994, pp.168-200.

¡Error! Marcador no definido.

THE INSTITUTIONALIZATION OF WESTERN SCIENCE IN DEVELOPING COUNTRIES

Hebe M.C.Vessuri

1. OVERVIEW

In the process of diffusion of scientific activity to less developed countries (LDC), the scientific institutions of the most advanced nations became "models" to be reproduced. The idea that it is necessary to have scientific institutions as one of the basic components of the recipe of modernization, is widely accepted in the developing world. But this notion, embodied in endless projects of institutions created throughout the history of LDC, has been accompanied by very unequal success and, in general, by a difficult consolidation process. It has been argued that the social weight of scientific institutions in LDC is very small, derived from the little prestige and marginality of science in those countries, that scientific institutions tend to have a premature obsolescence, that it is very difficult for them to survive their creators, that they have difficulties to evolve in adjustment to the transformations of society, that their excessive bureaucratization detracts them from their original aims. In synthesis, scientific institutionalization in developing countries is said to have been characterized by fragility, fragmentation and incoherence.

What is the truth in these generalizations? How was the historical process of scientific institutionalization in developing societies? The various models of metropolitan science that were introduced at one time or another in different social settings were differentially successful, or the same model could succeed in one case and fail in another? In which cases did they function? Which ones? Where? How? Did metropolitan models lead to different "styles" of scientific institutionalization? Generalizations about this topic should be avoided because differences in science and technology among LDC are enormous. However, even if we stop talking about them as if they were a homogenous lot, which they are not, and look at them one by one, is it not true that most of them -whatever their efforts to create and expand their scientific establishments -seem condemned to a mere semblance of scientific output? (Salomon & Lebeau, 1988).

As the numbers and variety of scientific institutions in LDC increased, one may attempt to discern the broader patterns of the institutionalization process in different groups of countries. This is the aim of this chapter. However, it must be said that despite growing enthusiasm for the study of science in LDC, our knowledge of institutional and intellectual traditions is still scant and imperfect. The place of science in LDC hardly constitutes a problem for historians or sociologists: within the larger disciplines of history or sociology, the subject attracts only a handful of devotees- most of them practitioners of a still unfashionable social or institutional study of science. Most existing literature merely sketches the terrain, using scientific institutions as markers and identifying significant social forms upon which more interpretative studies may be based. What follows is a topographical reconaissance that highlights some of the themes and concepts that have received attention from scholars.

2. OF INSTITUTIONS AND INSTITUTIONALIZATION

The influence of institutional patterns on scientific and educational activities is one of the recurring themes in the social study of science. Authors like Ben-David focused primarily on formal administrative properties like centralisation and decentralization, although he also examined the relationship of groups to the scientific reward system with a view to explaining the conditions for innovation.[1] He and others have examined the pervasive changes in the institutions through which the sciences are carried on, on the belief that these institutional changes radically alter patterns of scientific organisation, consciousness and participation. A classic work on the diffusion of modern science to the peripheries such as Basalla's (1967), placed special emphasis on the types of institutions characteristic of the various evolutionary phases. [2]

More recently, the focus of attention has moved away from concern with general forms of organisation and administrative procedure, and towards the study of the dimensions of institutional power, its distribution and impact. Consideration of scientific institutions as the formulated and communicated outcomes of thought, such as institutional ideologies, roles, and functions (Adler, 1987), allows to see them as "carriers" for particular collective understandings that have consequences of their own. They can be seen to represent ideals in operation, serving as the channel for the transmission of personal and intellectual will in the world of science and technology. The leaders of an institution provide it not only with the know-how and know-what but also with the know-where-to, that is, the beliefs, expectations, and goals that show the way, a particular way of identifying problems and their solutions. Although domestic and international economic and political constraints and opportunities played an important role in the processes to be described in this paper, analysis looks beyond them to consider the role played by institutions and ideological groups that catalyzed the processes of scientific development in LDC and were necessary, albeit not sufficient, conditions for success and failure.

Only occasionally did native institutional actors manage to develop a base from where to convince policymakers that their "esoteric and obscure" scientific problem was highly relevant to "visible problems" in the minds of decision-makers, such as public health, economic growth, or national security. When they did, these actors used their scientific knowledge and skills within political structures to insulate their research programs from political opposition and attain the status of "national projects" for them, so that political leaders could only back these projects or injure national pride. In the process, these actors helped bring about sufficient scientific development to change performance and achieve national goals. Revealing examples are those of J.C.Bose and the Bose Research Institute and H.J.Bhabha and the Tata Institute of Fundamental Research in India (Anderson, 1977); Oswaldo Cruz and the Manguinhos Institute in Brazil (Stepan 1979); Monge Medrano and high altitude biology in Perú (Cueto 1989); the group of scientists gathered around nuclear energy in Argentina (Sábato, 1973); Arnoldo Gabaldón and the anti-malaria campaigns in Venezuela (Gutierrez 1991).

"Institutionalization of science" in the present analysis is the process by which scientific institutions develop in a rich diversity of cultural settings, the multifarious manifestation of the possible patterns of cultural and economic response to the complex combination of ideas and developments that is often called Western science. In the present paper emphasis is placed on the diverse forms of the social organization of science, the contextual definition of norms, of the establishment of social control, and of the provisions made to ensure the continuity of scientific activity in peripheral settings. This approach differs from that of Ben-David. According to him, institutionalization is only achieved when the cultural patterns of the society become transformed in line with the values and norms of the scientific movement.[3] But this can only hold true given a complete cultural homogeneity in society. Yet as a rule societies are segmented sufficiently to allow for the social reproduction of culturally marginal or deviant activities (cf.Eisenstadt, 1965). And certainly the notion of cultural heterogeneity applies with even more propriety to LDC. The implantation and reproduction of modern science in them need not result in the society's adoption of the cultural value-system and orientations of science, nor does it deny the possibility of it doing so in particular cases. We simply believe it is still too early to delineate the fine structure of such patterns of regularity.

3.OPENING UP THE BLACK BOX OF "COLONIAL SCIENCE"

"Colonial science" is a blanket term. Conventional understanding characterized it as "low science" -limited to data gathering while the theoretical synthesis took place in the metropolis-, "derivative" -working on problems set by savants in Europe-, "dependent" on metropolitan recognition, often "a lodge in the wilderness", done by expatriate Europeans for European consumption. However, there was substantial variation depending on the period considered and among the major powers.

Differences among the major powers. Academic, administrative and, significantly, commercial interests were involved in Dutch colonial science. On the contrary, secular and commercial interests did not create, on their own initiative, observatories or physical laboratories in German and French spheres of interest; in the latter the civil and military authorities had a hand in all such projects from the beginning. Emphasis on original research in pure science emerged at German inspired institutions but not at French-inspired ones. The French, however, unlike the Germans, placed great emphasis on administrative allegiance to metropolitan authorities or, in colonies and mandates, their factotum. And Belgian cultural imperialism was essentially commercialist (Pyenson 1989, pp.183-84).[4]

Be it as it may, on reaching the culminating stage of imperialism in the early 20th century, the major powers had modified their international strategies. Conveying scientific practice from metropolis to periphery grew more intense and was marked by rivalry. It had two main aims: cultural influence and competition with other nations although, formally, it was possible to identify the need to support science as an inherently international activity (Schroeder-Gudehus, 1977). In the period preceding World War II, similar agencies and policy instruments were established in the major countries. Although Britain had organized scientific activity in India since the time the Crown took over the country from the East India Company (1857),the effort had been aimed primarily to meet the strategic needs of the empire -army, trade, and the welfare of European inhabitants. Around the turn of the century, however, coinciding with the final phase of British rule in India and the decline, in global terms, of Britain as a major industrial power leading to intrusions into Britain's monopoly in India by other rising industrial nations, scientific activity in India under the aegis of colonial rule received its final spur (Ramasubban & Singh, 1987, pp.165-66). The intense competition between the European colonial powers in seeking cures for major tropical diseases hindering the further colonisation and exploitation of the tropics led to the establishment of a roster of laboratories for medical research in the most distant places. The "Groupement des Universités et Grandes Ecoles de France pour les Relations avec l'Amérique Latine", created in 1907 (Petitjean, 1989, pp.428-442), reinforced French cultural influence in the region through the local establishment of French Institutes in several capital cities, and the journal **Revue d'Amérique Latine**. Probably the most important Latin American institution in whose creation and early years the French were involved was the University of Sao Paulo, founded in 1934. A considerable number of first rate European scientists and intellectuals gave shape to its Faculdade de Filosofia, Ciencias e Letras.

Also since the end of the 19th century, prominent American private foundations were instrumental in the creation and maintenance of an economic and political order of international scope, increasingly interconnected, with the United States in its centre. Among them Ford, Rockefeller and Carnegie Foundations, invested in the growth of institutions of higher education, think-tanks and research centres all over the world. They were the main architects of international networks of research and agencies involved in the production and diffusion of knowledge, networks connecting talented individuals and their institutional bases among themselves as well as with their benefactors, stretching from colonial China with the Peking Union Medical College (Brown 1982,pp.123-146) and Argentina's Institute of Physiology led by Nobel Prize winner Bernardo A.Houssay (Vessuri 1989) to W.Cannon's lab in Harvard University, which received scores of Latin American physiologists.

