Introduction: Innovation Context and Strategy of Scientific Research in Latin America

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Science Technology Society 2002; 7; 201
DOI: 10.1177/097172180200700201

INTRODUCTION

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THROUGHOUT THE TWENTIETH century the Latin American region remained the very heart of the developing New World as its pace of economic growth and political maturity went into a different path from that of the United States, while the latter became the strongest nation in the world. The complex intersection of international migrations, political and cultural formation, natural resources and commercial enterprise renders the region an ideal locality for studying the dynamic of competing Euro-American and other more recent global influences in scientific development in non-mainstream countries. Furthermore, the diversities and continuities of the region reveal how variously knowledge and science relate to power and are subjected to purpose. More concretely, it provides a vantage point from which to look at how the local infrastructure of science may or may not be effective in pursuing development.

The unprecedented growth of scientific and technological knowledge in the last half-century has added complexity to the challenges of economic and social development. Only a few countries can take advantage of the opportunities enabled by the mastery of new knowledge and the control of information. A certain level of capacity is required in educational, research, government, productive and financial institutions to

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Science, Technology & Society 7:2 (2002)
SAGE PUBLICATIONS NEW DELHI/THOUSAND OAKS/LONDON

transform S&T knowledge into an effective development lever. Knowledge is not acquired in simple direct transactions. It is created in specific contexts shaped by geographic, economic, social or political factors; and it requires a process of learning that is cumulative and endogenous, continuously building upon previous pieces of absorbed and adapted knowledge. That is why it is so difficult to successfully transfer knowledge from one location to another, especially when what is at stake is the need to address the organisational, economic, financial and political constraints that shape and condition its use in the recipient countries (Herrera 1981, 1984). The presence of Western-type scientific institutions in the developing world has been repeatedly accepted as an indication of modernity. But this notion, embodied in endless projects of institutions created throughout the modern history of developing countries, has been accompanied by very unequal success and, in general, by difficulties of consolidation (Vessuri 1994). In the confrontation between traditional cultures and modern scientific cultures, the former have been destroyed or deeply subordinated to the latter through social change and political domination, usually preventing the use of local indigenous knowledge and technologies in order to optimise knowledge resources (Vessuri 2000).

In this issue some of the recent strategies in the organisation of scientific research in Latin America are dealt with. The elusive theme of socio-economic development is touched upon either explicitly or implicitly in all the papers included. After more than fifty years of debate in the fields of policy and action with regard to the best way to achieve the condition of sustainable development, and to explore the role of science and technology in it, development continues to shun the region. The present context seems to be very different from the relatively recent past, with the world undergoing unusual turbulence and volatility, and reflecting the deployment of economic, cultural, social and political processes associated with globalisation. In the current turmoil, the fate of the region looks grim. Regional trends, with growing levels of extreme poverty, cruel contrasts of social inequity and marginalisation, and an insertion in the globalisation process in such conditions that leave the countries of the region with a serious vulnerability in their recovery capability, seem to be unsustainable.

In the evolution of modern science, its powerful conceptual structures for understanding the natural world and its historical articulation with economic and political intervention contributed to the rejection of other sources of knowledge held by marginal sectors of society. Nevertheless,

at this time of new technologies and sophisticated science, local and traditional knowledge remains crucial for vast numbers of people in developing countries, which constitute the broad majority of human society. Particularly in recent decades, there has been a sustained reentrance of other forms of knowledge in different domains of scientific research, particularly in connection with controversial S&T subjects that have clearly public dimensions. We still lack a comprehensive framework with regard to the multiple forms of local knowledge that could be used as inputs in scientific efforts and that have remained largely unknown by research systems as a potential source of innovation (ECLA 2002).

In their contribution to this issue, Kuramoto and Sagasti explore ways in which indigenous and local knowledge can be integrated into production systems, presenting a conceptual framework for examining the way knowledge and technology creation can contribute to economic development. They suggest ways in which technical cooperation could help in making better use of traditional knowledge and technologies. Three approaches to development are identified in their paper: (*a*) focused on productivity gains; (*b*) seeking development with equity; and (*c*) enhancing the capabilities and freedoms of the population. The three approaches envisage different roles for knowledge and for the way in which it interacts with production systems. Changes in the approaches to development (typically of types [*a*] and [*b*]) and poor performance of conventional technical assistance programmes have in their view gradually led to a revaluation of indigenous knowledge, technology and production. This helps explain how the third approach has come about, leading to a recognition of the wealth and potential of traditional and indigenous knowledge, and technology for development. To understand the relevance of this, suffice it to say that indigenous knowledge provides 80 per cent of the world population with a basis for local-level decision making in matters of food security, human and animal health, education, natural resources management and various other community-based activities. Being so closely related to different aspects of survival and subsistence it is, understandably, extremely valuable.

