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What Is the Role of Science in Developing Countries? José Goldemberg

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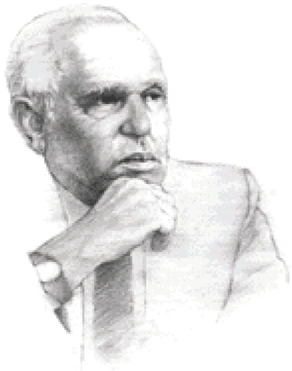


After the Second World War, a small technical elite arose in developing countries such as India, Pakistan, Brazil, and Iraq who had been educated as scientists in the industrialized world. They thought that by pushing for Manhattan project-type enterprises in nuclear energy, electronics, pharmaceuticals, or space research they could leapfrog the dismally low level of development of their countries. India, for example, started a nuclear energy program that mobilized thousands of technicians and cost hundreds of millions of dollars but failed to meet power demands.

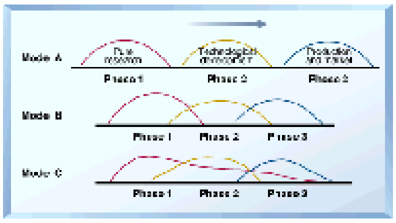
What my scientist colleagues and national leaders alike failed to understand was that development does not necessarily coincide with the possession of nuclear weapons or the capability to launch satellites. Rather, it requires modern agriculture, industrial systems, and education. The technical elite naïvely believed that spin-offs from their nuclear energy or space programs would somehow convert their countries to 20th-century industrialized states. Instead, there were heavy economic and political costs. In India, for example, such programs led to the development of nuclear weapons--which only encouraged Pakistan to do the same--while many basic human needs such as health and education were not given the support needed.

In my view, this scenario means that we in developing countries should not expect to follow the research model that led to the scientific enterprise of the United States and elsewhere. Rather, we need to adapt and develop technologies appropriate to our local circumstances, help strengthen education, and expand our roles as advisers in both government and industry. In this way, we can prevent the brain-drain that results when scientists are not in touch with the problems of their home countries or when they face indifference--and poor financial support--from their governments.

In Brazil, the use of ethanol as fuel is one example of how this approach can work.[1] By encouraging the wide use of ethanol produced from sugarcane--a traditional crop in the country--as fuel to replace gasoline, the government of Brazil was able replace half of the gasoline used by automobiles in the country (about 200,000 barrels of ethanol per day) with a renewable energy source. In so doing, Brazil became a pioneer in an area that had been neglected by industrialized countries.

The entire technology, from the agricultural to the industrial phase, was developed or improved upon by local scientists and technologists. I and other Brazilian scientists first had to convince the government that this approach was technically feasible, even though it had been ignored in industrialized countries. To do this, we had to address questions regarding motor technology, environmental concerns, and the trade-off between raising crops for food versus fuel.

In general, the misconceptions held by the technical elite are derived from an idea cherished by many in the developing world that pure research leads to technological development and then to products that open new markets or conquer existing ones (see figure, model A). This naïve "linear theory" or "cradle-to-grave" approach to science and development served as the blueprint for the establishment of the National Science Foundation in the United States and was widely copied throughout the world.[2] But that model fails to stress the interaction that should occur among the phases. As one moves from pure research to technological development and then to production and marketing, unanticipated problems arise that require reexamination and adaptation at the earlier stages.



Three models for the relationship between science and development.

More realistic are models B and C.[3] Model B corresponds, generally speaking, to present practices in the United States, where some overlap exists between the successive stages. Model C illustrates the Japanese practice of having the three phases completely superimposed. These are the more realistic models that developing countries should follow. In models B and C, practical needs--that is, demand--influence supply, namely, the type of pure research that is done. For example, after solid-state devices such as transistors made possible the expansion of switchboarding in telephone services, industrial laboratories such as Bell Laboratories lavishly financed solid-state physics.