Patterns of metropolitan involvement in scientific cooperation not necessarily reflected historical -usually colonial- relationships or were circumscribed by the language the recipient country adopted for "higher culture". By 1909 German officers had reorganised the general staff of the Argentine army; the Argentine navy had become tied into German wireless technology; and German-directed firms dominated the fields of electrical utilities around Buenos Aires. Between 1904 and 1913, the Prussian Kultusministerium (that is, the Prussian Ministry of Spiritual Affairs, Instruction and Public Health) planned and staffed a national normal school, the Instituto Nacional del Profesorado Secundario, in Buenos Aires, with lasting impact on the training of secondary school teachers (Pyenson, 1984). With the active support of the imperial foreign office, German learning was implanted in the new Argentine University of La Plata in open competition with North American interests, and the German tradition in exact sciences came to dominate twentieth century Argentine research until mid-century.

The Netherlands experienced an industrial revolution after 1890, while the Indies opened to Dutch planters and entrepreneurs in the 1870s. Dutch cultural imperialism had three components: an emphasis on excellence in research; loyalty to the government centre, in the colonies and in the metropolis; the enlistment of pure science for the practical end of commercial exploitation and the spiritual end of civilizing the exploiters, although not the exploited. Science certainly constituted part of the education given to Indonesian destined for positions in the bureaucracy, but facility in research had only a small place in the educational curriculum, even at the height of agitation for creating a westernized elite of lower-case Europeans (Pyenson, 1989).

Other small European countries, like Spain or Italy, which at the beginning of the century were experiencing a renaissance in science and the arts, also endeavoured to reinforce their linkages with the colonies or former colonies. Thus the Institución Cultural Española, created in 1914, had as its goal to make known in Hispanic America the scientific and literary studies carried out in Spain, through the establishment of chairs to be filled by Spanish intellectuals and the development of other activities directly related to the intellectual exchange between Spain and the region (Roca Rosell & Sanchez Ron, 1990, pp.217-260). [5]

Institution-building. Although the modern age of colonialism began with the discovery of America on behalf of the Spanish Crown in 1492, it was not until late in the 18th century that the "spread of western science" became effective through the establishment of institutions in the colonial outposts. From the 18th century agricultural and mineral sciences were employed more systematically to exploit the resources of the colonies. With the expansion of plantation industries and mineral resource exploitation, new soil conditions, surveying, pests, weather conditions, transportation and communication required scientific inputs. These activities were best carried out on in situ institutional locations. Thus one may observe a proliferation of institutions since the last quarter of the 18th century in many different latitudes. In Mexico, a Botanical Garden was founded in 1788 by the Royal Botanical Expedition, and a School of Mines in 1792 was part of a larger project, sponsored by Charles III of Spain, which included a mission of German mining experts (Chalmers 1987, p.311). In India, the institutionalization of modern Western science began in 1784 with the Asiatic Society of Bengal (Krishna & Jain 1990). In Batavia a Literary and Philosophical Society emerged in 1778, which evolved in the 1830s into a Society for Indological debate, both archaeological and ethnographical (Pyenson 1989).

Universities arrived in Latin America with the Spanish conquerors, as a conscious expression of the will of the Crown and the Church and not against them as had happened in Bologna, Oxford or Paris, a fact that determined their later development. The variety of functions they assumed as well as their organizational forms, made of them "original copies", rather than imitations or simulacres of European models. During the 19th century universities underwent a deep redefinitional crisis from which emerged the classic Latin American lawyers university, exemplified by the university created by Andrés Bello in Chile (Steger, 1974). During this century were founded the University of Buenos Aires (1821), the Central University of Venezuela (1826) as a result of the transformation of the former pontificial and royal University of Caracas, the University of Chile (1842), the University of Uruguay (1860), the National University of Asuncion (1889), the National University of Mexico closed and reopened several times (1833, 1857, 1861 and 1865) and only consolidated after 1920. However, higher education continued to be relatively simple until

1950. In half the 20 countries total enrolment did not reach five thousand students and in seven of them was less than two thousand. Only Argentina, Brazil and Mexico concentrated 64% of the regional enrolment. The total number of students in Latin American institutions of higher education in 1950 was less than the number of students currently enrolled in just one of the region's universities, the Universidad Nacional Autonoma de Mexico (UNAM) (Brunner, 1990, p.30).

Other institutions that witnessed expressive growth throughout the world during the 19th century were the museums of natural history, botanical gardens, zoological parks and aquariums. Successful metropolitan museums served as inspiration and example, not only for materials, but also for architectural designs, organizational models, and qualified personnel. New nations, such as Canada and Argentina, were as dependent upon European traditions at the end of the 19th century as were de facto colonies in Australia and New Zealand. In Africa, museums of natural history were concentrated in the extreme southern portion of the continent. South African and Rhodesian museums survived only in centers with large white populations, such as Cape Town, Durban, Pietermaritzburg, and Grahamstown. A common feature was the exclusion of blacks every day but Thursday, when admittance depended on wearing boots or shoes. In India, museums are said to have counted for little, were meagerly supported, few and far between. As in Africa, widespread illiteracy, extreme poverty, and patterns of rural settlement made museums irrelevant to the vast majority of the populace (Sheets-Pyenson, 1986). Elsewhere, however, the museum movement was more successful. A handful of active, enthusiastic, men directed museums located in the principal urban centres of Canada, Argentina, Australia, and New Zealand. South American museums tried to function both as research institutions and as instruments of popular enlightenment. Supported by national and provincial governments, important museums could be found in every capital city. Rio de Janeiro, Buenos Aires, Santiago de Chile, and Montevideo built autonomous museums of natural history. While not reaching funding equivalent to that of the top museums in the world, their budgets rank with those of the better European institutions. In South America, where European traditions were especially strong because of the dominating influence of French, Italian, and German curators, departmental keepers often doubled as professors of natural science in the local university.

<u>The science of European expatriates</u>. As has already been mentioned, colonialism in science need not follow the mapmakers' or diplomats' charts and it persisted even though nations could be politically independent. Thus in the colonies and former colonies, the pinnacle of the colonial hierarchy was reserved for Europeans, as Argentine paleontologist Florentino Ameghino learnt bitterly in his confrontation with German zoologist Carl Burmeister in Buenos Aires during the last decades of the 19th century (Romero, 1965; Babini, 1954). Ambition drove many a young European to accept a new opportunity in a colonial outpost. This decision was a socially acceptable alternative to occupying second- or third- rank academic positions in the European motherland. Maintaining the Eurocentric orientation, "colonial science" could be a subject for rational discourse of the small scientific communities on the new nations and peripheral dependencies of the empires which, with the growth of wealth on colonial commercial centers, fostered the cultivation of high culture. Planters, traders, and civil servants often

retired from the colonies to live in baronial splendour. A scientist could also pursue a calling on the world outside while hoping for a call to the motherland. An impressive colonial pension would be consolation enough it one were not elevated to the ranks of the chosen (Pyenson 1989).

The other side of "colonial science" was that its social structure discriminated against natives. Even though by the end of the 19th century a Board of Scientific Advice was constituted in India to co-ordinate the activities of various scientific services, they were contained within the governmental sphere and kept separate from Indian society. The requirements of colonial government made science dependent on the British metropolis and limited the scope of the Board in India (MacLeod, 1987). For a long time Indians were denied access to scientific departments. [6] Metropolitan support for university development in the hinterland was intended to foster expansion of western learning and knowledge of metropolitan languages to facilitate governance and the provision of public services. In the educational division of labour between metropolis and colonies, little importance was usually placed on developing local training and research capacities in applied scientific fields. In cases like that of the backward Portuguese Empire, timid, unstable and bureaucratized attempts were made simply to train cadres for the State administration and the discovery of new wealth in the huge possessions of Brazil. But there was total lack of a social sector with greater interest in the development of education and science locally (Schwartzman, 1979). In Africa, too, the establishment of governmental scientific institutions, usually preceded the founding of universities in many countries by several decades. The development of higher education in late colonial Africa was prompted by concern about the welfare and development of dependent peoples, hence the attempts at training African medical and veterinary officers and agricultural scientists to work with Europeans. The preponderant emphasis, however, was on undergraduate training in arts and sciences and on training for the learned professions, under the notion that Africans should be educated for higher civil service given the imminent prospect of self-rule (Eisemon & Davis 1991).

<u>A wealth of responses to Western learning</u>. The implantation of abstract Western learning had its counterpart in the growth of several nationalistic movements, including the regeneration of traditional modes of understanding. In India, many of the country's leading scientific and technical institutions were established by Indian philanthropy since the late 19th century. In 1876, as a reaction to British colonial science by the Indian political and scientific intelligentsia, the Indian Association of Cultivation of Science (IACS) was inaugurated, thus giving birth to "national colonial science". Among its aims it was explicitly stated that Indians "should endeavour to carry on the work with [their] own efforts, unaided by government. [It ought to be] entirely under [their] management and control. [They wanted] it to be solely native and purely national" (Sircar, M.L. Quoted by Krishna & Jain, 1990, p.6).