In connection with this, Kuramoto and Sagasti argue that among the relevant policies available for development are those aimed to the integration of domestic science, technology and production, considering both their traditional and modern components, and comprising several routes to create endogenous science and technology capacities that make full use of traditional knowledge. Besides, they also call attention to those policies aimed at the creation of linkages between developing countries

and the global knowledge, technology and production system, including measures related to scientific cooperation, technology transfer and the expansion of production facilities from developed to developing countries. Last but not least are policies aimed to create a favourable policy environment for the first two, that is, a policy environment conducive to innovation and to the selective upgrading and use of indigenous knowledge and technology.

Another notion that is common to the papers in this issue is that of network, as one of the most expressive mechanisms of the new forms of knowledge production and diffusion. Networks are perceived in general as promoting greater integration among the partners involved in the execution of research and in its results, as well as making it more dynamic and sharing the growing costs of scientific and technological research. Such an integration is to be observed in the different ways in which new knowledge reaches the peripheries. It is often brought back by former fellowship holders who have carried out graduate work in some of the world scientific centres or as a result of some other donor-initiated research capacity building in the South, in complex networks that result in more or less dependent or independent trajectories. Kreimer and Lugones study the particular articulation of the socio-cognitive network knit around the emergence and consolidation of molecular biology in Argentina, an interesting case study that suggests that it is not enough to have talented researchers, well trained in the leading centres of the world, in order to get effective results or even to produce original science. As the reader may appreciate, the differences in institutional and research management response considered in the Argentine case with the experience of Brazilian genomics as recounted by Egler and Negraes are remarkable.

The case history of molecular biology in Argentina as told by Kreimer and Lugones highlights the resistance of the older disciplinary institutional schemes identified with physiology and biochemistry to the new organisational and cultural arrangements, associating them closely to differing views of 'traditional' and 'modern' research in the biomedical sciences. In this case there would have been failure to realise the significance of novelty stemming from the existing preconceptions of very good scientists caught up in the old traditions, which prevented them from seeing what was there to be seen. Besides, the background common to this and to most cases in the periphery is a context of political and institutional weakness. In an approach that combines recent social history with the micro-sociology of science, the local growth of molecular biology's social and cognitive organisation is reconstructed. The period

under analysis is very recent history, where changes are described as a succession of events within a transitional phase of gradual generational renewal, putting to work Shinn's categories of research regimes (Shinn 2000). From being accepted in the role of 'auxiliary techniques of topical innovations' in the 1970s by the older local biochemistry practitioners in Argentina, molecular biology is shown to have grown in numbers in this country during the early 1980s, although research remained concentrated on only a few areas, some of them based upon earlier strengths in the study of local diseases, that is, parasitology (leading, for example, to developments in molecular parasitology around the *Trypanosoma cruzi*).

Kreimer and Lugones argue that two contrasting interpretations of the process are available: one of these provides a rationalisation for the practitioners' account of their own trajectories. The process is reconstructed in terms of subordinated integration to mainstream science, emphasising the continuities with disciplinary traditions rather than the discontinuities and schisms. The resulting picture is one in which auxiliary technical support is provided by the new knowledge holders to those traditional disciplines by an intense concentration on a few research topics, while this very ultra-specialisation atrophies creative participation in the conceptual issues that are crucial to bringing the new field forward.

The alternative interpretation, based on the distinction between different production regimes, tries to explain the local consolidation of molecular biology as a result of a progressive move from an initial powerful hegemony of the biochemical tradition in Argentina, in the absence of local schools of genetics and crystallography, to a second stage after the catastrophic end of the first one, when a group of scientists returned to the country imbued not only in the new knowledge but also in the new organisation of intra- and inter-laboratory work. They aligned themselves clearly with international trends despite the toll they had to pay to their local bosses, and it finally led to the extension of genetic engineering applications to various fields, bringing into the game actors that until then had been marginal or external to the academic field.

