• ABSTRACT

Since World War II, scientific activity has grown significantly in Latin America, and with it there has been a modest development of the social study of science (SSS). This paper investigates the changing significance of the work of science planners and social thinkers with respect to the understanding of the social role of science in Latin America. On the basis of this study it is argued that, despite promising signs, institutional developments in SSS in Latin America are very fragile, and that the chances for their survival and success lie in their capacity to demonstrate their ability to bridge the 'research gap' between academia, public decision-making and industry.

The Social Study of Science in Latin America

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In recent years, scholarly work in the social study of science (SSS) in Latin America has increased at a considerable rate. Books, articles, dissertations and journals are being produced in growing numbers in Spanish and Portuguese.[1] But we are still at a stage where there are many more topics than persons to pursue them in this intellectual terrain. To date, there have been no attempts to review the field. This paper is a modest contribution in this direction.

The social study of science in Latin America has been subject to a historical tension observable elsewhere – both serving public policy-making and drawing substance from relevant academic disciplines (sociology, history, philosophy, anthropology) as they are concerned with science. This tension goes far towards determining possible futures for the field, because during the past decade or so, a professional social study of science and technology has emerged, with an agenda that locates the social functions of science and technology in the special historical conditions of particular national traditions.

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SSS in Latin America has been profoundly affected by the growth of scientific activity in the region. Over the last twenty years, government expenditures in science and technology in the region have grown six-fold, and the number of research workers from Mexico to Chile has risen from approximately 30,000 in the middle of the 1960s to about 100,000 in the early 1980s. This has been accompanied by a remarkable process of expansion of the institutional infrastructure for science and technology. However, seen globally, the regional effort in this field continues to be marginal: in 1980, Latin America had 2.5 percent of world researchers, was responsible for 1.8 percent of world expenditure in research and development, and had 1.3 percent of all the world scientific authors. Comparatively, the region had about 8 percent of the world population, and approximately 5 percent of the global gross product.[2]

These global figures, however, hide a marked intra-regional heterogeneity, as shown in Tables 1 and 2. Three groups of countries can be clearly distinguished: the three larger ones – Argentina, Brazil and Mexico – which, despite their internal differences, have advanced ahead of the rest of Latin America, and already have viable scientific and technological communities; the middle-sized Andean countries – Bolivia, Colombia, Chile, Ecuador, Peru and Venezuela – which, with the only exception of Venezuela during the 1970s, had only a moderate (in cases even vegetative) growth; and the small Central American countries, where political and economic difficulties prevented great progress in this field despite awareness about the problem in the sub-region.[3] Cuba, Uruguay and Paraguay each stand apart because of their specificities.[4]

Looking at this period, some of the topics that loomed large thirty years ago – for example, the establishment of national systems of science, the ethos of scientific research, or the social identity of the research scientist – are now barely mentioned. Today attention is focused upon the cultural backwardness of particular countries, the cultural and technological heterogeneity of the region, the Science and Technology (S&T) lag in Latin America *vis-à-vis* advanced countries, the specific difficulties encountered by industrial firms, the behaviour and attitudes of entrepreneurs, and the role of universities in research and development. Currently the 'management' of science and technology, the effects of new technologies on Latin American societies (particularly in connection with the proposals of 'long wave' theorists), and the social nature of innovation are attracting urgent attention.[5]

Following the end of World War II, scientists in Latin America attempted to create a climate favourable to science and its institutionalization. Among

TABLE 1
Scientists, Engineers and Technicians Devoted to Research and Development Activities in Latin America

Countries	Years	Scientists and engineers in R & D		Technicians in R & D
		Total number	Per 100,000 inhabitants	
Large countries				
Argentina	1982	18,929	64.92	22,598
Brazil	1982	32,508	25.62	n.d.
Mexico	1984	18,247	23.68	n.d.
Andean countries				
Bolivia	1978	612	11.58	n.d.
Colombia	1982	4,769	17.71	2,086
Chile	1982	4,530	39.46	n.d.
Ecuador	1979	766	9.70	n.d.
Peru	1980	4,858	28.09	2,606
Venezuela	1983	4,568	27.86	n.d.
Other countries				
Paraguay	1980–81	1,019	31.67	1,731
Uruguay	1980	1,500	51.58	n.d.
Central America				
Costa Rica	1981	850	36.29	n.d.
El Salvador	1981	564	11.42	1,971
Guatemala	1978	549	8.39	432
Panamá	1980	601	30.73	n.d.
Caribbean				
Cuba	1980	11,400	117.14	9,100
Dominican Rep.	1980	100	1.80	n.d.

Source: Francisco Sagasti and Cecilia Cook, *Tiempos difíciles: ciencia y tecnología en América Latina durante el decenio de 1980* (Lima, December 1985).

the most significant of those were Eduardo Braun Menéndez, Francisco Cernuschi, Enrique Gaviola, Bernardo Houssay in Argentina; Carlos Chagas and José Leite Lopes in Brazil; Marcos Moshinsky, Arturo Rosenblueth and Manuel Sandoval Vallarta in Mexico; and Francisco de Venanzi and Marcel Roche in Venezuela. The importance of science was established in a successful campaign that led to the creation of science faculties in many a Latin American university, and of Science

TABLE 2
Total Research and Development Expenditures in Latin America and Percentage of the Gross National Product (GNP) which they Represent

Countries	National currency	Year	R & D expenditures (in millions)		% of GNP	Per capita expenditure (US$)
			In national currency	In US$		
Large countries						
Argentina	Peso	1980	1,258,700.00	683.70	0.47	24.21
Brazil	Cruzeiro	1984	2,272,000.00	1,231.24	0.58	9.28
Mexico	Peso	1982	24,969.54	442.71	0.27	6.05
Andean countries						
Bolivia	Peso	1978	120.00	6.00	0.07	1.14
Colombia	Peso	1982	2,754.27	42.97	0.15	1.60
Chile	Peso	1982	5,011.80	98.45	0.41	8.57
Ecuador	Sucre	1979	290.66	11.63	0.13	1.47
Peru	Sol	1980	18,387.10	64.23	0.30	3.71
Venezuela	Bolivar	1980	1,084.20	252.58	0.43	16.81

Other South American countries						
Paraguay	Guarani	1980	608.56	4.83	0.12	1.52
Uruguay	Peso	1980	115.02	12.64	0.20	4.35
Central America						
Costa Rica	Colon	1981	81.33	5.19	0.16	2.22
El Salvador	Colon	1980	7.92	3.17	0.10	0.66
Guatemala	Quetzal	1978	13.50	13.50	0.22	2.06
Honduras	Lempira	1980	4.13	2.07	0.10	0.56
Nicaragua	Cordoba	1980	20.61	2.05	0.10	0.74
Panamá	Balboa	1981	6.60	6.60	0.18	3.30
Caribbean						
Cuba	Peso	1983	163.00	196.39	0.72	19.82
Jamaica	J. Dollar	1980	4.02	2.26	0.10	1.04
Dominican Rep.	Peso	1981	23,157.00	3.80	0.35	0.67
Trinidad & Tobago	Dollar	1980	11.20	4.67	0.10	4.37

Source: Sagasti & Cook, op. cit. Table 1.

and Technology Councils (CONICITs) in most of the countries in the region.

From the late 1960s, significant advances were made in the understanding of scientific and technological underdevelopment, spurred by the works of Oscar Varsavsky, Jorge Sábato, and Amilcar Herrera in Argentina, and Máximo Halty Carrere and Francisco Sagasti in regional agencies in North America and Colombia, respectively.

As SSS has developed as a 'discourse', it has begun to draw the social importance of science and technology in society and industry to the centre of attention, nudging science policy as a body of recipes and prescriptions to the fringe of intellectual interest. However, it is useful to consider first some of the early developments in science policy, because this was a concern of the local pioneers of modern science. There was a close relationship between 'scientific modernizers' and science policy studies, as well as between science policy and the international agencies and other channels of bilateral cooperation in the past three decades.

Science, the 'State', and a Policy for Science

Scientists, physicians and to a lesser extent engineers have served as patrons, practitioners and audience for science policy in Latin America, and have been its only reliable constituency.[6] The region witnessed a substantial growth of what has been called a policy 'for' science, manifested in the expansion in the number of scientists and research projects, the regulation of the practice of scientific research and the generalization of evaluation criteria of performance that put a premium on academic excellence.[7] What has been more difficult to achieve was a programme for science 'in' policy, articulated effectively into social and economic development.