By the 1920s, as part of emerging nationalism, the efforts of eminent individual Indian scientists such as J.C.Bose, C.V.Raman and C.P. Ray, led to the creation of basic research institutions in physics, chemistry, mathematics and plant physiology, which were the genesis of Indian science. A common platform for the small teams and scientific societies spread all over India was provided by the launching of the Indian Science Congress Association (ISCA), in 1914. Mathematical and Engineering Societies were established in the 1920s. During the next quarter century about ten professional societies were established, along with scientific periodicals and professional journals. Current Science from Bangalore and Science and Culture from Calcutta as well as two scientific weeklies patterned along Nature's lines were launched in the mid 1930s. By the 1940s there were at least six universities established by Indians and more than one hundred colleges where science and technical teaching was introduced. The demand to indianise the colonial scientific organisations was an important plank of the political agenda to mobilise mass support. Thus, when India achieved her independence in 1947, Nehru could launch an ambitious program in science and technology.

4. INSTITUTIONAL DEVELOPMENT IN THE MOLDS OF "NATIONAL SCIENCE"

Distinguishing colonial and national periods of a scientific tradition has once and again proven to be of doubtful validity. Not only is there usually a considerable overlap between the supposedly colonial institution and the supposedly national institution, but also colonial science is seldom in any significant sense transformed into national science. A look at LDC universities allows to see this in a specially clear way.
They are among LDC institutions which await comprehensive study. There is no precise social definition of the role expected from the LDC University (Vessuri 1988).

The emergence of modern Latin American Higher Education. Despite the fact that the general pattern of industrialization that was adopted in Latin America did not foster the growth of dynamic R&D systems, the strength of the ideal of modernization helped higher education systems and governmental research to acquire momentum in several areas since the 1950s. Throughout, universities were the centerpieces of charters for national science policy -indeed they were the only institutions to which for some time they seemed to apply explicitly. The purpose was to form a "scientific-technical" infrastructure, assuming, often implicitly, that, on reaching a critical mass, there would be an automatic reinforcement of local technology, especially for exploiting the opportunities for development of raw materials and other domestic resources. All of this would increase production and productivity. The stage for a public policy of science and technology, which fructified in the 1960s, was set in the 1950s, and its most vocal advocates were leading figures from the academic scientific community. The rapid industrialization of the largest countries produced a strong demand for science and engineering graduates able to handle operational and service problems of the new assembly industries. However, the scheme was unable to reinforce local technology, which remained incipient and continued to complement minimally imported technology, without much influence on the productive structure (Vessuri, 1990).

The Indian institutional experiment on science for development. The Indian experience in scientific institution building from independence up to the late 1960s was based on a close and easy alliance between elite scientists and the top political leadership, represented by Nehru. In contrast to Gandhi's anti-modern technology stance, Nehru's modern, secular image and most of all his ideology of "scientism", made him a "messiah" for Indian science (Krishna & Jain 1990, p.12). The importance of the personal linkage between Homi Bhabha in Atomic Energy, S.S.Bhatnagar and H.Zaheer in CSIR, P.C.Mahalanobis in the Planning Commission and J.C.Ghosh with Nehru was crucial. The locus of scientific research shifted from the private research institutions characteristic of the previous period, such as the Indian Association of Cultivation of Science (IACS), Bose Research Institute and the Calcutta University of the P.C.Ray, J.C.Bose and C.V.Raman era, to science government agencies (Anderson, R.S.1977). A rare case among LDC, the academic research sector (i.e. universities) in India accounts for a mere 6% of national R&D expenditure while science government agencies and others from the private sector account for 94% of the R&D budget. Only six government science agencies share the largest part of the R&D budget, which during the last decade fluctuated between 40 to 45%. [7] The depleting of excellent and competent researchers from the universities began soon after independence. Teaching rather than research has become the raison d'etre of the universities. We are faced with what Choudhouri (1985, p. 480) calls a "partial scientific community", i.e. one in which one or more of the following criteria are lacking: (a) individuals well versed in the well-established scientific knowledge of the past; (b) members who are keeping themselves abreast with the current scientific developments, and (c) persons who are <u>steadily</u> making a worthwhile research contribution to science. The shift in the locus of science also meant a shift in the power base of scientists and their career structure and status in a socially and culturally stratified society. It also meant that science agencies became subordinated to overarching political structures. Major decisions on science came to be determined by or within the political structures -given the high status of civil servants (Indian Civil or Administrative Services) both with regard to bureaucracy and society. A very narrow elite made up of the heads of government agencies and departments have played multiple role positions keeping control over a large and fragile scientific community (Shiva & Bandyopsadhyay, 1980, pp.575-594). Although in theory representatives of the scientific community, they turned out to be servants of government and part of its hierarchical system. The power base and career path which draws more and more power and status has been located in the mission oriented science agencies sector rather than in the academic, university sector, which is marginal to decision-making processes (cf. Shils, 1969).

<u>The saga of African Universities</u>. It was clear that after independence the new nations would have to rely on the scientific and technical assistance of the advanced industrialized countries, often, though not necessarily, their former overlords. Illustrative of this situation is the debate in Nigeria about the reorientation of higher education after independence. The 1960 report of the Commission on Post-School Certificate and Higher Education in Nigeria -the well-known Ashby Report- was the point of departure for analysis and conceptualization. The discussion on some of its observations and recommendations, such as the relationship between education, manpower, and economic development, is still spirited in Nigeria and many other developing countries (Ahmed, 1989, pp.1-20). Based on the theory of human capital (Harbison & Myers, 1965), it argued that the economic development of every country is ultimately the result of the trained effort of its citizens. Therefore, the building of a reservoir of highly educated persons was the key to Nigeria's development.

These ideas, however, ran against the deeply rooted colonial tradition according to which the schools and colleges that emerged in Nigeria were developed as much as possible into replicas of similar institutions in England, i.e. "emphasizing in standard and curriculum, the thin stream of excellence and narrow specialism. In social function...[they were] restricted to an elite" (Colonial Office, 1945). The initial optimism and enthusiasm of the early days of independence obscured the signs of conflict which emerged from the effort to change the much criticised but highly revered system of higher education. One of the many problems that resulted from attempts to reform the Asquith "elitist" tradition in Nigerian higher education was the readiness of policy-makers merely to alter the aspirations and aims of education in favour of science and technology, but with little or no <u>institutional measures</u> to support such "change". [8] Indeed, the state of applied science and technology in relation to pure scholarship has not changed to any significant extent. Thus far, the traditional "classical" orientation of Nigerian higher education has, in effect, been maintained to the dismay of the initiators of reform. The preexisting curriculum of higher education with its primacy of academic subjects has been preserved.

<u>A common diagnose</u>. For all the diversity of institutions and national and cultural contexts, LDC universities share a number of problems:
(a) <u>High cost</u>. Universities are a costly affair for developing countries. The countries where the research effort is less productive are also those in which the social cost of science is higher. To retain their scientists or to make them come back, LDC must offer them salaries proportionally higher or living conditions more agreeable than to the rest of the active population, and equipments are imported at prices determined by the cost structure of developed countries (Salomon & Lebeau, 1988). Despite high cost, however, the quality of education has been deteriorating with an increase in the rate of student failure. In the natural sciences, agriculture, and engineering, observers have noted that many basic requirements of postgraduate studies are almost entirely lacking in universities in not a few LDC countries. Inadequate laboratories, inadequate libraries, excessive teaching loads will be difficult to improve under conditions of increasing austerity.
(b) <u>The explosion of numbers</u>. Latin American higher education experienced an unprecedented expansion from 1950 to 1980, increasing 20-fold from about 250,000 in 1950 to 5,380,000 in 1980. This growth took place in a very heterogeneous array of learning institutions of unequal quality. The traditional universities -especially the public ones, which were every country's pride- experienced a violent transformation that baffled public opinion. In ten years they became unmanageable mass institutions modifying their intrinsic nature as well as their relationships with the State and society. By 1985 they had reached the stage of <u>mass teaching systems</u>. Also in most African countries, enrolments have increased enormously since independence, but total numbers there are comparatively smaller than in other developing regions. In most African countries the entire university student body is less than 20,000, a situation comparable to the Latin American one in the 1950s. [9] Part of the reason is that universities are unable to absorb more students because, being residential institutions, they have reached the upper limits of their intake capacity. Residential provision for staff and students is not a luxury in the poor countries of Africa. There is often no private housing available for students and teachers who must live away from their homes which are usually in remote villages. Certain African countries are on the verge of huge expansion of their universities as a consequence of accummulated needs.

(c) Scarcity of trained human resources. After the Second World War, when the expansion of science to the world peripheries became more intense, the shortage of scientific and technical personnel was one of the main concerns of LDC governments and international agencies. In many African countries such shortages had serious consequences for the operation of governmental scientific services.[10] Throughout the developing world, universities were the chief institutional mechanism through which governments attempted - not entirely successfully- to form a stratum of educated persons devoted to the state and to the modern societies they wished to create. Sometimes one hears the criticism that a LDC has "over-invested" in or has "over-qualified" its human resources. As a matter of fact in societies such as these, which combine mass cultures in accelerated process of formation with a weak, heterogeneous and dependent base of prosperity and crisis cycles externally conditioned, the relationship between education and work posts becomes loose and tenuous.