It is obvious that informal networking between individual researchers and laboratories situated in different institutional settings or in different countries occurs in a range of forms and for a variety of purposes, and it is as old as organised science and technology. A particular form of networking emerges around some types of scientific meeting that not only affords settings where researchers exchange information about new theories, data and techniques, but, by analogy with scientific disciplines,

can also be seen as rhetorical-political units for the delimitation of cognitive territories and the distribution of scientific roles and status within a discipline's hierarchy. Researchers' participation in scientific meetings may be a useful source of information for the study of social aspects of science. Vessuri and Canino examine a type of meeting that has been taking place periodically for an extended period, arguing that meetings of this sort deserve the attention of students for a variety of reasons, especially because through time one may observe the evolution of the cognitive field that the series of meetings helped to create. The authors argue further that its significance may be particularly great in connection with applied knowledge fields, for in them representatives of firms and bridge entities with industry and other stakeholders may also be found among participants.

A specific topic is taken up for discussion in the paper, that is, the growth of several national research communities in a particular cognitive field, that of catalysis in Latin America, including the possible identification of national leaderships, and the development of national and international collaboration networks. Inspired by Söderqvist and Silverstein's (1994) illustration of the prosopographical method, the questions raised are: (*a*) can one use participation in disciplinary meetings to trace the evolution of a cognitive field and identify national leaders of a discipline and its subunits? (*b*) do these meetings say anything about the dynamics and morphology adopted by domestic and international collaboration? (*c*) what can be learned about different national groups from the study of their participation in serial scientific meetings? (*d*) can one learn something useful about regional and cosmopolitan profiles of participation through the data afforded by these meetings? and (*e*) is it feasible to map disciplinary dynamics—for example, to determine how and when peripheral research fields, with their own research agendas, become integrated into the discipline's mainstream?

Through the study of the participation of Ibero-American researchers in the Simposio Iberoamericano de Catálisis (SICA) (Ibero-American Catalysis Symposium), it is shown how such a non-mainstream meeting became in time a relevant network space for building up the cognitive and institutional field, and for regional collaboration, with unexpected results. Being an initially Spanish venture, Spaniards make up the largest participant contingent, but it has been the French researchers who reaped the fruits of this particular exchange arena, presenting the largest number of international collaborations with Latin Americans within the SICA circuit. Less numerous and advanced than their French colleagues as a

scientific community, Spaniards collaborate closely among themselves in catalysis but much less with foreign partners within the SICA scope. The collective behaviour of Latin American contingents presents significant variation in their international collaboration profiles and networking. Changing communication patterns in the peripheral region, which are usually invisible because they occur outside the mainstream, can thus be observed and monitored.

The frequent use of the network organisational form in the S&T field may be reinforced and pushed forward by research management when the latter tries explicitly to incorporate new, more structured, practices involving greater intensity in the use of information and knowledge. Broadly based on the 'new mode of knowledge production' approach (Gibbons et al. 1994), Negraes and Egler study the highly visible Brazilian network of the Sao Paulo Genome Project of *Xyllela fastidiosa*, sponsored by FAPESP, the Sao Paulo Sate Foundation for Science. The paper traces this feat that proves that it is possible for developing countries to actively participate in cutting-edge research, in a narrative that, without undermining the talents and skills of the research groups involved, underlines the role of research management in the success of this network. In 1997 FAPESP leaders began to discuss how to share scientific and economic opportunities that might accrue from the genome sequencing by producing its own data, analysing and using its results for local scientific projects. Aware of the Brazilian deficiency in molecular biology and genomics, a conscious decision was made to bookstrap Brazil's genome research, which so far had been fragmented among dozens of laboratories throughout the large state of Sao Paulo.

After studying the idea of building a new facility, Negraes and Egler explain how and why it was preferred instead of creating a 'virtual institute' of experts in the form of a network of thirty-five laboratories scattered throughout Sao Paulo state. They narrate how, as reported by the DNA coordinator, when the project started no one knew the bacteria, the coordinator had never sequenced a genome before, he had not worked with bacteria and did not even know what *Xyllela fastidiosa* was; the informatics coordinator had never dealt with a DNA project in his life nor with a team spread throughout Sao Paulo state. Not a single researcher had sequenced anything and several knew almost nothing of molecular biology. Nobody in the state had a live bacteria, even less DNA or a DNA library. But both FAPESP and the core group of scientists involved were convinced of the local availability of important research capacities and skills that would enable the development of genomics in the country,

although they recognised the difficulty of integrating such a disperse and heterogeneous critical mass. The implications of this for developing countries is obvious: the existence of a scientific community and its professionalisation are very important. Without some critical size of modern biological labs and specialist groups, the feat could not have been successfully completed. But besides, there was also the required support offered by the always timely and adequate financial and close but flexible managerial monitoring of FAPESP.