A number of approaches – one cannot properly call them schools or traditions – to 'science and/or technology policies' can be distinguished since the late 1960s. Whatever may be said about the position of government *vis-à-vis* science and technology, there has been a widely held view that the 'state' in Latin America represents the interests of nationalist groups geared towards autonomous development, and that 'policy' consists in a programme to convince and motivate those in power to develop locally scientific and technological capacities.[8] The inadequacies of such a view in facing the complex social and economic problems of the region have given rise to concern for a deeper understanding of the specific contexts of underdevelopment, the structures of power,

conflicting interests within the state and the features and behaviour of the different branches of industry.[9]

National governments and regional and international agencies financing scientific and technological activity (such as Unesco and OAS) began in the early 1970s to produce statistical surveys and inventories of scientists, technologists and research and higher education infrastructure to help national governments evaluate their own scientific capacities. This kind of study provided much of the information used in the design of national policies. With the creation of national agencies for the promotion and financing of local scientific activity – the CONICITs – continuous efforts were then made in the formulation of science and technology policy from the perspective of the scientific community, and, less consistently, from the viewpoint of the state (see Table 3). The Organization of American States (OAS) reinforced the national S&T agencies,

TABLE 3
Central Councils of Science and Technology Policy in Latin America

Country	Year	Current name
Mexico	1942*	Comisión Impulsadora y Coordinadora de la Investigación Científica. In 1970 it became CONACYT.
Brazil	1951*	CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico)
Argentina	1958*	Consejo Nacional de Investigaciones Científicas y Tecnológicas, later known as CONICET
Uruguay	1961*	CONICYT
Chile	1967	CONICYT
Venezuela	1968	CONICIT
Colombia	1968	COLCIENCIAS (Fondo Colombiano de Investigaciones Científicas y Proyectos Especiales 'Francisco José de Caldas')
Peru	1968	CONCYTEC
Ecuador		CONACYT
Costa Rica	1972	CONICIT

* At an early stage, these institutions were actually instruments of the local scientific communities in their dealings with government, with the aim of ensuring research funds.

Sources: M. Marí, *Evolución de las concepciones de política y planificación científica y tecnológica. (Topics of Science and Technology Policy)*, Working Paper No. 1 (Washington, DC: OAS, December 1982); 'Los organismos centrales de política científica y tecnológica en América Latina', *Studies About Scientific and Technological Development*, No. 38 (Washington, DC: OAS, 1980).

promoting cooperation in regional and subregional studies and diagnostic analyses, and in the training of specialists in science policy.[10] Over the last twenty years, it has also carried out a series of methodological workshops that have helped develop a common regional approach to science and technology policy.[11] Unesco, in its turn, has produced statistical information and propositions related to higher education and human resources for research and development, while also promoting mechanisms for science and technology budgeting and for the improvement of science and technology documentation and information.[12] Despite the limited value and usefulness of some of the OAS and Unesco statistical data, they do provide some of the few regional and international sources of cross-country comparisons. The role of these two agencies has been paramount in helping to develop mechanisms, at governmental levels, for policy-making in connection with higher education and science and technology.[13]

Probably the most important economic and political forum in the region was the United Nations Economic Commission for Latin America (ECLA), created in 1949. This synthesized a common conceptual framework of autonomous development valid for the whole region, particularly during its first decade, when the Commission faced the opposition of the United States. The ECLA was influenced by social scientists from the southern countries, particularly Argentina (Raúl Prebisch), Brazil (Celso Furtado), and Chile (Jorge Ahumada and Osvaldo Sunkel), and by an ideological and political pluralism, reflecting the influence of ideas current in the post-war years: 'structuralism', Keynesianism and Marxism.[14] It became known by its 'developmentalist' – *desarrollista* – orientation.

An array of circumstances during the 1950s (among which the change of US policy towards Latin America at the end of the Kennedy administration was not the least important), broke the previous unity of thought and approach of the ECLA thinkers and the so-called 'theory of *dependencia*' came into being. The term became widely used during the 1960s by Osvaldo Sunkel, Fernando Henrique Cardoso, Enzo Faletto, Pedro Paz, Celso Furtado, Anibal Pinto and others within ECLA, and rapidly spread to the community of social scientists of the southern cone – Argentina, Chile and Uruguay – whence it radiated to the rest of Latin America.

Both *desarrollismo* and *dependencia* can be recognized as parts of the same school of thought, placing the global nature of development and underdevelopment in the context of the 'centre–periphery' model, sharing theoretical influences, methodological criteria and diagnostic analyses.

Differences between them lie perhaps in the different policies put forward to overcome 'dependency'.[15]

Among the most commonly cited economic features of 'dependency' are several connected with technology. These include the presence of heavy foreign investment and foreign capital-intensive technologies, forcing countries to specialize in exporting raw materials or labour-intensive manufactured goods, with consumption patterns among the élites determined by the 'centre', with unfavourable exchange terms, and demonstrating increasing concentration of wealth and growing unemployment, particularly in the cities.[16]

Throughout the 1970s, the North American 'systems approach' had many enthusiastic supporters among science and technology policy-makers in Latin America, reaching high levels of formalism but without receiving an exhaustive exploration of its possibilities and limitations.[17] The Science and Technology Policy Instruments Project (STPI), financed by the International Development Research Centre (IDRC) of Canada, is an example of this approach. An ambitious exercise, it involved ten Third World countries and more than 150 research workers in examining the formulation and implementation of science and technology policies. Its objective was to analyze the impact of several factors that influence the functions and activities related to the generation, diffusion, transfer and use of knowledge, particularly in the industrial sector. An attempt was made to explore systematically possible cause–effect relationships, and to generate hypotheses that, once verified, could allow a better control over the science and technology functions and activities. This project was an important experience of collective learning for the researchers involved, which also left a number of valuable studies and monographs.[18] But it could not overcome completely the failings of previous work that it had tried to criticize. It remained a largely formal, abstract, reductionist analysis of science and technology development which was difficult to translate into action. 'Social agents' were conceived in too abstract terms and looked unreal. Despite being 'action-oriented', the project's unrealistic picture of public decision-making ignored differences between interest groups, which prevented its effective application to the *politics* of science and technology development.[19]

By the time this project was finished, a certain degree of disillusionment with science and technology planning was apparent in different Latin American countries. In 1978 Eduardo Amadeo reached a pessimistic assessment of the first ten years of the CONICITs.[20] In Venezuela, Marcel Antonorsi and Ignacio Avalos dissected what they called the 'illusory practice of planning science and technology' in their country.[21]

Despite the heterogeneous picture of the region, the general impression is that plans, programmes and documents of policy had little effectiveness, and to a large extent the development of the regional scientific and technological capacity took place without the formal guidance of the central agencies of science and technology policy. Nevertheless, both national governments and international agencies continued to focus their attention on the *methodological* problems of science and technology policies. If anything, more emphasis was given to the relationship between the institutional mechanisms for science and technology planning and programming and the specific content of policies. Possibly results in this field will be visible in coming years, as conceptual advances filter into the sphere of political and governmental action.[22]

Overall, these early attempts at assessing the nature, scope and direction of the relationships between science, technology and science policy in Latin America revealed several common characteristics:

1. The inherent difficulties in studies of this nature.
2. The limitations of the models related to science and technology planning, particularly those arising from an excessive formalism and a lack of attention to the contextual differences of the several countries.
3. The need for improvement at the level of theory, in understanding the politics of science and technology, the role of the state, and the dynamics of productive sectors.
4. The need for an integrated view of S&T policies within the general scope of economic policies.
5. The importance of a real understanding of the implications and consequences of S&T policies for different disciplines, sectors, types of innovations, regions, and so on.
6. The growing recognition, even in bureaucratic quarters, that governmental practice on this subject needs to be supported on a much stronger knowledge base than is the case at present.

From the dissatisfaction voiced in the late 1970s has come greater interest in a down-to-earth strategy to explore what is, ironically, relatively unknown territory – our own national realities, and the perceptions, interests and alliances of social agents involved in science and technology. Such work has recently been more exciting and relevant than normative accounts of what 'ought' to be done under assumptions hardly confirmed in reality.

Science, Society and Politics

The 1960s was an intensely creative period in Latin America, marked by the triumph and early years of the Cuban revolution and the spread of guerrilla movements in several other countries. In Argentina, in particular, science experienced a small renaissance, especially in the Facultad de Ciencias Exactas at the University of Buenos Aires. Undergoing deep institutional reform after the fall of Peronism in 1955, this Faculty became the centre of interest, criticism and applause both within and without the country, culminating in the 'night of the long sticks' ('la noche de los bastones largos'). Then, following the military coup d'etat of 1966, one of the first actions of the government was to decree the *intervención* of the university, and the physically brutal eviction of teachers and students of the Faculty.[23]

It was in this context that people like Oscar Varsavsky, Amilcar Herrera, Jorge Sábato and Rolando García developed their views. The work of mathematical physicist O. Varsavsky, a powerful and original mind who made a range of contributions to the mathematical and the social sciences, was very influential in the 1960s and early 1970s. Varsavsky developed a searching critique of that routine

> researcher who has adapted himself to the scientific market, who chooses to ignore the social meaning of his activity, removing it from the political problems, and who devotes himself fully to his 'career', accepting the norms and values of the large international centres, as crystallized in the academic hierarchy.[24]

His views became influential in the intellectual current that came to be known as *ciencia nueva, ciencia politizada* or *anticientificismo*.[25]

Varsavsky was a scientist who believed that society needs radical transformation. Must such a scientists devote himself to political activity? Ought he to abandon science and become a professional politician? Or should he relinquish his training, to contribute to the scientific analysis and preparation of desired changes? Varsavsky's answer was to produce a criticism of the current influence of the social system upon science. In the post-peronista years, the older peronista and pre-peronista populist/nationalistic teachers of science were replaced by apolitical *cientificistas* scientists, concerned only with their own individual careers and indifferent to the social problems of their country. Varsavsky's critique pointed to these people, and not to the former whom he summarily dismissed as 'fossils'. Moreover, he outlined a new kind of scientific activity, clearly linked to social change. The decisive task, in his view, was the

definition of the relevant topics, the allocation of priorities and the organization of scientific work.