(d) Poor quality of instruction at all levels. Allowing for all the individual exceptions, it may be said that LDC secondary and university students are poorly educated despite the high costs of higher and secondary education. The low quality of scientific and technical training and achievement is usually attributed to the cumulative effect of deficiencies beginning at the primary level. Inadequacy of teachers, of laboratory equipment, of textbooks, combines to produce a poor result. However, the estimated average cost per higher education student in sub-Saharan Africa in the mid-1970s was about 100 times the cost per elementary student, which is an extreme case, but the ratio in other developing regions is substantially higher than in the industrialized countries. This obviously raises searching questions about the whole process.

(e) Privatisation of higher education. The developing world shows almost the maximum possible range in the private sector's proportion of total enrollments by nation. China, Cuba, and most of Africa have 0% while the Philippines approaches 90%, South Korea has 75%, and the list of others with majority private enrollments includes Bangladesh, Indonesia, Brazil, Colombia, and the Dominican Republic, with India close. Over 30% private are Chile, El Salvador, and Peru; over 20% are Turkey, Nepal, Malaysia, Guatemala, and Paraguay. Of Latin America's twenty republics, only the small nations of Bolivia, Uruguay, and perhaps Haiti show small private shares, under 10% (Levy, 1991). In many nations, most private growth occurred in recent decades. Latin America's private percentage jumped from 3% in 1935 to 34% by 1975 (Levy, 1986). While Africa has seen much less privatisation, ferment there is obvious. Privatisation's advocates, based on the experience of internally non pluralist institutions, often ignore the problems inherent in pluralist sectors. [11] The highly heterogeneous private sector has not contributed to developing a scientific and technological capability in LDC. The approach of assuming the public sector's presence and then promoting the private sector's additional contribution is legitimate but, since it typically leaves the public sector with the most difficult burdens, it is needed to look at not just how private institutions perform individually but also at the more elusive and yet vital question of their impact on the whole system. By this criterion, the performance of privatization in Asian and Latin American higher education to date leaves considerable room for debate (Levy, 1991).

5. A RAREFIED RESEARCH ENVIRONMENT

Scant attention has been paid by social science to the institutional research environment in developing countries. The picture we have is very general. The Latin American research tradition was built basically in the public universities, although Latin American countries do not have a tradition of research universities. Research was carried out by small groups formed around some relevant scientific figures, whose continuity and multiplication were jeopardized by political instability and a lack of social demand, working in isolated units like museums, observatories or medical schools formally associated to the universities, or as a result of individual scholarship in a University Institute or Department. The introduction of research in the traditional professional Universities was often the result of technical assistance received from the more advanced countries or of professional and scientific training obtained by individuals abroad. A forceful description, which could be easily extended to many a national tradition in the developing world was given with regard to Brazil: "in such a turbulent and hostile environment, where constance, quality, excellence, seriousness, obstinacy and the disinterested search are of little or no value at all, those scientific groups that are implanted, prosper, and bear fruit, can best be considered as islands of competence" (Araújo e Oliveira, 1985).

Current institutional arrangements for scientific research in Latin American countries, mostly linked to Universities, are a recent phenomenon, hardly going back a few decades. An illustration of this is the case of scientific research in Mexico, closely associated to Autonomous National University (UNAM). Despite earlier antecedents, its "formal" history is about 30 years old and is still largely circumscribed to Mexico city. A combination of factors contributed to it. One of them was the building of the University Campus at UNAM in 1950 where, for the first time, specific space was allotted to scientific research institutes. But research budgets continued to be too small. The University provided the buildings but expected scientists to obtain the means for their work. By then some people began to be hired on a full-time basis to carry out research, but no support for experimental work was provided. In 1972 there was a strong salary increase for full-time personnel at UNAM. This was the first acknowledgment by the University of the importance of researchers, who constituted most of the full-time staff (Pena (1990, pp.270-277). Benefiting from wealthier budgets as a consequence of the oil bonanza, the number of research groups and institutes increased rapidly, expansion that was soon curtailed by the general economic crisis that became evident in the early 1980s.

Around the 1950s, research financial mechanisms in some of the major LDC, which so far had operated according to the <u>small science</u> model, began to be transformed. The new demands began to force the emergence of intermediaries in the form of research managers, project administrators and negotiators in the financial agencies, with the resulting change of the centre of power and the increasing formalization of research activities. The mechanisms and criteria adopted were not always compatible with the experience and tradition accumulated until then through isolated and small group efforts, typical of <u>little science</u>. But the simultaneous growth of the number of people linked to research allowed in many areas a remarkable progress in the formalization of knowledge, the establishment of evaluation mechanisms, the strengthening of the communication and information infrastructure, the constitution of committees and panels for reviewing papers submitted for publication, etc. In Brazil, these efforts gave place by mid 1970s to the bureaucratic gigantism of the State apparatus for science. The presence and importance of administrative, managerial and bureaucratic values came to compete, with greater or lesser success, in the different institutions, for power control. Scientific groups, trying to assert and consolidate themselves, struggled to implant values and criteria, almost always assimilated in a foreign culture, into a local bureaucratic culture that was inadequate for scientific development.

In India, too, the management of the scientific system along bureaucratic lines is said to have resulted in research activity being plagued with problems of hierarchy, lack of coordination, and the distribution of personal patronage (Ramasubban & Singh, 1987). Since the bulk of scientific research is carried out in the laboratories and institutes working under the overall direction and supervision of several apex public bodies, political goal direction and political legitimation play an important part in the research environment. Laboratory hierarchy frequently increases at least two or three tiers to the top level of Director-General or Head of the science agency who is also Secretary to the Government. In a society where social stratification based on caste is still deeply rooted, with a corresponding distribution of power, status and prestige, it is not surprising to find that age and seniority pose real problems in science organizations. The distribution and ranking of role patterns continues to be contaminated by ascriptive criteria rather than achievement ones. Time and again the question of recognition and reward structure in science organisations poses a big challenge both to the organisations and the scientific community. Widespread frustration and dissatisfaction among scientists have been reported for reasons such as the pirating of the work of junior scientists by their bosses, the denial of promotions and research facilities to those who deserve them, the subordination of working scientists to scientist-administrators, and the granting of facilities and rewards for inappropriate reasons. The organisation of science along bureaucratic lines has resulted in a stifled and distorted scientific activity in the country.

Outside the "islands of competence", found particularly in those countries like India, Argentina, Brazil or Mexico, which at one time or another seemed on the verge of making the last leap of becoming truly independent centres of scientific creativity, but have not quite made it, in most LDC the scientific capability is precarious, in some it is simply derisory. Even after independence no provision was made in many new African nations for training in research as part of the work of the universities. The purpose for which universities were established was the indigenization of educational, technical, scientific and administrative services. Progress was measured in terms of the supply of trained manpower chiefly to the public sector. What did expand, generally speaking, because it lay within the power of politicians to create them, were not industrial jobs as expected of "high-level manpower planning in practical subjects", but appointments in the public services. An increased number of graduates was what politicians wished to see so that they could fill the civil service. What the graduates studied was of less interest to them than the fact that they had academic degrees. An effective demand was thus created (although not the one served by public rhetoric) and African universities responded accordingly.

A research capability came to be demanded when governments decided that they could not endogenise their teaching and research staff without providing local graduate training. Graduate programmes were hurriedly introduced in LDC beginning in the late

1960s and 1970s. Brazil and Mexico are the Latin American countries that have developed the most this educational level, with over 1,500 programs each. Doctoral programs in Latin America continue to be few and little productive. In Mexico, only about 25% of researchers devoted to basic science held a Ph.D in 1983. In Brazil, 26% of researchers hold doctoral degrees, while 56% have some graduate training. In Colombia until the late 1980s the doctoral level had not been started locally. The weaknesses of scientific training in LDC universities are especially marked at the graduate level, a result of the combined effects of poor instruction, poor laboratory skills, lack of necessary facilities and funding for graduate students' research and absence of a dynamic and competitive research environment . Their high mortality rate and the diversity of aims and objectives as well as the remarkable differences in quality among them, insures that the older mechanism of sending students on scholarships to the advanced countries continues to operate whenever there are enough funds and opportunities available.[12]

The institutionalization of graduate education seems to have started in the older public universities of greater prestige, which had a greater density of higher level academic staff, as, for example, the Universidade de Sao Paulo, Universidad Autónoma de México, Universidad Nacional de La Plata and Universidad Central de Venezuela. From there they spread to the newer universities, such as the Universidade Estadual de Campinas (UNICAMP) which is one of the few Latin American universities placing significant emphasis on the graduate level (over 40% of its students are in graduate courses) and research (Dagnino, 1990). A third form of institutionalization of graduate programs took place in non university research centres, commonly as the only educational level offered by the institution. An example of this type of centre is the Instituto Venezolano de Investigaciones Científicas (IVIC) which with its graduate program going back to the early 1960s, has about forty per cent of the basic science graduate programs in the country.