The strategy of a network structure is shown to have been particularly apt for the Brazilian case, where the scientific community is relatively small and there is not such an intense competition as in the case of larger communities. In this case inter-institutional rivalries were reduced, increasing cooperation and concentrating attention in a small number of relevant scientific challenges. The sequencing of bacteria was finalised in January 2000, almost four months ahead of schedule. This was the first time scientists had ever mapped the structure of the genome of a plant pathogen. The choice of the organism to be mapped was made on the basis of criteria of scientific relevance, technical feasibility and local socio-economic relevance. *Xylella fastidiosa* is a bacterial pest that damages 34 per cent of Brazil's orange crop. Sao Paulo state is one or the largest orange producing regions in the world, with almost 30 per cent of the world production of orange juice. The project generated the knowledge and mastery of the most modern research techniques in molecular biology, training some sixty research groups in Sao Paulo state. The network organisational form, in the view of the authors, involves much more than the simple integration of the actors or their interaction through advanced communication networks. The key to its success, it is argued, would be in the way the complex actors' integration took place.

The 1990s witnessed an explosion of reforms in Latin American public policies and in the institutional framework within which R&D is carried out. However, despite a few honourable exceptions, there is a common perception that the executive and judicial Latin American apparatus continues to be immersed in a stalemate with the same bureaucracy, dissatisfied functionaries, poor service to clients and other unsavory defects as in the past. Party politics and short-term electoral criteria interfere with processes that ought to be clearly of a technical nature, and bureaucratic morass is entrenched in the midst of supposedly modern institutions (Waissbluth 2002). Public technology institutions tend to be rather costly and inefficient. Many R&D institutions do not support productive technological activity. Research bodies are generally de-linked from the sectors

they are to serve, doing basic research of poor quality and no practical use. Many are out of touch with international trends, have outdated equipment and libraries, and employ underpaid, badly managed and unmotivated personnel. Most universities do little research, and cannot link what they do to what the firms need. Nevertheless, the need for good knowledge infrastructure is undeniable. This is part of the reason why socio-institutional constraints as well as new attempts to overcome them are watched closely by several contributions in this issue. Two papers in particular emphasise the significance of the socio-institutional conditionings in the analysis of innovation and they do so in complementary ways: one of them by considering the effect of Brazilian and Venezuelan R&D policies upon the behaviour of firms, and the other by putting the accent on the recent evolution of the Mexican R&D institutions belonging to the Secretaría de Education–Consejo Nacional de Ciencia y Tecnologia (SEP–CONACYT) public technology subsystem.

A comparative study of the industrial chemical complexes of Brazil and Venezuela carried out by Mercado contributes to the understanding of innovation and technological change in intermediate countries, for it shows how different socio-institutional development processes exerted a significant influence in shaping their technological capabilities. A greater consolidation of socio-institutional spaces for innovation in the Brazilian case (including policy and R&D) helped achieve a more complete integration of the industrial complex and the development of greater learning capacities than in the Venezuelan case. Comparison is carried out at two levels: a general one where the broad trends of technological learning are drawn for each complex and an analysis is made of aspects relative to entrepreneurial culture on the basis of the perceptions by the firms of the socio-institutional constraints upon technological capability; and at a second, more specific level, the techno-productive specificities of the industrial segments are considered and both the role of technological patterns in guiding innovation as well as the influence of the socio-institutional environment upon the development of learning capabilities are examined.

Mercado finds confirmation of the hypothesis that the techno-productive features of the industrial segment determine the technological trajectory followed by the firms. However, the socio-institutional environment is shown to have a large influence upon firms' innovative possibilities: it may induce them to innovate or not to, to foster learning to a greater or lesser extent, and even to foster changes in the technical structure. Thus, socio-institutional arrangements turn out to be basic in the

learning process of an industrial sector. Industrial policy programmes, agreements between actors and the formation of networks of the different institutions promote or induce innovation within productive units. Probably one of the most significant findings of the paper is that the process of techno-productive integration is associated to higher levels of technological capability, making it possible to assert that, at least for the chemical industry, there is proportionality between the level of techno-productive integration and the deployment of greater innovative efforts. Through an analysis of the competitive capacities of both industrial complexes, it is shown that Brazilian firms tend to present the best performance profiles. However, some Venezuelan firms also manage to do so despite devolving in a socio-institutional context less favourable to innovation. Access to regional markets emerges as a space of important opportunities for firms that have built up intermediate capacities of technological learning.