Another influential thinker in this period was Amilcar Herrera, a colleague of Varsavsky at the Faculty of Exact Sciences in Buenos Aires. A practising geologist, he published a book in 1971 – *Ciencia y política en América Latina* – on the socio-historical context of scientific activity and science policy in the region.[26] This constituted one of the earliest Latin American criticisms of the use of conventional socio-economic indicators for development. Now in its ninth Spanish reprinting – quite unusual for non-fiction in Latin America – it is a 'must' in any reading list on Latin American science. Adopting a 'structural' approach, Herrera threw light on the relationship between science institutions and their surrounding social and economic context. He distinguished, in the phrase fashionable at the time, between 'explicit' and 'implicit' science policy. 'Explicit' policy was, to him, the 'front' – a formal, prestigious façade for 'progressive' or modernizing governments, presented as panacea for curing urgent material problems of underdevelopment without recourse to the change of social system. By contrast, the 'real' science policy, which remains 'implicit', is in the service of the ruling classes. Its purpose is to create a science and technology system which is not fully autonomous (for this could lead to fundamental questioning of the social system), but which presents the façade of liberal modernity in the solution of minor problems. In his view, the gap dividing the developed from the underdeveloped worlds is not merely quantitative but also qualitative. The causes of Latin American backwardness are explored through examples expressed in simple descriptive language. Modern science is seen as potentially contributing to the solution of the problems of underdevelopment; and the book ends with an optimistic plea for the creation of an effective scientific and technological capacity in the region, in order to overcome the fundamental problems of malnutrition, misery and ignorance.[27]

Following Herrera, came a collective volume, edited by metallurgist Jorge Sábato (1975), another brilliant member of the cohort of Argentine scientists active in those years.[28] Sábato and his colleagues tried to show how the ideas and policies of the previous decade bore on science, technology, development and contributed to a persisting *dependencia*. The importance of the book lay in its independent thinking, and in its insistence upon views unfashionable in the advanced countries. It looked at Latin American conditions with Latin American eyes, in terms of local traditions, obstacles and desires.

This period of intellectual excitement ended for Argentina with the

military *coup* of 1976, which sent into exile a second and much larger wave of people, this time affecting all layers of society and not only the scientists, as had been the case in 1966.[29] Despite the return to a democratic regime in 1983, and the ensuing renascence of some cultural manifestations such as cinema and drama, science and the universities – seriously damaged during the dictatorship – are much slower in recovering. Argentina suffered a serious 'brain-drain'. With the return to democracy quite a few scientists and engineers, who in previous years had left the country for political reasons, tried to go back to participate in the national economic and social recovery and development. But they found it difficult to get positions in society that would take advantage of their expertise. This technological regime, adopted since 1977, entailed important economic costs to the nation, and ignored the experience accumulated in this field in the country. It allowed a spectacular increase in technology payments abroad – particularly intra-firm payments – which can in no way be attributed to a genuine importation of technological know-how, but to profit made from fiscal and exchange advantages in a context of deindustrialization and growing technological lag.[30]

In the meantime, other countries assumed a more positive attitude towards science and technology during the 1970s. This was the case in Brazil, which registered a spectacular expansion in its scientific and technological activity. The growth of Brazilian expenditure in S&T activities has been impressive (from 0.84 percent of the federal budget in 1970, the S&T budget rose to 3.64 percent in 1982).[31] This reflects a political intention to incorporate science and technology into government's development plans. It is true that the total R&D expenditure began to decrease since 1979, and a restructuring of spending also became noticeable, to the detriment of basic research and the training of human resources. Applied programmes in priority sectors such as energy, agriculture and aerospatial research were favoured. But the national scientific community has become an important pressure group to defend their own interests, and the recent creation of a Ministry for Science and Technology in 1985 has as one of its aims to recover the levels of budget assignment for science and technology reached at the end of the 1970s.

To some extent a positive political attitude towards science and technology development is also observable in Mexico. Between 1971 and 1979, while the average inter-annual growth rate was 5.9 percent, the national S&T expenditure was 9.86 percent.[32] In more recent years, efforts in the area of human resources led to the establishment of a 'system' of science and technology by which active researchers are

stimulated to remain in the country through a special fellowship programme which involves a monetary allowance equivalent to several times the legal minimum monthly salary. During the 1970s, Venezuela increased substantially the financial resources for science and technology, and started an ambitious programme for the training of high-level human resources. But by comparison with the countries just mentioned, it had only an incipient scientific community and did not possess a developed and sophisticated productive system that could generate a sustained demand for scientific and technological knowledge.[33] Cuba is an altogether different case from the rest of Latin American countries, for it has followed a separate way to development, more directly dependent on the socialist countries' orbit of influence. Some of the results in the science and technology field are spectacular and, in general, efforts in this country seem to be among the highest in Latin America.[34]

The Changing Nature of SSS

Traditionally, the thin ranks of recruits to our field in Latin America have been comparatively long on scientific, and short on sociological and historical training, although this is rapidly changing. The beginning of this change is due to the inspiration and effort of, among others, Marcel Roche, who, having made a medical career, came into the social study of science late in life, contributing to it assiduously and even devoting time to a formal postgraduate programme at Sussex; and Amilcar Herrera, who was a practising geologist until he developed a second career in science policy, to which he is now almost totally devoted.

But apart from men such as these, Latin America has more commonly seen practising scientists – *los científicos* – who have written celebratory articles, obituaries and review articles that take a skewed view of their subject, offering more often than not biased accounts disguised as objective efforts to 'put the record straight'. These 'meta-analyses' offer interesting interpretations, but more often pose problems for the specialist in the social study of science.[35] Trained *científicos* typically have more expertise on technical issues than do historians or sociologists of science. But they often lack a sense of the larger picture. Thus they may produce research on a range of topics they believe to be 'socially pertinent', but which are in fact of a boring triviality.

However, a change has taken place in the last decade or so in the emergence of a small cadre of sociologists and historians of science who are professionally devoted, rather than occasionally recruited, to the

social study of science. The change is at once intellectual, ideological and professional. The new practitioners identify with one another and with the problems, techniques and assumptions of sociologists, historians and political scientists. The *científico*'s expertise no longer serves as a deterrent to the socio-historical analysis of the physical, biological and medical sciences.[36] Signs of a similar change are apparent, although much less developed, in the economics and history of technology, where pioneer professionals in industrial countries are still producing the first generation of trained scholars.[37] There is also a modest tradition of socio-historical analysis of the social sciences, as reflected in the work of Edmundo Fuenzalida, José Joaquin Brunner, Enrique Bernales, Mariza Peirano and Rogelio Pérez Perdomo.[38]

The change, however, is not restricted to SSS. Another novelty, and likely to be of increasing importance in the years ahead, is a greater awareness on the part of *científicos* of their role *qua* scientists in the development of Latin American societies. Related to this, has come a more 'politicized' perception of the nature and commitment of science to peripheral, underdeveloped nations. In other words, there has been an end to naive optimism and faith in development, and in the scientist and engineer as its prophets.

Of course, the commitment of science to production, social service and society at large is more urgent today than ever before. But the frequent unease displayed towards the social role of science has a different meaning. In the 'First World' countries, nuclear power, genetic manipulation and the role of 'experts' are the objects of deep moral concern. In Latin America, this anxiety is subordinated to concern about the capacity of science to satisfy the tremendous challenges of poverty, malnutrition, disease and the increasingly unequal terms of international development.[39] Understood to be inextricably linked to economics, politics and philosophy, science, as seen by Latin American *científicos*, appears as a spectrum of activity with no sharp edges. But it is difficult to put these insights into practice in institutions that still reflect the conventional and familiar textbook view of science as an autonomous body of knowledge. The subject of premature institutional stagnation and obsolescence and the need of reforms arouses many a heated debate in the region's scientific community today.[40]

Problems and perceptions such as these create a social context favourable to the discussion of science and technology as part of culture and society. Although SSS in Latin America is underdeveloped, in fact there is a relative wealth of analysis, an abundance of questioning and the beginnings of empirical and interpretive answers which bode well

for the future. No consensus appears to be likely to dominate the field for some time and a synthesis seems remote. The situation, however, is in fact changing so rapidly that it is already possible to discern research trends, as well as convenient to comment upon what can be done, and what ought to be done. To this end, the subject can be subdivided into several units that appear to have evoked most interest. These are the formal institutions of science as strategic sites for research; scientific communities; the social history of the implantation and consolidation of scientific disciplines in Latin American societies; science policy; and technological innovation and industry. Each in more than one respect overlaps at least some of the others, and it is their combination that helps to provide a comprehensible overview, emphasizing the social context of science and focusing on particular periods of national cultures, or on special social dimensions of S&T activity.

Current Concerns in SSS

Institutions

Independently of whether they are enthusiastic or sceptical about the aims and power of institutions, SSS specialists cannot avoid considering institutional developments when they study modern science. Thus the topic has a respectable tradition in the history of science in industrialized countries. This category is very broad: it includes institutes, societies, academies, associations and organizations of various kinds, as well as libraries, museums, laboratories, observatories and scientific publications. When attention moves to less-developed countries, one finds that the consolidation of scientific activity is inseparable from its process of institutionalization, which immediately brings us to the problem of institutional models and organizational patterns of science. The analyses of S&T institutions in Latin America provide, as it were, 'topographical landmarks' of the socio-intellectual terrain, allowing the identification of significant social forms in the evolution of scientific activity upon which future comparative studies will be possible.