<u>Regional institutional collaboration.</u> Although there has been much rhetoric about regional integration by LDC governments and some international organisations have recommended concentration of advanced scientific training in regional centres, this has usually been resisted. Regionalism in scientific training and research has at times been moderately successful when institutions are supported by international organisations and by foreign governments in bilateral arrangements with particular governments. Instances of such successes have been the Latin American Centres of Mathematics in Buenos Aires, of Physics (CLAF) in RIo de Janeiro, and of Biology (CLAB) in Santiago, or the international agricultural research institutes established in Africa like that of Tropical Agriculture in Nigeria, the International Livestock Centre for Africa in Ethiopia, and the International Laboratory for Research on Animal Disease in Kenya. However, their connections to national scientific institutions, especially with African universities, have always been fragile and have been weakened in recent years by the declining research efforts of many countries. When a LDC government and its universities are asked to share the costs of regional institutions, or to contribute to the development of institutions outside their country, these efforts have failed.

INTERNATIONAL INFLUENCE IN DEFINING LDC RESEARCH AND TRAINING AGENDA

Institution building as part of international assistance provided scope for projecting the political, educational and cultural influence of the donor country. Major western universities were "twinned" with developing country "sister institutions" in a pattern closely resembling the affiliation of colonial institutions with metropolitan ones, as in the case of the London University network for British colonial dependencies and Université de Bordeaux for the French ones. A large number of developed country universities and other institutions became involved in institution building overseas. Hegemony in science and technology came to be increasingly used to fight for positions of dominance in the international system. America's successful development (and subsequent use) of atomic weapons and the controls enforced for nuclear science have provided a paradigm for broader efforts to use science and technology as a diplomatic lever in the contemporary world (Dickson, 1984; Cabral, 1990). The Atoms for Peace initiative created an international institutional framework within which the US. was able to reap a maximum economic and political advantage from its position of world leadership in nuclear science and technology, by establishing the conditions under which the U.S. could profit from foreign sales of nuclear technology, while essentially retaining control of that technology in economic, political, and military terms and with doubtful results for the LDC that became hooked into such expensive and problematic technology. [13]

Down to the 1970s a high degree of congruence between the policies of DC donors and the needs articulated by LDC recipients characterized international educational and scientific assistance. Those were the days when the most influential (western) studies demonstrated the productivity raising effects of investments in higher education (e.g.Schultz 1963) and showed that the magnitude of effects increased with educational level. Since then, however, international support in LDC began to decline and has continued to do so. Simultaneously, funds for research in critical areas such as tropical medicine, agriculture, engineering and developing area studies programs have also declined in many developed country universities which thereby had linkages with LDC universities. Combined with this, the populist premises of the rhetoric of developmental relevance influenced against the maintenance of donor established institutional centres of excellence. It is surprising, in retrospect, how quickly both donors and many LDC governments discarded their preoccupation with maintaining "excellence" in higher education.

Donors' influence today on policies relating to LDC science and higher education, and in shaping key sectors of research and teaching is very great. They became increasingly involved in determining what training universities should provide, the staffing needs of scientific institutions, and the priorities for research. But the fact is that the agenda of the international scientific establishment is hardly interested in subjects of research that are relevant to the special problems of LDC. Support for training programs and research on themes of concern to the international (DC) community are common, resulting in a proliferation of LDC university centers and programs often established simply to capture external funding. [14] Or, when a cooperation agency agrees to maintain a Science and Technology program for developing countries, predefines the research agenda circumscribing it to very few areas -as, in the case of the European Economic Communities, agriculture and biomedicine. In addition to this orientation of the research agenda, current donor responses to the growingly complex LDC problems involve no longer an integral conception guiding action but a vast number of ephemeral projects, with emphasis on better management of university systems, "networking", institutional sharing and use of new planning and information technologies, totally insufficient solutions to face the problems besieging LDC science and higher education, to a considerable extent a legacy of the Western institutional models and policies transferred in previous decades.

THE UNEQUAL ROLE OF THE STATE

The complexity of many of the issues facing the institutionalization of science in LDCs today stems from the fact that when scientific institutions were first developed in Latin America, Asia, and Africa, newly independent and colonial governments, philanthropic foundations and later bilateral and multilateral donors which supported institution building, established the traditions of state control and created the high cost models of research systems and public higher education they now deplore as wasteful. Often the organisation of research along bureaucratic lines, like in India, resulted in a stifled and distorted scientific activity, leading to widespread frustration and dissatisfaction among scientists and uselessness of the formal research system in terms of development.

In Latin America, the period immediately preceding World War II witnessed several attempts to increase the institutional activity and the instruments of public policy to establish a national scientific capability. As a result of its relatively early industrialization, Latin America became the space of the Third World that experienced the largest semi-industrialization. By contrast with other regions that have known pockets of modernity, two thirds of the Latin American population was forced to face the technological shocks of substitutive industrialization since the Great Depression, and specially since the War (Fajnzylber, 1983). This period influenced considerably the future development of science in the region (Herrera, 1971). The local manufacture of final products received priority, replacing imports without concern for the persisting technological dependence. Most technology transferred to Latin America was incorporated in equipments and procedures. Selection, negotiation, acquisition and assimilation of disembodied technology were largely disregarded; the same happened with national R&D. Tariff policies, mortgage practices and lack of control in payments of technical assistance turned insignificant the cost of importing technologies to the individual entrepreneur. On the contrary, the absence of protection of capital goods production and the lack of stimuli for technology investments increased the risk and the necessary ripening time of technological investments. Objectively, this state of affairs made more expensive the domestic technological development; it also explains the late development of the capital goods sector (Chudnovsky et al. 1983), the late start of graduate education (Klubitschko 1986), the marginal structure of experimental R&D and the low entrepreneurial participation in the financial support of these activities (Katz 1974). All these factors gave form to the current industrial situation of the region and have conditioned the institutional set up for scientific activities.

However, the national responses differed. While the military government that came to power in Argentina in 1976 created a ministry of planning out of which no development nor science and technology plan came out, in Brazil, technocrats found a greater space for maneouvre with the ruling military. Active lobbying by groups of technocrats and intellectuals succeeded in convincing policymakers and then in creating the bureaucratic apparatus and the financial devices to enable the idea of autonomous scientific and technological development to survive. Brazil's economy has been a mixture of market mechanisms, state intervention, and planning; the productive sector has combined private (domestic and foreign) and state enterprises. The state has played an important economic role through guidelines and planning, incentives and controls -establishing the objectives and the means to achieve progress (Gereffi & Evans 1981). In the 1970s it consistently increased public spending; its development banks have reinforced the science and technology infrastructure, focusing on the education system and technological adaptation and innovation; and some of its enterprises are among the largest in Brazil. [15]

As a result of vigorous promotion by UNESCO of "science planning" in the 1960s and 1970s, many African countries also created national science units but most of their objectives have not been achieved (Davis, H. 1983). Several such units have been abolished in recent years. Others have been absorbed into ministries of education. Most surviving science policy units engage in such activities as passing on requests for the clearance of foreign research workers who wish to work in the country. A few national units have acquired important but more modest functions: the Kenyan National Council on Science and Technology administers a fund that supports university research.

In the last decade or so research and policy attention has moved away from the formal research systems of LDCs, focusing increasingly on private initiative and market forces. To an extent, this was a a useful correction to the ideas propagated earlier by scientific elites that there was a simple, causal and linear relationship from fundamental research to applications and, hence, to economic development. This model was appealing because it was simple to interpret and transmit. For many years, nobody contradicted this model of the genesis of technological innovation, a model that was also of political benefit to academic scientists in their claim for public support. In the real world, however, things did not function according to such a simple, elegant picture. In practice, this scheme helped increase the number of higher education and research institutions, as well as the number of researchers. However, it was unable to reinforce local technology, which remained incipient and continued to complement imported technology, without much influence on the productive structure (Vessuri, 1990).

But in most LDCs, instead of providing for a correction of the failings of earlier constructs, support of the available domestic scientific and technological capacity is threatened by the ruling neoliberal orthodoxy. Some answers to the development problem discovered in the 1960s, such as the need to insure the existence and expansion of local research capabilities, although clearly an insufficient condition for success, remain as much a necessary condition as earlier. Such concerns were not necessarily "incorrect" nor have they become invalidated by new findings. The Asian NICs are a clear illustration that only strong governments could ensure the endogenous S&T capability of those countries, which is essential to meet challenges to their competitiveness. Earlier formulations of the problems and their solutions were shown to be too simplistic, and further research has provided additional dimensions, relationships and complexities. But given the widespread and generally inefficient state intervention in most of the Third World, it is necessary to look into the complex web of relationships between the society, the institutions, the State, and the economy, in order to understand the sources of the specific modes of state intervention and the causes for the (always relative) success or failure of such intervention in terms of the development outcome.

The groups of scientists, engineers, and government officials who, at one time or another, managed to put their projects into practice in LDCs also got something else in the process. For a while they managed to change the conditions of the competitive game by their unexpected achievements. The development of local capabilities in science, technology, industry, management and labour skills introduced significant changes in the local social structures, created new sets of actors with technical and managerial skills, and gave them a better understanding of the art of negotiation. But the changes they produce have been usually insufficient to alter the background of social and economic conditions. The special case of the NICs lies in the fact that sharing most of the features adopted by other Third World countries for S&T development, they exploited successfully those very features of developing and strengthening endogenous S&T capabilities, but combined them with the strategic linking of their industries to First World economies, taking advantage of some global economic opportunities which no longer exist and which at the time were not made use of by other LDCs.

