Science in Latin America

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Excellence in science and technology has a long tradition in Latin America. The elegant curved walls of El Caracol ("The Snail") set it apart among the other, quadrangular monuments that grace the archaeological Mayan site of Chichén Itzá, in the Yucatán Peninsula of Mexico. El Caracol is the most magnificent ancient astronomical observatory standing in the world, built while Europe lay in the Dark Ages. Slanted openings in the walls and roof allowed Mayan astronomers to observe the alignments and measure the movements of planets and stars. Mayan astronomers contrived precise tables for the positions of Venus and Mars and predicted solar eclipses. They developed a dual calendar that identified every one of the 18,980 days in a cycle of 52 years by a combination of a name and a number. The Mayans' advanced mathematics included the invention of the zero and positional notation. Mayan knowledge and history are recorded in stellae, monuments, and codices written in a language with 850 hieroglyphic and phonetic characters.

The city of Cuzco (Quechua for "Navel"), perched 4000 m above sea level in what is now Peru, was, when Francisco Pizarro arrived in 1533, the capital of an Inca empire that covered most of South America west of the Andes, and commanded a population of 12 million people. The Incas had domesticated guinea pigs, ducks, llamas, alpacas, and dogs, and cultivated corn, potatoes, tomatoes, peppers, squash, cassava, coca, peanuts, and cotton. The Incas, like the Romans, maintained dominance over the empire through an array of roads that facilitated rapid communication between distant parts of the empire and the governing center. Two 3600-km-long systems of roads, one along the coast and the other along the Andes, made possible a relay service that, without horses, conveyed messages at a rate of 250 km per day.

During the colonial period of the 16th and 17th centuries, 30 universities were founded in Spanish America, well in keeping with policies then prevailing in Spain, where in the 16th century the proportion of university students was greater than anywhere else in Europe. The New World universities provided education to the economic, political, and religious elites, but, like contemporary universities in the rest of the world, were not centers of scientific research.

Scientific research during the colonial period was performed by expeditions that studied geography, agriculture, botany, and natural history. In 1570, Francisco Hernández, Philip II's personal physician, headed a 7-year-long expedition to find plants with medicinal and commercial applications. José de Acosta published in 1591 a *Natural History* that cataloged metals, plants, and animals from the Americas. Many animals and plant crops were, during this period, transferred from Europe and adapted to local conditions: rice, wheat, barley, sugarcane, bananas, and all sorts of legumes and fruits.

Expeditions and scientific activity slowed down after the 17th century, except for a burst of activity during the Spanish Enlightenment, coinciding with the reign of Carlos III (1759–1788). The model of the research university, born in continental Europe in the early 19th century, was introduced late. Scientific research as an integral component of the modern university begins in earnest in Latin America only after World War II.

During the 1950s and 1960s many governments in the region created national research councils dedicated to promote and finance scientific research; science, or science and technology, ministries became established in several countries. Consequently, investment in science increased in the universities, as well as in specialized research centers and institutes created to meet distinctive objectives.

In Argentina, Brazil, Chile, Colombia, Mexico, Venezuela, and other countries the pace of investment in scientific research and development (R&D) hastened during the late 1970s and early 1980s, as the countries experienced rapid economic expansion, largely financed by external loans. But investment in R&D was curtailed in the 1980s as the countries encountered difficulties meeting the principal and interest payments of their large debt. The net result of the two decades was, however, positive. Moreover, a new wave of investment in and expansion of scientific activity has started with the 1990s that augurs well for the scientific future of the region.

The 27 countries of Latin America and the Caribbean region have a combined population approaching 450 million people, larger than the population of the United States (U.S.) or the European Union (EU). Yet the 1991 Latin American share of the world's scientific publications was only 1.4%, whereas the U.S. share was 26 times that (35.8% of the world's) and the EUs share 20 times that (27.7%) (*1*). That is the bad news; the good news is that between 1983 and 1991 the world's share of papers published by Latin American scientists had increased from 1.1 to 1.4%.

There is another way of examining the productivity of Latin American scientists that provides grounds for cautious optimism. The gross domestic product (GDP) of Latin America is $715 billion (data for 1990), the GDP of the U.S. is 7.5 times as great and that of the EU is 6.8 times as great. Per dollar of GDP, scientific productivity in the U.S. or the EU is four times that in Latin America. The difference, however, disappears if we look at the fraction of the GDP invested in R&D, which is 0.45% in Latin America but 2.9% in the U.S. and 2.0% in the EU (Table 1). In dollars, Latin America invests 2.9 billion in R&D, whereas the U.S. and EU invest 40 to 50 times as much. Thus, in terms of the amount invested in R&D, the Latin American scientists are holding well their own: The U.S. and EU invest 40 to 50 times as much money but produce only about 20 to 25 times the publications. This observation should reassure those Latin American governments that are making a sustained effort to increase the fraction of the GDP their countries invest in R&D.

Latin American governments are increasingly acknowledging the impact of science and technology on the industrial and economic development of a nation. In President Clinton's words, "Technology—the engine of economic growth—creates jobs, builds new industries, and improves our standard of living. Science fuels technology's engine" (*2*). The number of patents granted are one indicator of the economic impact of scientific research. In 1991, Latin

Table 1. R&D investment in selected Latin American countries and publications. Data from [(*1*), p. 34]; updated to 1990 for Colombia and 1991 for Chile (*4*).