Given the fact that many of the pioneers of science in Latin America established and maintained institutions from which their lives and work could hardly be distinguished, the demarcatory line between biography and institutional history cannot always be neatly traced. Such is the case of Oswaldo Cruz and his institute, as shown by Nancy Stepan's *Beginnings of Brazilian Science*.[41] The volume is a historical account

of a successful institutional project, the Oswaldo Cruz Institute, and of the discipline developed in it – biomedical science. It shows how the scientific activity of a developing country achieved a remarkable level of effectiveness at an early stage of economic growth and industrialization. The solutions given by the Institute to the problems of ensuring the necessary support for science in a society having little scientific tradition provide Stepan with a particular vision of the role of institutions, which she develops throughout her work and leads her to end with a discussion of the science policy literature concerning the function of science and technology in development. Particularly interesting are her arguments summarizing the debates about the meaning of 'national' science, the need for national capacities in basic research, applied research and technology, and the institutional locus of research science.

That biographies, as well as institutional studies, offer a convenient focus for socio-historical research is well demonstrated by Marcel Roche's biography of the Venezuelan bacteriologist Rafael Rangel, who died tragically in 1909. Roche does a good job of analyzing Rangel's written scientific work as well as his activity in the organization of research and public health in Caracas. Among its many interesting contributions, the book presents a description of Rangel's laboratory equipment and budget at the Hospital Vargas in 1902, and of the local conditions of medical training and practice at the turn of the century.[42]

In 1978 José Murilo de Carvalho studied the Escola de Minas de Oura Preto in Brazil, concentrating on its earliest (1876–93) and most recent (1939–76) phases.[43] He was concerned with the problem posed by George Basalla of colonial science as carried out exclusively by foreign researchers dependent on foreign institutions, and of the growth of a national scientific activity performed in national institutions by local scientists. His analysis reveals the peculiarities of the institutionalization of mining education in Brazil. The author makes clear that there was not an effective demand for geologists and mining engineers in the slave-based Brazilian economy of 1876, geared only to the export of agricultural raw materials. However, the Escola is shown to be part of an awakening in Brazil to the importance of scientific research, as is demonstrated by the creation during the same period of other institutions such as the Escola Politécnica in Rio and the reforms of the Museu Nacional and the Observatorio Nacional, as well as the attempts at reform in the medical schools.

The creation of the Oura Preto School was an act of political will by Emperor Pedro II, guided more by ideological motives than by economic ones. On a trip to Europe in 1871–72, he met Auguste Daubrée, director of the École des Mines in Paris, and commissioned him to prepare

a document to explore the mineral wealth of Brazil. The latter recommended Claude Gorceix to organize a school for the training of geologists, which he did in the shape of the Escola de Oura Preto.[44] In 1919 John Casper Branner reported that the foundation of this School had been 'a step of the greatest importance for engineering and geology', and that 'some of Brazil's ablest engineers and with but few exceptions, all of her geologists and mining engineers have been educated in that School'.[45]

But not only are successes important: the causes of failure can also be interesting. Hebe Vessuri and Margarita Safar studied the evolution of the Venezuelan Chemistry Society, founded in 1938, exploring the reasons for its lack of impact and premature demise, despite the importance of chemistry for an oil-producing country.[46] The Society was part of the growth of a modernizing culture in a country which, according to some authors, had entered the twentieth century only in 1938, with the death of dictator Juan Vicente Gómez, who had ruled with an iron hand since 1909. The Society responded to local conditions and disappeared when it ceased to attract support. The members of the Society had a naive notion of Venezuelan industrialization, which prevented them from developing a more consistently realistic attitude towards issues such as conflicts over industrial responsibility, unionization and the social role of chemistry. Their view of the profession of science was also ambiguous. Thus, as the 'academicization' of chemistry occurred at the end of the 1950s, tensions between scientists, technicians and amateurs grew. Chemical engineers chose to go their own separate way, not only by developing a career of their own – chemical engineering – in the university, but also by creating a Society of Chemical Engineering in 1958, more directly concerned with industrial developments. The 'scientification' of chemistry at the university in the 1960s meant preference for mathematical treatments, while the technical practice and empirical intuition that had been well received in the early days of the Chemistry Society were carefully cornered by the profession, as a guarantee of academic respectability. The Chemistry Society lost impulse and grew increasingly isolated. It ceased to function both as a scientific society and as a professional association.

The study of institutions seems to offer many fruitful possibilities. We need more work on scientific and para-scientific institutions and reinterpretations of some of the few classical works on colonial or early republican science. We need to delve into the motivations and impacts of the learned societies, the national academies of science and the associations for the advancement of science; we should look into the nature

and evolution of local and international private foundations and study the effects of their manipulation of support in connection with particular fields in the region. Works on these topics, written by Latin American scholars from the viewpoint of Latin American countries, would make interesting comparisons.[47] Almost all of the formal institutions of science merit socio-historical study, and some of their key participants deserve particular consideration. The role of local or regional scientific journals also remains to be explored.[48] To date, their importance can be grasped only indirectly through studies of scientific productivity. The full extent of their collective influence can at present only be imagined.

Scientific Communities

Among our earliest concerns has been the need to understand the behaviour and dynamics of national scientific communities. Edmundo Fuenzalida produced a pioneer work in 1971 on the Chilean scientific community.[49] In Brazil, Simon Schwartzman coordinated a research team on the contemporary social history of science in that country, one of its products being *Formação da comunidade científica no Brasil* in 1979.[50] This characterized the main traditions of scientific work in the country, and the interplay between international scientific conditions and local institutional developments. The social history of Brazilian science was seen in terms of efforts to establish a scientific community, and to bring out the relationships between the scientific community and the broader social and economic context.

This area's vitality has been retained since the second half of the 1970s by projects which share the basic tenets of the 'community study' approach. In Venezuela, for example, Marcel Roche and Yajaira Freites have studied their national scientific community, with the aim of exploring the attitudes of research scientists towards politics, the international scientific community and the philosophy of science. Carried out at the Venezuelan Institute of Scientific Research (IVIC), this survey turned out to be cumbersome; yet a number of valuable results were gained, particularly in measuring the productivity of scientists and their views about science policy.[51]

More recently, another study on the scientific community in Peru was conducted by Francisco Sagasti and collaborators and closely linked to those carried out in other Latin American countries during the 1970s.[52] This considered scientists belonging to four fields: seismology, mathematics, biology and economics, and studied the informal organization

of the scientific community in each in an attempt to examine the tissue of professional relationships. The networks of interpersonal relationships in each field were analyzed by means of a set of 'sociograms' representing particular aspects of social interaction. Unfortunately, the sociograms were done in terms of a desirable situation, not of an actual one, and this reduced their usefulness.

This review of the literature on Latin American scientific communities, then, shows that the questions asked about science and society have changed with time, with increased attention now being paid to the qualitative orientation of science. The almost exclusive initial concern with the formal features of the scientific community has given place to a range of orientations which illuminate different facets of science in society. Although there is still no attempt to give a synthetic account of these facets, it seems that the social relevance of science to particular countries will be an increasingly important issue, especially as the inclination to study twentieth-century scientific communities grows stronger.

Disciplines

The socio-historical study of scientific disciplines in the national contexts of Latin America offers a meeting ground in which traditional concerns with scientific ideas converge with new interests in the politics of science and an awakening curiosity about scientists and social groups. It also offers a complex intellectual framework for the analysis of contemporary national problems, allowing a fresh awareness of contextual, cultural factors on the part of practising scientists. *Ciencia académica en la Venezuela moderna*, edited by Hebe Vessuri, sets out to explore the modalities adopted by scientific activity in Venezuelan society, through the differentiated structure of several disciplines and specialties.[53] Nine studies in this volume consider concrete aspects of different disciplines related to teaching and research. The contributions take elements from both the 'internalist' and 'externalist' research programmes, producing as much an understanding of the evolution of the cultural profile of specific disciplines as an interpretation of the socio-cultural contextual framework in which they have grown. The book argues that the transfer of knowledge is rarely made into an empty socio-cultural space. New knowledge, together with its associated institutional paraphernalia, arrives in contexts where there are other intellectual traditions, institutions, interest groups and given schemes of privilege and reward, and has to come to terms with these in ways that are always specific.