Important cases of technological development in Latin America and Sout East Asia illustrate the crucial role that tactical alliances have between the scientific elites and the state. The state has once and again revealed itself the most important factor in LDCs successful use of S&T for industrial development. Despite the ideological discourse of free market economists and politicians, who today try to find in the mythical reconstruction of the process of economic development in the Asian Pacific Rim the lost paradise of "laissez faire" capitalism, recent research contributions show the systemic and comprehensive state intervention in the NICs economy, as well as the state's strategic guidance of the performance of national and multinational companies located on the shores of its territory (Castells, 1991). The "developmental state" so reviled in Latin America these days has been a fundamental factor in creating the conditions for economic growth in South East Asia, as well as insuring the transition of their industrializing economies to each one of the different stages they were reaching in their evolving articulation to the world economy (Gereffi, 1989).

Much has been written about the pros and cons of the attempts to build up a scientific capability in LDC (see, for example Salomon & Lebeau, 1988). The economic crisis that affected most of the developing world in the 1980s has increased the difficulties of the best research institutions. A growing flow of diagnostic studies confirm the deterioration of working conditions and the increasing alienation of researchers as a result of greater financial restrictions and physical and intellectual isolation. In a world in which academic networking is rapidly expanding, LDCs remain as very poorly connected areas. The marginality of Africa and Latin America in science and technology is increasing both in quantitative as in qualitative terms. Given the difficulties in which academic science is immersed in Latin America and the serious menace of an intensified "brain drain", several countries have tried to implement programs to halt this process. Following the lead of Argentine's Carrera del Investigador, which has been administered by CONICET since 1961, the Mexican government (1984) and the Venezuelan one (1990) implemented programs at the level of the elite cadres of their science and technology systems, aimed at preserving the core of the national stock of researchers, propitiating their further improvement and productivity, and fostering the participation and self-evaluation of the research community. Brazil has maintained an equivalent mechanism by which active academic researchers may receive a salary supplement.

But in these as in other most advanced developing countries, the research systems contain a multitude of actors and institutions that have very diverse objectives and institutional locations and which do not fit into the profile of these programs. At a time when the basic institutions for the production and reproduction of knowledge must be refurbished and reoriented strategically to serve effectively their host societies in the 1990s, the importance of having strategic institutions hosting highly trained personnel is crucial. More emphasis ought to be placed on the importance to salvage a small number of competent highly specialized scientific institutions where real science and not a mere semblance of it is produced in the developing world. It is well to take into account than in the largely undifferentiated scientific systems of many LDCs, there is real danger that discretionary funding be disbursed too widely on too few activities to have much impact. The review of the process of institutionalization of science in LDC shows that a lot has gone wrong, that in order that science take root in a society without scientific tradition, money, laboratories and libraries are not enough.

At this time, after several decades of efforts to build up scientific capabilities in the LDC, a substantial mass of very well trained scientists is in existence. But they are in large measure contributing to the further development of the developed world and not to that of their own countries. The reason for this lies not on a natural predisposition of scientists to emigrate but on the structural conditions which combine to make it too streneous for them to work in the LDC institutional milieux. It is necessary to have institutional loci where collective behaviour patterns insure that there is a steady flow of contributions to science and can serve as seed-beds for further institutional developments. Instead of global programs of reconstruction and social development, why not take advantage of the possibilities offered at the local level by the diverse sectors of pluralist, heterogeneous and eclectic societies? Are not the university and the research centre strategic loci of society, a reservoir of innovations, where the transformations of the future are designed?

SUMMARY

The present article analyses how the institutionalization of Western science in the developing world proceeded, both as an instrument of foreign policy of the most advanced countries and as a result of active attempts by non Western peoples to master the knowledge that was the promise to modernity. At different times the major colonial powers and the new independent nations established S&T institutions but it has been difficult for science to take root, particularly since they were expected to produce economic growth. The article underlines some of the factors of the process.

Most marked feature of this evolution has been the attempt at building up endogenous capabilities of S&T, giving particular relevance to the constitution of modern universities and R&D institutes. Somehow as a result of the very experience of developed countries, the models exported to LDCs corresponded to the model of science policy current in their own countries, while the problems involved in LDCs was that of socioeconomic development. Frustration and dissatisfaction with the results achieved have given place in more recent years to the hurried attempt to reject inward-looking S&T capability strengthening strategies and public sector science and technology involvement in favour of outward-looking strategies and massive privatisation. On the contrary, it is argued that the role of the State continues to be paramount in LDCs for the institutionalization of modern science, with the responsibility of guiding even the participation of the private sector in ways conducive to the achievement of national development and social change.

REFERENCES

Adler, E. (1987) The Power of Ideology. The Quest for Technological Autonomy in Argentina and Brazil. Berkeley, University of California Press.

Ahmed, A. (1989) The Asquith Tradition, the Ashby Reform, and the Development of Higher Education in Nigeria, Minerva, vol XXVII, N.1, pp.1-20.

Alvares, C. (1980) Homo Faber. Technology and Culture in India, China and the West from 1500 to the Present Day (The Hague/Boston/London: Martinus Nijhoff).

Anderson, R.S. (1977) The government of Scientific Institutions [Case Studies of of Research Laboratories in India in the late 1960s] Contributions to Indian Sociology (NS), vol. 11, N.1, pp.137-168.

Araújo e Oliveira, J.B. (1985) Ilhas de Competencia. Carreiras Científicas no Brasil (Sao Paulo: CNPq/Brasiliense).

Ashby, E. & Anderson, M. (1966)Universities, British, Indian, African: A Study in the Ecology of Higher Education (London: Weidenfeld & Nicolson).

Azevedo, F.de (1955) As Ciencias no Brasil (Rio de Janeiro: Melhoramentos, 2 vols.).

Azevedo, F. de (1963) A Cultura Brasileira. Introducao ao Estudo da Cultura no Brasil (Sao Paulo: Universidade de Brasília, 4th edition,

Babini, J. (1954) La evolucion del pensamiento cientifico en la Argentina (Buenos Aires: La Fragua).

Barros Medina & Paladini, A.C. (eds.) (1989) Escritos y discursos del Dr. Bernardo A.Houssay (Buenos Aires: Eudeba).

Basalla, G. (1967) The Spread of Western Science, Science, n.s. 156, pp.611-622.

Ben-David, J. (1960) Scientific Productivity and Academic Organisation, American Sociological Review, XXV, pp.828-843.

Ben-David, J. & Zloczower, A. (1962) Universities and Academic Systems in Modern Society, European Journal of Sociology, III, pp.62-84.

Ben-David, J.. (1971) The Scientist's Role in Society: A Comparative Study (Englewood-Cliffs, N.J.: Prentice Hall).

Ben-David, J. (1977) Organisation, Social Control, and Cognitive Change in Science. Ben-David, J. & Clark, T.N. (eds.) Culture and its Creators: Essays in Honour of Edward Shils (Chicago: University of Chicago Press), pp.244-265.

Brockway, L. (1979) Science and Colonial Expansion. The Role of ther British Royal Botanic Gardens. New York, Academic Press.

Brown, R. (1980) Rockefeller Medicine in China: Professionalismn and Imperialism, R.F.Arnove (ed.) Philanthropy and Cultural Imperialism. The Foundations at Home and Abroad (Bloomington: Indiana Univ. Press).

Brunner, J.J. & Barrios, A. (1987) Inquisición, mercado y filantropía. Ciencias sociales y autoritarismo en Argentina, Brasil, Chile y Uruguay. (Santiago: FLACSO).

Brunner, J.J. (1990) Estado actual y desarrollo de los recursos humanos para la investigación en América Latina. Final Report (Santiago: IDRC-FLACSO).

Buck, P. (1980) American Science and Modern China, 1876-1936 (Cambridge: Cambridge University Press).

Cabral, R. (ed.) (1990) The Nuclear Technology Debate in Latin America (Gothenburg: S.T.I.C., University of Gothenburg).

Carvalho, J.M.de (1978) A Escola de Minas de Ouro Preto. O Peso da Glória, Rio de Janeiro, FINEP/Editora Nacional.

Castells, M. (1991) Four Asian Tigers with a Dragon Head: A Comparative Analysis of the State, Economy, and Society in the Asian Pacific Rim, Doc.de Trabajo N. 14 (Madrid: Universidad Autonoma de Madrid, Instituto Universitario de Sociología de Nuevas Tecnologías).

Chambers, D.W. (1987) Period and Process in Colonial and National Science, N.Reingold & Rothenberg, M. (eds.) Scientific Colonialism. A Cross-Cultural Comparison (Washington, D.C.-London: Smithsonian Institution).

Choudhury, A. (1985) Practicing Western Science Outside the West. Personal Observations on the Indian Scene. Social Studies of Science, vol. 15, N.3, pp.475-505.

Chudnovsky, D., Nagao, M. & Jacobsson, S. (1983) Capital Goods Production in the Third World. An Economic Study of Technology Acquisition (London: Frances Pinter).

Colonial Office (1945) Report on Higher Education in the Colonies, Cmd 6647 (London:HMSO).