Country	$ million	% GDP	Publications (per 10^6 inhabitants)
Argentina	466	0.80	62.1
Brazil	3,179	0.89	26.4
Chile	148	0.52	92.0
Colombia	206	0.60	16.5
Costa Rica	43	0.89	38.5
Cuba	171	0.85	15.3
Ecuador	11	0.11	6.1
Mexico	961	0.35	19.3
Peru	106	0.23	8.5
Uruguay	18	0.20	32.0
Venezuela	200	0.45	27.1

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Americans received 0.1% of all patents granted in the EU and 0.2% of those granted in the U.S. This poor show reflects the region's scarce investment in R&D. But the increased rate of investment of the last decade is having an impact here as well: Between 1986 and 1991 the number of all patents granted to Latin American applicants augmented faster than those to U.S. or EU applicants by 28 and 32%, respectively.

A model eyed with interest by Latin American policy-makers are Southeast Asia's "five tigers": Hong Kong, Malaysia, Singapore, South Korea, and Taiwan (3). Twenty years ago, these countries invested about 0.1% of their GDP in R&D, by 1981 it was 0.6%, and by 1991 it had grown to 1.6%. Concomitantly, between 1983 and 1991 their share of the world's scientific productivity and patents tripled. The economic consequences are well known: The five tigers have changed from underdeveloped countries to industrialized nations that enjoy high living standards.

REFERENCES

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Future of Science in Latin America

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The rapid progress of technology and the great achievements of science in this century have produced profound changes in our lives, in the world economy, and in our perception of the physical world. These accomplishments were, however, achieved by a small community, concentrated in industrialized nations. One is left to wonder what could have happened if the full potential of human resources had partaken in this effort. Understanding the reasons for the small contribution to science and technology (S&T) from Latin America is not only of academic interest but essential for promoting the economic and social development of the region. While the role of technology is to a large extent well understood by the governments, the importance of basic research is not. Unless their interconnection is recognized, it is doubtful that a productive system of S&T can be implemented.

In order to understand the dearth of scientific productivity in Latin American countries, it is necessary to review both the origin of the educational and research systems, and the obstacles faced by the scientific communities in the recent past. Most of the difficulties encountered today are a result of the social organization of the countries in the area. These countries are characterized by small dominant elites, strong central governments, oppressive bureaucracies, weak economies, fragile institutions, and unstable political systems. These characteristics largely account for the ineffectiveness of Latin American research efforts. Improvements of the S&T systems in the region will require, above all, fundamental changes in attitudes and administrative habits of the governments, while scientists will have to recognize the need for making realistic decisions regarding new investments.

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Origin of Educational and Research Systems

In Latin America, the process of industrialization had a late start, and access to higher education was until recently limited to the upper class. Emphasis was placed primarily on subjects such as literature and law rather than on more technical careers. Few universities were created in Latin America during the colonial period. In Brazil, the first university was formally founded as late as 1920.

Only recently did countries in the region awaken to the importance of developing their own technological capabilities. The foundations for an S&T system were established only after World War II, coinciding with the process of industrialization of major countries in the area. At that time, national research councils were created to coordinate and fund scientific research, and the first research centers were organized to complement the existing university system. In the late 1960s universities were subjected to major reforms and the first graduate programs were implemented.

Period of Growth: The Brazilian Experience

During the economic boom of the 1970s, heavily influenced by the military dictatorship, research in Brazil was reasonably well funded and large numbers of graduate students were sent to study abroad. The main policy goals were to train the necessary personnel for the new graduate programs and to expand the disciplines of research, with special emphasis in strategic areas such as the nuclear and space programs. These investments resulted in a remarkable growth of the scientific community.

On the negative side, several active scientists were forced to leave the country for political reasons, and their absence created a large vacuum in leadership. In addition, no significant effort was made to modernize physical installations or organize local institutes, in preparation for the return of new graduates. These graduates had to face problems such as the lack of office space and inadequate libraries and computer facilities. Instead of concentrating on their research, they had to spend valuable time setting up basic infrastructure. They often had to face resistance to change from the existing senior staff, which controlled the institutes, mostly because of their seniority rather than scientific merit or vision. Ironically, the same government that sponsored the research program prevented the upgrading of the installations through several restrictions on the importation of lab equipment and computers.

Because of the lack of leadership, there was no coordinated effort aimed at modernizing the institutes. Instead, this process had to rely on individual grants, and young scientists had to get immediately involved in fund raising. This condition resulted in an uneven growth of research groups and extremely heterogeneous institutes, ultimately leading to serious power struggles. Not rarely, individuals took precedence over institutions, and a number of institutes were unduly divided. These internal disputes seriously weakened the institutions and jeopardized their ability to define long-term goals and to optimize the local human and financial resources through support of a few well-defined research programs. Instead, research was carried out in a number of fields, none of which had enough scientists to make it internationally competitive.

Serious problems also occurred at the national level (*1*). In some fields, the relatively small number of scientists caused the break-down of the peer review process as considerations other than merit guided the distribution of grants. This practice resulted in intense regional disputes, which generated mistrust and undermined attempts to define common national goals.