The different essays in this volume argue, with reference to particular disciplines, that since the 1950s a new way of organizing scientific and technological *practice* developed in Venezuela with an attempt to 'grow' a professional, internationally legitimated scientific community. Somewhat paradoxically, the programme to develop a *national* scientific community involved rejecting 'national cultural traditions' to embrace the cause of modern international science and technology. Analysis concentrates on the strategies of local intellectual 'gate-keepers', who have appropriated science in order to enhance their own factional or national interests – often sharing the goals of the international community, but ultimately serving their own purposes. The book also explores some of the limitations and possibilities of the *científicos* modernization programmes.[54]

Two very different works on Argentine physics shed light on interesting aspects of the development of the discipline in that country. The first is by the North American historian, Lewis Pyenson. His book on the expansion of the German exact sciences in the early twentieth century contains a well-documented chapter on the growth and consolidation of physics, physical chemistry and astronomy in Argentina in the period before World War I, leading to Argentine dominance in these fields in Latin America until 1950.[55] The second work, by Argentine physicist Mario Mariscotti, consists in a chronicle of the origins of atomic energy in Argentina, since the days in 1948 when General Perón hired the Austrian Ronald Richter to produce cheap atomic energy.[56] Very little was known of the 'Argentine atomic bomb' – the Huemul project – before the publication of this book. But the book is more than the first detailed analysis of the Richter affair on the remote Huemul Island in Bariloche. Mariscotti's analysis is made against the background of local developments in physics in the years 1940–55, and particularly in relation to the activity of the Argentine physicist Enrique Gaviola (an old pupil of Richard Gans at the University of La Plata, who later did postgraduate work in Göttingen and Berlin, at Johns Hopkins and at the Carnegie Institution and Caltech, before returning to Argentina in 1930 to the chair of physico-chemistry at the University of Buenos Aires). Mariscotti asks whether it was necessary to pass through the 'Huemul experience' to crystallize atomic energy in Argentina. Written by an active nuclear physicist, it is no surprise that his view of atomic activity is ultimately optimistic, but the picture he draws of the relationships between science and politics is nevertheless realistic and instructive.

Among the subjects that still await to be treated in connection with physics in Latin America is the role of the armed forces in the post-war

development of nuclear physics. It may be argued that the selective stimulus of nuclear physics by the military left almost completely undeveloped certain areas, including solid state physics, which could have risen to the technological challenges posed by the electronic revolution.

Comparisons between physics and chemistry also promise to be revealing. Chemistry has in the Latin American region a history much longer than physics. However, some of the most developed countries – Brazil and Argentina, for example – seem now to be relatively more advanced in physics than in chemistry. The reason may lie in the almost total control of the chemical industry by multinational firms, resulting in a lack of demand for local scientific research. Latin American oil-producing countries – Venezuela and Mexico – offer interesting comparisons in both chemistry and petrochemistry.

In the social sciences, it will be interesting to explore the transfer of knowledge and the development of national schools of sociology and anthropology following on from previous traditions of law or history, or developing independently as ideological instruments for modernization. In this area, work will produce not merely descriptive histories of achievements and failures of particular disciplines located in a particular regional context, but also a rich map of the social sciences resulting from peculiar syntheses between existing cultural materials and the cognitive and organizational matrixes available in international science. Thus hypotheses could be tested about the social sciences as universal and transnational disciplines, emphasizing the specific circumstances that may promote, inhibit or deform them in specific socio-cultural contexts.

In this vein, Mariza Peirano has traced the development of a nationally-defined social science in Brazil, through the analysis of the work of Florestán Fernandes, Darcy Ribeiro, Antonio Candido, Roberto Cardoso de Oliveira, Roberto da Matta and Otávio Velho. She discusses the relationship between the development of the social sciences and the ideology of nationhood in Brazil. The nation became an issue for Brazilian social scientists in the course of their enquiry into *their own society*, and in terms of their social and political responsibilities as citizens. The integration of social strata as the process by which a nation assimilates its different groups and sectors under a unifying ideology of participation, and territorial integration as the process by which the nation conceives of itself as a geographical unit, informed the thinking of social scientists in general after the 1940s in Brazil, leaving little space for topics and approaches which did not fit into this overall scheme. For example, Peirano shows how, starting from a model in which Indians were

studied as the 'different others', Brazilian anthropologists progressively moved their focus from the Indians themselves to the peasantry and the national society and, in so doing, became increasingly involved in the issues of 'territorial' and 'strata integration'.[57]

José Joaquin Brunner, in turn, has tried to account for the processes of disciplinary diffusion and the reception of sociology in Chile.[58] He has studied the discipline's legitimation strategies, as well as the uncertain process that characterized the transit from 'armchair' sociology to professional sociology. Sociology in Chile was received from the outside; even its professional model was imported, but it did not grow according to the classic patterns of integration to a communication network based on recognized products of knowledge. Institutional aspects prevailed over clearly disciplinary ones, and the strategies of legitimation and professionalization predominated over concerns of a cognitive or conceptual kind.

Science Policy

Compared with other topics, science policy in Latin America has been rather well studied, although usually in terms of the administrative history of funding agencies (such as the CONICITs), or in terms of the Atomic Energy Commissions, institutes of agricultural research, national systems of health and the like. An enormous amount of work still remains to be done on these bodies. Little is known about the impact of the money spent or of the criteria set by the funding agencies. A refreshing work in this field is Lea Velho's recent doctoral thesis on Brazilian agricultural research scientists.[59] The picture that emerges from her analysis of the Brazilian agricultural science community is intended to invite policy-makers to reflect upon their subject. She shows that agricultural research in Brazilian universities is mostly oriented towards practical problems, often for this reason lagging behind recent 'basic work' at the international level. Even so, the typical form of communicating research results is the mechanism of 'in-house' journals. There is little communication with client groups who ought to be the direct recipients of practical results. At the root of this lies the premium placed on 'academic behaviour', and the keeping of scientific standards at the expense of results. The evaluation criteria of government research funding agencies, which play a major role, thus require radical revision.[60]

An approach to science policy from the point of view of higher education in general, and science education in particular, appears to be

important too. There is a considerable tradition of educational research carried out by educators, but until recently the educational system and educational matters were considered separately from matters scientific. During the last few years efforts have been made to have science play a key role in the reorientation of the Latin American universities, and to analyze the effect of the university upon the character of scientific activity. A substantial literature has arisen since the days when Fuenzalida (1974) and Sagasti (1981) advocated the removal of scientific research from the universities to more favourable institutional settings, down to the recent controversy in *Interciencia* about the role of the university in the regional development of science.[61] Nevertheless, more studies are needed, particularly on themes that have come to prominence in recent years, such as the impact of new scientific knowledge in the region and the information revolution. The future agenda for science policy must envisage a redefinition of national research policies and of professional training, as well as a rethinking of the mass universities.[62]

The social study of science has generated one other development in the field of science and technology policy, that of 'prospective analysis'. In view of the depth and duration of the current economic crisis of Latin American countries, the 'prospectivist approach' is an attempt to provoke a change in the manner in which decision-makers face problems, broadening the criteria upon which their decisions should be based. In Colombia, Cuba, Brazil, Mexico and Peru, 'prospective analyses' are being carried out both by government agencies and academic research groups. The Technological Prospective in Latin America cooperative project currently underway is coordinated by Amilcar Herrera, and conducted by research teams in Argentina, Brazil, Mexico and Venezuela, with the support of the United Nations University and the IDRC of Canada. It takes as its point of departure that the *uncertainty* contained in any long-term prospective view can be seen as a potentially positive factor, it if is understood to be the extent of freedom of the system. The project is exploring those margins of freedom in the hope of contributing to a flexible science and technology strategy for the Latin American region, capable of taking advantage of new technological, political and economic options.[63]

Technological Innovation and Latin American Industrialization

The growth of interest in Latin America in the process of technological change, particularly in connection with the problems of socio-economic

development, has led to some interesting insights. As early discussions in the 1960s about technology imports, the transfer of technology, technology negotiation, and control mechanisms of imported technologies soon expanded, the importation of technology and the local production of technology were seen not as mutually exclusive but rather as complementary activities.

An important bench-mark in social research on technological change in the region was the programme of studies promoted jointly by the Inter-American Development Bank and the Economic Commission for Latin America, carried out by a research team led by Jorge Katz.[64] This showed that one of the most important sources of national technology is the modification and adaptation of imported technological packages which, in developing countries, do not in general take place in specialized research institutions but directly within firms. This informal R&D activity, usually dependent on the demands of production, is mainly a response to the need to adapt a package to the changing conditions of the real world.[65] Craft production, largely disregarded by government agencies responsible for science and technology, was thus shown to be a very important component of national technology in Latin America. Governments not only ignore craft technology production but frequently also lack definite policies on development of industrial technology production.

In 1982 Jorge Sábato and Michael Mackenzie called attention to the inadequate understanding in most Latin American countries of the role of technology in the productive structure. They analyzed how the model entrenched in government circles resulted in the establishment of national institutes of industrial research, with the unrealistic expectation that, in time, by their mere existence, they would produce the technology required by the productive structure.[66] These authors argued that such institutions are not organized as technology firms, and consequently do not function in terms of economic factors but rather as academic units, more concerned with the scientific and technical quality of their results. Neither do they buy technology, nor do they sell it except through 'extension services'.

Parallel to the increasing interest in innovation and the technological process, there has come an intellectual and practical concern about the deep dysfunctionality of Latin American industrialization *vis-à-vis* the needs and potentialities of the region. Numerous analyses have been made of Latin American industrialization and of the empirical features distinguishing it both from the advanced countries and from the 'late-comers' of South-East Asia.[67] Progressively a better understanding has been

gained of the role of the national bourgeoisie and its imitative consumption patterns, the precariousness of the national industrial entrepreneurial class, and the other social forces that have contributed to define the industrial policy of Latin American countries. Also more attention has been paid to the indiscriminate presence of foreign firms which have exerted their leadership over a wide range of sectors, particularly in those that define the profile of industrial growth.[68]

A critical analysis of the so-called 'neo-liberal'[69] tenets characterizing the Latin American industrialization process, against the background of the advanced countries and of the newly industrialized countries of South-East Asia, is that of Fernando Fajnzylber.[70] He takes as his starting point the frustrations and deformities of industrialization in the region. He shows the precariousness of the industrial vocation of the national entrepreneurial classes and of the other social forces that contributed to governmental 'frivolous protectionism' which reinforced inefficiencies. His analysis reveals the marked asymmetry between the repercussions that leading industrial firms have in advanced countries and in Latin America. He considers the scarce or non-existing internal production of capital goods, the distorted linkage between the industrial and agricultural sectors, and finally the dysfunctionality of the energy-base, markedly dependent on oil, which most of the countries in the region lack.