Cueto, M. (1989)Excelencia científica en la periferia. Actividades científicas e investigación biomédica en el Perú, 1890-1950 (Lima:GRADE-CONCYTEC).

Dagnino, R. (1990) A capacidade brasileira de formacao de recursos humanos para o desenvolvimento tecnológico: um estudo de caso na UNICAMP (Campinas: DPCT-UNICAMP, mimeo).

Dantes, M.A. (1980)Institutos de pesquisa científica no Brasil. Ferri, M.G. & Motoyama, S.(eds) História das Ciencias no Brasil. (Sao Paulo: EDUSP-E.P.U.-CNPq).

De Gortari, E. (1973) La Ciencia en la Historia de México, México, Grijalbo.

Dickson, D.(1984) The New Politics of Science (New York: Pantheon Books).

Djerassi, C. (1968) A High Priority: Research Centres in Developing Nations, Bulletin of Atomic Scientists, vol 24, pp 22.

Eisenstadt, S.N. (1965) Transformation of Social, Political, and Cultural Orders in Modernization, American Sociological Review, 30, 659-673.

Eisenstadt, S.N. (1972) Conditions Conducive to the Development of Cultural and Scientific Institutions, in E.Tal and Y.Ezrahi, Science Policy and Development: the Case of Israel (Jerusalem: National Council for Research and Development), pp.23-37.

Eisemon, T.O.(1982) The Science Profession in the Third World (New York: Praeger).

Eisemon, T.O.& C.H.Davis (1991) Can the Quality of Scientific Training and Research in Africa be Improved by Training? Minerva, vol.XXIX, N.1.

Eisemon, T.O. & M.Kourouma (1991) Foreign Assistance for University Development in Sub-Saharan Africa and Asia. Paper prepared for the Senior Policy Seminar on Improvement and Innovation in Higher Education in Developing Countries organized by the World Bank, Kuala Lumpur, 1-4 July.

Erber, F.S. (1981) Science and Technology Policy in Brazil: a Review of the Literature. Latin American Research Review, vol.16, 1.

Evans, P. (1986) State, Capital and the Transformation of Dependence: the Brazilian Computer Case, World Development, vol.14, 7.

Fajnzylber, F. (1983) La industrialización trunca de América Latina (México: Nueva Imagen).

Federal Ministry of Education (1960) Investment in Education. Report of the Commission on Post-School Certificate and Higher Education in Nigeria (Lagos: Federal Ministry of Education).

Gereffi, G. & Evans, P.(1981) Transnational Corporations, Dependent Development, and State Policy in the Semiperiphery: a Comparison of Brazil and Mexico. Latin American Research Review, vol.16, 3.

Gereffi, G. (1989) Rethinking Development Theory: Insights from East Asia and Latin America, Sociological Forum, vol.4, N.4.

Goonatilake, S. (1982) Colonies: Scientific Expansion (and Contraction), Review, vol. 5, N.3, pp.413-436.

Goonatilake, S. (1982) Crippled Minds: An Exploration into Colonial Culture (New Delhi: Vickers).

Gutierrez, A.T. (1991) La búsqueda de una ilusión: la investigación sobre malaria en Venezuela (Caracas: CENDES, mimeo).

Harbison, F.H. & Myers, C.A. (1965) Manpower and Education: Country Studies in Economic Development (New York: McGraw-Hill).

Herrera, A. (1971) Ciencia y política en América Latina (Mexico: Siglo XXI).

Herrera, A. (1973) Social Determinants of Science in Latin America: Explicit Science Policy and Implicit Science Policy. Cooper, C. (ed) Science, Technology, and Development: the Political Economy of Technical Advance in Underdeveloped Countries (London: Frank Cass).

Inkster, I. (1985) Scientific Enterprise and the Colonial "model": Observations on Australian Experience in a Historical Context, Social Studies of Science, vol. 15, N.4, pp.677-704.

Jimenez, J., Navarro, M.A. & Rees, M.W. (1986) Scientific Research Areas in Mexico:Growth Patterns in the Late Seventies, Scientometrics, vol.9, 5-6, pp.209-223.

Katz, J. (1974) Oligopolio, firmas nacionales y empresas multinacionales: la industria farmacéutica argentina (Buenos Aires: Siglo XXI).

Katz, J. (1986) Desarrollo y Crisis de la Capacidad Tecnológica Latinoamericana: el Caso de la Industria Metalmecánica. Burenos Aires, CEPAL.

Kenny, M. et al. (1979) Inmigrantes y Refugiados Españoles en México. Siglo XX.Mexico, Casa Chata.

Klubitschko, D. (1986) Postgrado en América Latina (Caracas: Centro Regional de Educación Superior para América Latina y el Caribe-CRESALC).

Krishna, V.V. & A. Jain (1990) Country Report: Scientific Research, Science Policy and Social Studies of Science and Technology in India. Report prepared for the First Meeting on the Comparative Research Programme on Scientific Community (Paris: ORSTOM).

Levy, D. (1986 Higher Education and the State in Latin America. Private Challenges to Public Dominance (Chicago: University of Chicago Press).

Levy, D. (1991) Problems of Privatization. Paper prepared for the World Bank's Worldwide Seminar on Innovation and Improvement of HIgher Education in Developing Countries (Kuala-Lumpur, 30 June-July 4).

Lomnitz, L. (1979) Hierarchy and Peripherality: the Organization of a Mexican Research Institute, Minerva, vol.17, 4, pp.527-548.

MacLeod, R. (1987) On Visiting the "Moving Metropolis": Reflections on Architecture of Imperial Science. Reingold, N. & Rothenberg, M. (eds.) Scientific Colonialism. A Cross-Cultural Comparison (Washington, D.C.-London: Smithsonian Institution).

Mariscotti, M. (1985) El secreto atomico de Huemul (Buenos Aires: Sudamericana/Planeta).

Moravsik, M. (1966) Some Practical Suggestions for the Improvement of Science in Developing Countries, Minerva, vol. 4.

Nader, C. & Zahlan, A.B. (eds.) (1969) Science and Technology in Developing Countries. Proceedings of a Conference Held art the American University of Beirut, Lebanon (Cambridge: Cambridge University Press).

Oteiza, E. (ed) (1989). Examen de la política científica y tecnológica nacional.Perspectivas a mediano plazo (Buenos Aires: SECYT-PNUD).

Pena, A. (1990) Estado actual y perspectivas de las ciencias biológicas en México. J.E.Allende (ed.) La biología como instrumento de desarrollo para América Latina (Santiago: RELAB).

Piñeiro, M. & Trigo, E.(eds) (1983) Technical Change and Social Conflict in Agriculture: Latin American Perspectives (Boulder, Co.: Westview Press).

Prebisch, R. (1963) Towards a Dynamic Development Policy for Latin America (New York: United Nations).

Puryear, J. (1983) Higher Education, Development Assistance and Repressive Regimes (New York: Ford Foundation).

Pyenson, L. (1978) The Incomplete Transmission of a European Image: Physics at Greater Buenos Aires and Montreal, 1890-1920, Proc. Amer. Phil. Soc., 122, pp.92-114.

Pyenson, L. (1984) **In partibus Infidelium**: Imperialist Rivalries and Exact Sciences in Early Twentieth-Century Argentina. Quipu, vol. I.

Pyenson, L.(1985) Cultural Imperialism and Exact Sciences: German Expansion Overseas 1900-1930 (New York: Peter Lang).

Raj, K. (1986) Hermeneutics and Cross-Cultural Communication in Science: the Reception of Western Scientific Ideas in 19th century India, Revue de Synthese, 4eme série, N.1 & 2, Janv.-Juin, pp.107-120.

Ramasubban, R. & Singh, B. (1987) The Orientation of the Public Sciences in a Post-Colonial Society: the Experience of India. Blume, S., Bunders, J., Leydesdorf, L. & Whitley, R. (eds.) The Social Direction of the Public Sciences (Dordrecht: D.Reidel).

Ríos, S., Santaló, L.A. Balanzat, M. (1979) Julio Rey Pastor matemático (Madrid: Instituto de España).

Rivera, M. (1983) El desarrollo de una actividad científica en Venezuela: el caso de la catálisis. M.Sc. Thesis (Caracas: CENDES).

Roca Rosell, A. & Sánchez Ron, J.M. (1990) Esteban Terradas. Ciencia y técnica en la España contemporánea (Madrid & Barcelona: Instituto Nacional de Técnica Aeroespacial/Ediciones del Serbal).

Roche, M. (1987) El discreto encanto de la marginalidad: La Fundación Luis Roche. Vessuri, H. (coord.) Las Instituciones en la Historia de la Ciencia en Venezuela, Caracas, Fondo Editorial Acta Científica Venezolana.

Romero, J.L. (1965) El desarrollo de las ideas en la sociedad argentina del siglo XX (Mexico-Buenos Aires: Fondo de Cultura Economica).

Sábato, J. y Botana, N. (1970) La ciencia y la tecnología en el desarrollo futuro de América Latina (Lima: Instituto de Estudios Peruanos).

Sábato, J. (1973) Atomic Energy in Argentina: a Case History. World Development, vol.1, 5.

Sábato, J.(ed) (1975) El pensamiento latinoamericano en la problemática ciencia-tecnología-desarrollo-dependencia (Buenos Aires: Paidós).