Turning their attention to the situation of public technology institutes of Mexico, Jimenez and Zubieta describe a broad range of institutions that vary considerably as far as the activities in which they engage, although several play multiple roles. There has been a persistent debate about the relative merits of multi-sector technological centres vis-à-vis those that are sector specific. Although in other regions of the world there are examples of highly successful multipurpose technological institutes, in Latin America in particular the concept of a large multi-sector technological centre has lost favour in view of the difficulties found by several of these institutions to develop and sustain adequate links with firms that would be prepared to pay for their production. In the early 1990s Colombia closed down its Institute of Industrial Technology (ITI) and Peru did the same with the Institute of Industrial Technological Research and Technical Norms (ITINTEC) a few years later. It may be that the management style constitutes a more critical variable than the sector approach to determine the success or failure of individual technological centres (Mullin et al. 2000). The Mexican institutes specialise in fields that go from leather and shoe industry to applied chemistry, materials research, electrochemical research, research and consulting in technology and design, and industrial and development engineering, trying to promote closer links between the processes of technological development and their application to production.

As shown by current evidence, it is increasingly recognised that technological institutes are in a better position to interact with the firms they are destined to serve if they have a more entrepreneurial non-bureaucratic management style. In many countries the application of the rules of public

service to technological institutes has rendered them unable to respond effectively to the needs of their potential clients. One of the Mexican institutes, the Mexican Corporation on Materials Research (COMIMSA), was already created as a firm, and contributes the largest amount of self-generated income of the group under analysis.

A basic consideration in the functioning of technology institutes today refers to budget sources. The days when governments were ready or in condition of contributing 100 per cent of the operational budget to those institutes belong to the past. Today there is more emphasis in diversifying the sources of income. They are expected to become more economically self-sufficient. With the exception of COMIMSA, in the Mexican cases under analysis of the SEP-CONACYT technology subsystem, the average federal contribution in the annual budgets is still over 80 per cent. It is also admitted, however, that there is the need to have a relevant and balanced portion of the funding of these institutions allocated through stable and long-term resources. Otherwise they could be forced to act exclusively with a short-term self-financing orientation that may be is 'economically efficient' but that will inevitably distort strategic long-term missions. Unless the relevance of many of the technological subjects for the competitiveness and well-being of the nation, and an image of trust and accountability are adequately transmitted to the broader society it will be difficult to achieve the stable long-term resources required for the construction of capacities in critical subjects (OTI 1999). It seems clear from the authors' analyses that the public functions of the technology institutes of the SEP-CONACYT subsystem involve a complex group of functions, generally related to failures of the economic market, aimed at establishing conditions for an innovative economy, fostering the development of key elements of the national economy, and providing the infrastructure for a modern economy.

The scientific changes that receive attention in the papers gathered in the present issue of *Science, Technology & Society* involve not only new scientific knowledge in the traditional sense of discipline building, be it molecular biology, genomics, fine chemistry or catalysis, but also different work methods, management techniques and organisational relations between a varied number of social actors besides scientists. They imply new linkages, networking and information flows between countries and institutions, and the research, service and productive sectors. While the main locus of scientific progress continues to be the advanced industrial world, Latin American countries, being a part of the developing world, are also participants in the techno-scientific revolution. All papers, even

those dealing with basic scientists in academia, lend attention to the correlated issues of technology, the Achilles heel of the region's national innovation systems at the time of using the knowledge they possess. Capability building must occur at all levels. Formal R&D and advanced basic research in particular are at one end of the spectrum of creative activity and do not exhaust it. R&D becomes important as more complex technologies are used. The efficacy with which the new knowledge produced by the interaction between foreign and local knowledge is used depends on a complex of local efforts to promote learning by enlarging and deepening the absorptive base. But the onus is not only on the local stakeholders. It seems obvious that the international rules governing today's market economies must change their moral character if we are all to have equal opportunity of a common humane future.

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