Fajnzylber's arguments point to the fact that far from being a faithful – though temporarily lagging – image of industrialization in advanced countries, Latin American industrialization is a truncated and distorted reproduction of the original source of inspiration, being at least partially dysfunctional to the needs of a substantial portion of the population, and moreover incapable of developing its creative potential. In his view, it is clear that the 'neo-liberal' answer in Argentina, Chile and Uruguay to the precariousness of existing industrialization has been to question its very existence, going back to a past scheme of the international division of labour in which the Latin American countries are relegated to the subordinated role of exporters of natural resources. This, he shows, not only fails to satisfy accumulated social needs, but intensifies them, adding an extra burden that discourages national creativity. He proposes a 'new industrialization', aimed at the satisfaction of needs and the development of specific potentials, resources and traditions. The constitution of a creative and dynamic endogenous core capable of entering the process of technological dynamism is posed as a necessary condition for entering and remaining in the international market, and an alternative to delegating to foreign agents the responsibility of defining the productive structure of the region.

The Cooperative Research Project on Agricultural Technology in Latin America (PROTAAL), carried out in the late 1970s by a group of Latin and North American researchers coordinated by Martín Piñeiro and Eduardo Trigo, has attempted to interpret the importance of public policy and technology in Latin American agricultural development.[71] This project criticized the traditional theory of induced innovation, rooted in classical economics, according to which relative market prices, which indicate relative scarcity of factors of production, induce the adoption of technological innovations. PROTAAL finds that this interpretation fails to explain the range of technical changes in developing countries, and integrates the economic reasoning of the induced innovation model with the theory of the political economy of technological change. The market imperfections found in developing countries and the role of interest groups in fostering technical change are stressed, while international industrial and financial capital is shown to force agriculture into a subordinate position.[72]

Recent Institutional Developments

Science, in one form or another, was involved in many central issues facing Latin America after World War II, including health, education and diplomacy. This tendency became recognizable partly because the world economic order dominated local national economies, and partly because science and technology were embedded in the mass culture exported from North America and Europe.

In this context, a few Latin American universities have recognized the increasing importance of the social study of science. The Center for Development Studies (CENDES), at the Universidad Central de Venezuela, has one of the oldest and broadest SSS postgraduate programmes in the region, having trained over forty students since 1976.[73] This programme has played an important role through research, meetings and exchanges with individuals, groups and international agencies. In particular, this has been achieved through cooperation with the Secretariat of the Science, Technology, and Development Commission of the Latin American Council for the Social Sciences (CLACSO), and the Research Committee on the Institutionalization of Science of the Latin American Society for the History of Science and Technology (SLHCT). Also in Caracas, at the Venezuelan Institute of Scientific Research (IVIC), Marcel Roche, the editor of *Interciencia*, has a small group for the social study of science. More recently a postgraduate

programme on Science and Technology Policy has been created in Maracaibo at the University of Zulia.

In Mexico, the Colegio de Mexico has a research programme on science, technology and development, with projects on history, economics and sociology of science and technology; science and technology policies; the transfer, diffusion and implantation of technology; and industrial research and development. Among the Mexican researchers, Miguel Wionczek, Alejandro Nadal Egea and Francisco Cepeda may be mentioned. The Science Faculty of the Universidad Autónoma de Mexico (UNAM) also has a programme in science and society, led by physicists, mathematicians and chemists concerned with the history of science. The radical orientation of this group was expressed in 1984 in its intention to produce

> an integral criticism of the educational system that is a product of the capitalist system. . . and to question the form, methods and content of research in the country, resulting from the capitalist relationships of production and the underdevelopment and dependence deriving from those same relationships.[74]

At the Institute of Social Research of UNAM, Lusia Rodríguez de Gomezgil and some of her colleagues have continued research in SSS.[75] Another interesting group at UNAM is the newly created Technology Centre coordinated by Mario Waissbluth, which tries to develop links between university and industry. This group has recently been joined by Larissa Lomnitz.[76] The Institute of Economic Research of UNAM has a science and technology programme led by Fausto Burgueño, and the postgraduate programme of the Economics Faculty of UNAM has a seminar devoted to political economy of science and technology. Leonel Corona, of this group, has founded a Latin American Association for Science Policy. The history of science in Mexico has recently taken a significant step with the appearance in 1984 of the first Latin American journal in the field – *Quipu* – edited by Juan José Saldaña of UNAM, current president of the Latin American Society for the History of Science and Technology.

Brazil also presents some interesting developments. Recently, through a programme of the Brazilian Science Council (CNPq), a number of academic nuclei for the social study of science were created. Among the most active are the groups at the University of Campinas (UNICAMP), headed by Amilcar Herrera, and that of COPPE (Coordination of Post-graduate Engineering Programmes) in Rio de Janeiro. At UNICAMP, SSS courses are offered to undergraduate students in different subjects

and a postgraduate programme is being prepared. Emphasis is placed on research. COPPE also has a postgraduate programme which is in its second year. The University of São Paulo has two groups, one in the history of science, led by Shozo Motoyama (who is also the president of the newly-founded Brazilian Society of the History of Science), and another on technology management, led by I. Marcovich. The Rio de Janeiro University Research Institute (IUPERJ) also has a research group, of whom the most well-known member is Simon Schwartzman, who was involved in the Brazilian study of Unesco's project on scientific productivity (ICSOPRU).[77]

In Peru, the Grupo de Estudios para el Desarrollo (GRADE), a private institution whose executive president is Francisco Sagasti, specializes in projects on the design, execution and control of S&T policies and on forecasting and assessment in the field of S&T. In Cuba, the Centro Carlos Finlay para el Estudios de la Historia y Organizacion de la Ciencia, part of the Cuban Academy of Sciences, is directed by Tirso Sáenz. This also has a broad research and training programme that relates figures in Cuba's past to science and technology policy today. In Colombia, the National Science Council (COLCIENCIAS) coordinates the research activity of several groups located in different parts of the country as far as science studies are concerned. In Argentina, some efforts are currently underway in CONICET, the National Institute for Industrial Technology (INTI) and elsewhere to revive the activity which before the military regime was so dynamic.

If one were to summarize conceptual developments, one could say that for quite a while intellectual dependence, as elsewhere in scientific activity, was a *leitmotif*. In more recent years, there has been a change in the perception of the role of culture in Latin America, which is perhaps even more pessimistic than the *dependentista* views of the early 1970s, with regard to the possible development of the region's potential. Instead of posing the problem as a question of 'cultural penetration' or 'dependent culture', now the picture is more often one of a world-system in which, besides controlling economic and military affairs, the 'centre' asserts a general cultural hegemony. Modernity has fragmented Latin American culture to such an extent that it can no longer produce an integrated conceptual identity. Neither can it provide a point of cohesion and stability for the economy, politics, social structure or even the lives of individuals. The cultural institutions of the region have been modelled according to the demands of the international market for cultural goods, from television series to the production of educational certificates that are internationally valid.

An account of the social study of science in Latin America may occasionally give the impression of 'distance', almost unreality. It would have been difficult for these meta-studies to escape the general 'climate' in which science has largely devolved in the region: scientists have often lived sealed off from the social and economic reality, oriented to the symbols, messages and rewards of the world centres, as if they were not settled in a continent full of enormous potential, desperate disease and poverty, military dictatorships, multinational corporations and political intrigues. The SSS world to some degree shared this 'distance'. Its role, in this sense, has been parallel to that of the universities in which it emerged, with little intellectual and institutional autonomy relative to world centres, but with a degree of political autonomy in intellectual criticism. The role of SSS in consciousness-raising is diversifying and enriching. It is beginning to penetrate undergraduate science programmes and secondary schools in its endeavour to produce a richer and deeper understanding of science and technology in development and underdevelopment.

But despite these promising signs which we have briefly reviewed, the institutional developments of SSS are very fragile. They reveal defects variously attributable to tactical mistakes, or to peculiarities in the structure of Latin American scholarly life. There is a limited potential of organizational forms and resources at the disposal of Latin American scholars entering the field. The chances for their survival and success lie in their capacity to demonstrate their utility in the preparation of students for academic or scientific careers, and in bridging the 'research' gap between academia, public decision-making and industry.

• NOTES

I would like to thank Roy MacLeod for his useful comments on earlier drafts. Any errors or omissions are, of course, solely mine.

1. See, for example, the journals *Interciencia* (Caracas), *RBT: revista Brasileira de tecnologia* (Brasilia), *Quipu* (Mexico), and more recently the *Revista da sociedade Brasileira de história da ciencia* (São Paulo).

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

3. This is the usual grouping of ECLA documents which has been adopted by the recent surveys of Latin American science and technology made by Francisco Sagasti and

collaborators in GRADE. See F. Sagasti, F. Chaparro, C. E. Paredes and H. Jaramillo, *Un decenio en transición: ciencia y tecnología en América Latina y el Caribe durante los setenta* (Lima: GRADE, 1983); Sagasti & Cook, op. cit. note 2.