Sábato, J. (1976) El cambio tecnológico y posible en América Latina, Comercio Exterior, vol.26, 5.

Safford, F. (1976) The Ideal of the Practical: Colombia's Struggle to Form a Technical Elite. Austin, The University of Texas Press.

Safford, F. (1985) Acerca de la incorporación de las ciencias naturales en la periferia: el caso de Colombia en el siglo XIX. Quipu, vol. 2, N.3, sept.-dic.

Sagasti, F. & Guerrero (1974) El desarrollo científico y tecnológico de América Latina (Buenos Aires: BID/INTAL).

Sagasti, F. & Cook,C. (1985) Tiempos difíciles: ciencia y tecnología en América Latina durante el decenio de 1980 (Lima: GRADE).

Sagasti, F. and collaborators. Conocimiento y desarrollo: ensayos sobre ciencia y tecnología (Lima: GRADE-Mosca Azul, 1988).

Salam, A. (1966) The Isolation of the Scientist in Developing Countries, Minerva, vol.4, N.4, pp.461-465.

Salomon, J.J. & Lebeau, A. (1988) L'écrivain publique et l'ordinateur (Paris: Hachette).

Saldaña, J.J. (1989) La ciencia y el Leviatán mexicano. Actas de la Sociedad Mexicana de Historia de la Ciencia y de la Tecnología. , vol. I, México.

Schwartzman, S. (1979) Formacao da Comunidade Científica no Brasil, Rio de Janeiro, Cia. Editora Nacional/FINEP. Translated into English as Schwartzman, S.(1990)A Space for Science. The Development of the Scientific Community in Brazil (

Schwartzman, S. (1985) The Quest for University Research: Policies and Research Organization in Latin America. In Wittrock, B. & Elzinga, A (eds) The University Research System. The Public Policies of the Home of Scientists (Stockholm:Almqvist & Wiksell International).

Schwartzman, S. & Moura Castro, C. (eds.) Pesquisa Universitaria em Questao (Campinas: UNICAMP/Icone/CNPq).

Sheets-Pyenson, S. (1986) Cathedrals of Science. The Development of Colonial Natural History Museums during the Late Nineteenth Century (Kingston & Montreal:McGill-Queen's University Press).

Sherman, M.A.B. (1990) The University in Modern Africa, Journal of Higher Education, vol.

61, N.4.

Shils, E. (1975) Center and Periphery: Essays in Macrosociology (Chicago: Chicago University Press).

Schultz, T.W. (1963) The Economic Value of Education (New York: Columbia University Press).

SOPHICYT (1986) Estudios de Historia de la Ciencia en el Perú, 2 vols. Lima, CONCYTEC/Sociedad Peruana de Historia de la Ciencia y la Tecnología.

Stepan, N. (1981) Beginnings of Brazilian Science. Oswaldo Cruz, Medical Research and Policy, 1890-1920, Nueva York, Science History Publications.

Texera Arnal, Y. (1991) La exploración botánica en Venezuela (Caracas: Fondo Editorial Acta Científica Venezolana).

Tigre, P.B. (1987) Relacao pesquisa-industria na informática no Brasil. Lisbon Workshop of the Jorge Sábato Seminar (Lisbon: OAS-JNCT).

Uberoi, J. (1978) Science and Culture (Delhi: Oxford University Press).

Varsavsky, O.(1969) Ciencia, política y cientificismo (Buenos Aires: Centro Editor de América Latina).

Varsavsky, O. (1972) Hacia una política científica nacional (Buenos Aires: Ediciones Periferia).

Vessuri, H.(ed) (1984) Ciencia académica en la Venezuela moderna (Caracas: Fondo Editorial Acta Científica Venezolana).

Vessuri, H. (1984) El papel cambiante de la investigación científica académica en un pais periférico. E.Diaz, Y.Texera y
H.Vessuri (coords.) La Ciencia Periférica. Ciencia y Sociedad en Venezuela, Caracas, Monte Avila.

Vessuri, H. (1987) El proceso de Profesionalización de la Ciencia Venezolana: la Facultad de Ciencias de la Universidad Central de Venezuela. Quipu, vol. 4, N.2, May-Aug., pp.253-281.

Vessuri, H. (1987) Las instituciones científicas en la historia de la ciencia en Venezuela (Caracas: Fondo Editorial Acta Científica Venezolana).

Vessuri, H.(1988) Universités et développement scientifique et technologique en Amérique Latine. CRE-action N◦ 84, 4.

Vessuri, H. (1990) El Sísifo Sureño: las Ciencias Sociales en la Argentina. Quipu, vol. 7.

Vessuri, H.M.C. (1990) O Inventamos o Erramos: the Power of Science in Latin America, World Development, vol. 18, 11, pp 1543-1553.

Vessuri, H.M.C.(1991b) La capacidad de I y D en América Latina. Herrera, A., Furtado, A., Vessuri, H., Gallopín, G. y Dagnino, R. Prospectiva Tecnológica en América Latina (Tokyo: UNU-IDRC, forthcoming).

Notes

1. For an account of institutionalization of science in the literature on sociology of science, see Ben-David, J. The Scientist's Role in Society: A Comparative Study (Englewood-Cliffs, N.J.: Prentice Hall, 1971); Ben-David, J., Orgsanisation, Social COntrol, and Cognitive Change in Science, in Ben-David, J. & Clark, T.N. (eds.) Culture and its Creators: Essays in Honour of Edward Shils (Chicago: University of Chicago Press, 1977, pp.244-265); Ben-David, J. Scientific Productivity and Academic Organisation, American Sociological Review, XXV, 1960, pp.828-843; Ben-David, J. & Zloczower, A. Universities and Academic Systems in Modern Society, European Journal of Sociology, III, 1962, pp.62-84.

Recent work on the includes

2. Nota sobre lass instituciones en la ciencia colonial segun Basalla

3. "Neither scientific movement nor institutionalization of science refers to expert scientific activity, but to the behaviour of people in general in relation to science. The scientistic movement consists of a group of people who believe in science (even though they may not understand it) as a valid way to truth and to effective mastery over nature as well as to the solution of the problems to the individual and his society. Empirical and mathematical science, in this view, is a model for the solution of problems in general and a symbol of the infinite perfectability of the world. The word "movement" implies that the group strives to spread its views and to make them acceptable to society as a whole. Institutionalization follows when the movement achieves its aim and has its values actually adopted by society" (Ben-David, 1971, The scientist's Role in Society: A Comparative Study, Englewood-Cliffs, N.J.: Prentice-Hall).

4. poner referencias sobre los varios poderes imperiales y sus actitudes hacia la ciencia

5.The Spanish Civil War led considerable number of scientists and other intellectuals to settle down temporarily or on a permanent basis in different Latin American countries. It was through this program that Spanish mathematician Rey Pastor inaugurated the higher studies in mathematics in Argentina (Sanchez Ron, 1990c; Ríos, Santaló & Balanzat, 1979).

6.An illustration of this is the fact that in the sixty year-lapse between 1836 and 1895 Indians could hardly publish 18 papers in the Bengal Asiatic Society's journal Asiatic Researches (founded in 1799). The Europeans in contrast accounted for 1021 papers.

7. Those agencies are DAE (Department of Atomic Energy), CSIR (Council of Scientific and Industrial Research), DRDO (Defense Research and Development Organisation), DST (Department of Science and Technology), ICAR (Indian Council of Agricultural Research) and DOS.

8.The development of higher education in the colonies was marked by deliberate attempts to reproduce the principles and practices of higher education in the United Kingdom. As crystallized in the curricular recommendations of the Asquith and Elliot reports in the early 1940s, emphasis was placed on basic, or fundamental, rather than applied, or practical, subjects.

9. Of course, Nigeria is an exception to this, with its large student enrolment and system of higher education.

10. In the 1952-63 period, French Africa produced only four university graduates in agriculture and British Africa about 150 (Yudelman 1975, 356).

11. Only in the social research area in some Latin American countries a system exists comprised almost exclusively of private, specialist institutions. Individually, they do very well at their delineated tasks, but largely neglect teaching, disciplinary development, and long-term and large-scale projects (Brunner & Barrios, 1987; Vessuri, 1990).

12. Professional training as a prolongation of undergraduate courses, accreditation linked to the access to and/or promotion in bureaucratized labour markets, conspicuous cultural consumption, are different aims of graduate courses having nothing to do with scientific education for the preparation of researchers but much more common.

13. Among the institutional loci that were developed for the pursuit of atomic and nuclear physics were the national atomic commissions or centres in Argentina, Brazil, India, Pakistan, Israel and United Arab Republics. The resulting research agenda for physics in many LDC was largely a reflection of this state of affairs.

14. In recent years fashionable subjects for which there has been international funding were development, women, and of late, environment, independently of eventual priorities of LDC.

15.It is worth noting that the roughly US$ 700 million appropriated by I PBDCT (First Science and Technology Brazilian Development Plan) was more than twice the financial aid granted by the United Nations to all developing countries for science and technology development (US$ 320 million). II PBDCT alone allocated $ 2.27 billions for 1975-77, an unprecedented expenditure on science and technology in a developing country.