4. See T. Sáenz, *El progreso científico y técnico en 25 años de revolución* (La Habana: Academia de Ciencias de Cuba, 1984). See also *CASTALAC II: estadísticas sobre el personal científico y tecnológico y gastos para la investigación y desarrollo experimental en América Latina y el Caribe*, Doc. SC-85/CASTALAC II/ref. 3 (Paris: Unesco, February 1985). The situation in Uruguay, recently returned to democracy, does not seem to have changed noticeably yet, while Paraguay has displayed a greater activity in engineering as a result of the large hydroelectric projects in progress.

5. C. Pérez, 'Las nuevas tecnologías: una visión de conjunto', in C. Ominami (ed.), *La tercera revolución industrial: impactos internacionales del actual viraje tecnológico* (Santiago: RIAL-Grupo Editor Latinoamericano, 1986); F. S. Erber, 'The Development of the "Electronic Complex" and Government Policies in Brazil', *World Development*, Vol. 13 (1985), 293–309; H. Vessuri, 'The Universities, Scientific Research and the National Interest in Latin America', *Minerva*, Vol. 24 (1986), 1–38.

6. The use of the term 'Latin America' in this context does not mean ignoring the heterogeneity of the scientific community in the several countries of the region. It simply points to the existence of certain overall trends.

7. For a recent exposition of this view in the Latin American context, see A. Herrera, *Technological Prospective in Latin America: Methodological Proposal* (Campinas: UNICAMP-United Nations University-International Development Research Centre, 1984).

8. For a discussion of the topic of the state in Latin America, see, among others, F. H. Cardoso and E. Faletto, *Dependencia y desarrollo en América Latina* (Mexico: Siglo XXI, 1969); H. R. Sonntag, 'Hacia una teoría política del capitalismo periférico', in Sonntag and H. Valecillos (eds), *El estado en el capitalismo contemporáneo* (Mexico: Siglo XXI, 1977), 134–83; T. Evers, *Buergerliche Herrschaft in der Dritten Welt; Zur Theorie des Staates in oekonomisch unterentewinckelten Gesellschaftsformationen* (Frankfurt am Main: Europaeische Verlagsanstalt, 1977).

9. Efforts began to be made, in particular by the Organization of American States (OAS), Pilot Project of Technology Transfer (PPTT). See OAS, Department of Scientific Affairs, *IV reunión de coordinadores de los puntos focales nacionales del proyecto piloto de transferencia de tecnología, evaluación e informe final*, DOC, SG/PI/PPTT/34/35 (Washington, DC: OAS, June 1975). See also J. Katz, *Importación de tecnología y desarrollo tecnológico* (Mexico: Fondo de Cultura Económica, 1972).

10 V. Yackovlev, 'El programa regional de la OEA', *Materiales del seminario Iberoamericano 'Jorge Sábato' de política científica* (Madrid: Consejo Superior de Investigaciones Científicas/OAS, 1985), 225–29.

11. For a list of the main international meetings on S&T policy and planning organized by the OAS in Latin America, see *V seminario metodológico sobre política y planificación científica y tecnológica* (Washington, DC: OAS, 1982), 336.

12. Unesco, *Statistical Yearbooks* (Paris). See also the abundant documentation produced by Unesco's Division of S&T Policy.

13. An interesting institutional development in this respect has been the creation of Unesco's Latin American and Caribbean Regional Centre for Research in Higher Education (CRESALC), located in Caracas, which is fulfilling a useful role in information retrieval and research in this field.

14. A. Pirela, *La escuela Latinoamericana del pensamiento económico y social CEPAL–dependencia* (Caracas: CENDES, mimeo, 1986).

15. Pirela, op. cit. note 14, 21ff.

16. See, for example, C. Furtado, *La economía Latinoamericana* (Mexico: Siglo XXI, 8th edn, 1976).

17. F. Sagasti, *La política científica y tecnológica en América Latina: un estudio del enfoque de sistemas* (Mexico: El Colegio de México, Jornadas 101, 1983).

18. F. Sagasti, *Ciencia y tecnología para el desarrollo: informe comparativo central del proyecto STPI* (Ottawa: IDRC, Doc. 109, 1978).

19. Sagasti, op. cit. note 17, 113–28.

20. E. Amadeo, 'Los consejos nacionales de investigación en América Latina: éxitos y fracasos del primer decenio', *Comercio exterior* (Mexico), Vol. 18 (1978), 1439–47.

21. I. Ávalos and M. Antonorsi, *La planificación ilusoria* (Caracas: CENDES-Ateneo, 1980).

22. *Materiales del seminario Iberoamericano 'Jorge Sábato'*, op. cit. note 10.

23. O. Varsavsky, *Ciencia política y cientificismo* (Buenos Aires: Centro Editor de América Latina, 1969); M. Slemenson, *Emigración de científicos Argentinos: organización de un exodo a América Latina: historia y consecuencias de una crisis político-universitaria* (Buenos Aires: Instituto Torcuato Di Tella, mimeo, 1970).

24. Varsavsky, op. cit. note 23, 14–37. Other works by Varsavsky are *Proyectos nacionales: planteo y estudios de viabilidad* (Buenos Aires: Ediciones Periferia, 1971); *Hacia una política cientifica nacional* (Buenos Aires: Ediciones Periferia, 1972); *Estilos tecnológicos: propuestas para la selección de tecnologías bajo racionalidad socialista* (Buenos Aires: Ediciones Periferia, 1974); *Marco histórico constructivo para estilos sociales, proyectos nacionales y sus estrategias* (Buenos Aires: Centro Editor, 1975).

25. An influential popular journal from this period, published by a group of people linked with the Facultad de Ciencias Exactas y Naturales in Buenos Aires, was called *Ciencia nueva*.

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

27. Herrera, op. cit. note 26, 84–97, and passim.

28. J. Sábato (ed.), *El pensamiento Latinoamericano en la problemática ciencia – tecnología desarrollo – dependencia* (Buenos Aires: Paidós, 1975).

29. H. M. C. Vessuri, 'Scientific Immigrants in Venezuela; National Identity and International Science', in A. F. Marks and Vessuri (eds), *White Collar Migrants in the Americas and the Caribbean* (Leiden: Dept of Caribbean Studies, Royal Institute of Linguistics and Anthropology, 1983), 171–98.

30. Subsecretaría de Ciencia y Técnica, Ministerio de Educación y Justicia de la República Argentina, *Contratos de importación de tecnología, 1977–1983* (Buenos Aires, April 1985); CONICET, *Consulta regional sobre recursos humanos para la investigación en América Latina y el Caribe: estudio del caso Argentino* (Buenos Aires: CONICET/IDRC, July 1986).

31. *Boletin CNPq de estadística, indicadores básicos de C y I insumos*, No. 3 (Brasilia: CNPq, 1981).

32. Dirección Adjunta de Desarrollo Tecnológico, *Estrategia de acción tecnológica* (Mexico: CONACYT, 1980).

33. After the relatively good governmental support given to the development of scientific and technological activities in the 1970s, since 1982 the Venezuelan scientific community has experienced a continuous deterioration of its working conditions, which threatens its survival.

34. See op. cit. note 4. For a report on higher education, see Departamento de Estudios para el Perfeccionamiento de la Educación Superior de la Universidad de la Habana, *La educación superior en Cuba* (Caracas: CRESALC-Unesco, July 1985).

35. See A. Thackray, 'History of Science in the 1980s', *Journal of Interdisciplinary History*, Vol. 12 (1981), 299–314, on the limitations of the practising scientist writing on SSS.

36. It is difficult to estimate the number of scholars in our field in Latin America today, and even more difficult to say something about trends as to where they were educated. However, a recent OAS directory of researchers and research projects on SSS, even if it omits Cuba, Colombia and Chile, allows us to make a very rough estimate of some 250 scholars (the directory lists 203). See *Directorio Latinoamericano de estudios sobre la ciencia y la tecnología e investigaciones en curso 1983–1984* (Washington, DC: OAS, 1986).

37. M. Moreno Fraginals, *El ingenio: el complejo económico social Cubano del azúcar* (La Habana: Comisión Nacional Cubana de la Unesco, 1964); R. Gama, *Engenho e technologia* (São Paulo: Livraria Duas Cidades, 1983); E. Arcila Farías, *Historia de la ingeniería en Venezuela* (Caracas: Colegio de Ingenieros de Venezuela, 1961); J. Katz, *Domestic Technological Innovations and Dynamic Comparative Advantages: Further Reflection on a Comparative Case-Study Programme* (Buenos Aires: Universo, 1983).

38. E. Fuenzalida, 'Building Transnational Capitalism. The Role of Knowledge Institutions' (Stanford University. mimeo, 1983); J. J. Brunner, *Los orígenes de la sociología professional en Chile* (Santiago: FLACSO Chile, Working Paper No. 260, 1985). E. Bernales, *El desarrollo de las ciencias sociales en el Perú* (Lima: Centro de Investigación de la Universidad del Pacifico, 1981); *Ciencias sociales en México: desarrollo y perspectiva* (Mexico: El Colegio de México, 1979); R. Pérez Perdomo, *Los abogados en Venezuela: estudio de una elite intelectual y política 1780–1980* (Caracas: Monte Avila Editores, 1981); M. Peirano, *The Anthropology of Anthropology: the Brazilian Case* (unpublished PhD dissertation, Harvard University, 1981).

39. An interesting Latin American exception, given his concern with the arms escalation and the risk of a nuclear holocaust, is A. Herrera, *La larga jornada: la crisis nuclear y el destino biológica del hombre* (Mexico: Siglo XXI, 1981).

40. The universities need to be revisited by fresh socio-historical analysis. Thus far, Latin American universities have typically been studied by celebratory historians. For a modest but solid example of the recovery of the past of a Latin American university see I. Leal, *Historia de la UCV 1721–1981* (Caracas: Ediciones del Rectorado de la UCV, 1981). See also Vessuri, op. cit. note 5.

41. N. Stepan, *Beginnings of Brazilian Science: Oswaldo Cruz, Medical Research and Policy, 1890–1920* (New York: Science History Publications, 1981).

42. M. Roche, *Rafael Rangel: ciencia y política en la Venezuela de principios de siglo* (Caracas: Monte Avila Editores, 1973).

43. J. Murilo de Carvalho, *A escola de minas de Ouro Preto: o peso da glória* (Rio de Janeiro: FINEP-Companhia Editora Nacional, 1978).

44. Ibid., 24–36.

45. J. Casper Branner, 'Outlines of the Geology of Brazil to Accompany the Geologic Map of Brazil', *Bulletin of the Geological Society of America*, Vol. 30 (1919), 263, quoted in ibid., 93. See the review of this book by Simon Schwartzman in this issue of *Social Studies of Science*, 569–73.

46. H. M. C. Vessuri and M. Safar, 'Elementos para la historia social de la química en Venezuela: la sociedad Venezolana de química', in E. Díaz, Y. Texera and Vessuri (eds), *La ciencia periférica: ciencia y sociedad en Venezuela* (Caracas: Monte Avila Editores, 1984), 121–65.

47. See, for example, M. Ardila, *Origen y evolución histórica de la asociación Venezolana para el avance de la ciencia* (unpublished undergraduate thesis, Universidad Andrés Bello, Caracas, 1981); A. J. J. Botelho, *La sociedade Brasileira para o progresso da ciencia* (unpublished MSc thesis, Centre Science, Technologie et Société au CNAM,

Paris, 1983); Y. Freites, 'Las sociedades científicas Venezolanas del siglo XIX' (Caracas: CENDES, mimeo, 1986).

48. For a recent analysis of one such journal – *Acta científica Venezolana* – see H. Vessuri, 'La revista cientifica periférica. El Coso de "Acta Científica Venezolana"', *Interciencia*, Vol. 11 (Caracas, 1987).

49. E. Fuenzalida, *Investigación científica y estratificación internacional* (Santiago de Chile: Editorial Andrés Bello, 1971).

50. S. Schwartzman, *Formação da comunidade científica no Brasil* (Rio de Janeiro: FINEP-Companhia Editora Nacional, 1979).

51. M. Roche and Y. Freites, 'Producción y flujo de información científica en un pais periférico Americano (Venezuela)', *Interciencia*, Vo. 7 (Caracas, 1982), 279–90; Freites and Roche, 'La planificación de la ciencia y la tecnología en Venezuela: opiniones de un grupo académico', in Díaz et al. (eds), op. cit. note 46, 199–230.

52. F. Sagasti et al., *Comunidad científica y científicos en el Perú: un estudio de cuatro campos: versión preliminar* (Lima: GRADE, mimeo, 1985).

53. H. Vessuri (ed.), *Ciencia ácadémica en la Venezuela moderna: historia reciente y perspectivas de las disciplinas científicas* (Caracas: Fondo Editorial Acta Científica, 1984). See the review of this book by Simon Schwartzman in this issue of *Social Studies of Science*, 569–73.

54. This underlines the difficulties faced by a researcher within the university, owing to the institutional encapsulation of the scientific community.

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

56. M. Mariscotti, *El secreto atómico de Huemul: crónica del origen de la energia atómica en la Argentina* (Buenos Aires: Sudamericana-Planeta, 1985).

57. Peirano, op. cit. note 38.

58. Brunner, op. cit. note 38.

59. L. Velho, *Science on the Periphery: a Study of the Agricultural Scientific Community in Brazilian Universities* (unpublished DPhil dissertation, University of Sussex, Brighton, 1985); Velho and J. Krige, 'Publication and Citation Practices of Brazilian Agricultural Scientists', *Social Studies of Science*, Vol. 14 (1984), 45–62.

60. Velho, op. cit. note 59, 267–68.

61. See, for example, *Interciencia*, Vol. 8 (1983), 82–92, 93–96, 236–42, and 303–07.

62. H. Vessuri, 'La evaluación de la capacidad científica de América Latina', *Acta científica Venezolana*, Vol. 37, No. 4 (1986).

63. See for example, A. Herrera and R. Dagnino, 'Prospectiva tecnólogica na América Latina', *Cadernos para discussão, No. 1 (Campinas: Núcleo de Política Científica e Tecnológica, 1983).*

64. Among the many publications in this programme, see J. Katz, 'Cambio tecnológico, desarrollo económico y las relaciones intra y extra-regionales de la América Latina', Monograph No. 30 (Buenos Aires: IDB/ECLA Research Programme on Science and Technology, 1978); Katz and R. Cibotti, 'Marco de referencia para un programa de investigación en temas de ciencias y tecnología en América Latina' (Buenos Aires: IDB/ECLA, 1976).

65. J. Katz et al., Productividad, tecnología y esfuerzos locales de investigación, Monograph No. 13 (Buenos Aires: IDB/ECLA Research Programme on Science and Technology, 1978).

66. J. A. Sábato and M. Mackenzie, *La producción de tecnología: autónoma o transnacional* (Mexico: ILET/Editorial Nueva Imagen, 1982).

67. A. O. Hirschman, 'La economia política de la industrialización a través de la sustitución de importaciones en América Latina', *Trimestre económico* (Mexico, February 1968); R. Prebisch, *Transformación y desarrollo: la gran tarea de América Latina* (Mexico: Fondo de Cultura Económica, 1970); C. Furtado, *Subdesenvolvimiento e estangnação na América Latina* (Rio de Janeiro: Civilização na Brasileira, 1967); M. C. Tavares, *Problemas de industrialización avanzada en capitalismos tardíos y periféricos* (Mexico: CECADE, 1981); special issue of *Economía de América Latina* on 'Crisis and Industrialization Strategies', No. 12 (Buenos Aires, 1984).

68. F. Fajnzylber (ed.), *Industrialización e internacionalización en América Latina* (Mexico: Fondo de Cultura Económica, 1980); R. Prebisch, *Capitalismo periférico: crisis y transformación* (Mexico: Fondo de Cultural Económica, 1981).

69. In the economic domain, so-called 'neo-liberalism' places the emphasis upon the market, and displaces the central motive force from the internal market towards the external market, as in earlier phases of Latin American development. Industrialization ceases to have the leading role in economic and social transformation, and the activities or products that come to be privileged are those which can find customers in the international market. These economic policies have been more systematically adopted in Argentina, Uruguay and particularly Chile, and partially in Peru, Venezuela, Colombia, Costa Rica, Brazil and Mexico.

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

71. M. Piñeiro and E. Trigo, *Technical Change and Social Conflict in Agriculture: Latin American Perspectives* (Boulder, CO: Westview Press, 1983).

72. Piñeiro & Trigo, op. cit. note 71. See also E. Trigo, M. Piñeiro and J. Sábato, 'La cuestión tecnológica y la organización de la producción agropecuaria', *Desarrollo económico*, Vol. 23 (Buenos Aires, 1983), 99–118.

73. Science and Technology Division, 'A Description of Research Activities' (Caracas: CENDES, mimeo, 1985).

74. Programa de Ciencia y Sociedad, Facultad de Ciencias, *Revalorización social de la ciencia: simposio internacional de ciencia y sociedad* (Mexico: UNAM, 1984).

75. See among the works of this group, M. L. Rodríguez de Gomezgil, *El científico en México: su imagen entre los estudiantes de enseñanza Media* (Mexico: Instituto de Investigaciones Sociales, UNAM, 1977); Rodríguez de Gomezgil and A. Chavero González, *El científico en México: su formación en el extranjero, su incorporación y adecuación al sistema ocupacional Mexicano* (Mexico: Instituto de Investigaciones Sociales, UNAM, 1982).

76. L. A. Lomnitz, 'Hierarchy and Peripherality: the Organisation of a Mexican Research Institute', *Minerva*, Vol. 17 (1979), 527–48; Lomnitz, M. W. Rees and L. Cameo, 'Publication and Referencing Patterns in a Mexican Research Institute', *Social Studies of Science*, Vol. 17 (1987), 115–33.

77. For the general features of the ICSOPRU project, see *International Comparative Study on the Organisation and Performance of Research Units* (Paris: Unesco/NS/ROU/386/EV.ADM., March 1977). Argentina participated in the project in its second round in 1982. Apparently, the usefulness of the project, carried out during the military dictatorship, was impaired by the way the sample was selected and the questionnaries completed. The Brazilian study is now producing results, and Mexico is currently carrying out a study with the same methodology, which would bring to three the Latin American countries with (in principle) comparable data.

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