In developing countries, government goals and the "demand side" pull are often lacking. As a result, universities and research centers have become isolated from the rest of the country in an ivory tower, more connected to research centers in Europe or the United States than to the obvious needs of industry, agriculture, and education in their own countries. Science and technology budgets receive little support from the private sector and instead depend on the national treasury.[4] Heavy government bureaucracies wind up cultivating whatever science and technology is fashionable in the developed countries, waiting indefinitely for the time when such competence would trigger development in a manner that resembles the wait for Godot in Beckett's play.

What, then, is a realistic view of the role of basic science in developing countries? After all, many outstanding scientists born and educated in developing countries have contributed significantly to the advancement of science. Talent exists everywhere. What can they do to help their countrymen in solving the problems of development? The answers, in my view, are the following:

1. Help adapt technology to local circumstances. Even when technologies are imported from abroad, research is necessary to make them work. Rather than insisting on developing indigenous technologies, when abundant and well-proven technologies exist, scientists can help choose the right ones, given the local environment and available raw materials, and learn how to use them. An example is given by the "green revolution." Despite its shortcomings, this "imported" technology, when applied properly in the developing world, helped eradicate hunger. Problems with the use of pesticides and fertilizers arose because of abuses by commercial interests and because, owing to a lack of knowledge, users and local scientists failed to provide the expertise or make the adaptations necessary to make the best use of the imported technology.
2. Incorporate new science into education. Development requires a well-trained work force; therefore, high-quality education must be put in place early in development. The teaching of modern science in engineering or medical schools cannot be restricted to the same old classical textbooks but has to be done by active scientists who read the current literature and are capable of conveying the latest advances to their students. This approach worked well in the 19th century during the Meiji restoration, which brought Japan into the modern world.
3. Be involved in government. Science and scientists are an important element in choices and decisions made by governments and can make a difference. For example, at one time the Brazilian government had to set the reservation boundaries for the Yanomamis, a primitive group of some 10,000 indigenous people living in the mineral-rich Amazonia. The issue was whether to set up one large, or several small, reservations. The military and the mining groups favored small reservations, as Indian reservations are "out of bounds" for them according to Brazilian law and could restrict their movements in that region. But anthropologists advised that this solution would destroy the Yanomami civilization, because these Indians were accustomed to long-distance migrations. As the federal Secretary for Science and Technology, I argued for one large reservation, a solution that was adopted.

I also helped to mediate a conflict in Brazil between multinational enterprises that had computer technology and wanted free access to local markets, and local entrepreneurs who wished to preserve the markets for themselves. In the 1980s, the local entrepreneurs convinced the government to establish high import barriers, virtually isolating the region and condemning it to use obsolete technology. I helped resolve this issue by convincing foreign companies and local enterprises to set up joint ventures in which the technology came from abroad but the manufacturing was local.

Scientific research is motivated not only by curiosity or love for science, but also by fashions and the perception that some areas of research are more rewarding than others. The current emphasis given to costly therapeutics for the treatment of AIDS is counterproductive in developing countries, where a vaccine against the disease is the only real hope. It is important that developing countries avoid the allure of costly but ineffective programs and establish a system that rewards solving practical problems. Although that emphasis may seem to stray from the tradition of academic research, the truth is that many seemingly mundane problems require very sophisticated tools and technologies. And science can accelerate progress. This has occurred in agricultural research, which is highly advanced in developing countries such as Mexico (corn), Brazil (soybeans and sugarcane), and the Philippines (rice).

In conclusion, my experience has shown that the transition of a country from developing to developed is a complex process that requires facing up to the established interests in society. The impetus for this has to come not only from scientists but from other sectors of society as well. In a world where globalization and competitiveness are the rule, progress requires that developing countries find areas in which they are significantly better than their competitors because of a better trained work force, favorable natural resources, or scientific and technological capabilities. Science and scientists can play an important role in determining those choices and implementing development strategies.

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[1]J. Goldemberg, L. C. Monaco, I. C. Macedo, in *Renewable Energy--Sources for Fuels and Electricity*, T. B. Johansson, H. Kelly, A. K. N. Reddy, R. H. William, Eds. (Island, Washington, DC, 1993), pp. 841-863. [2]V. Bush, *Science, the Endless Frontier* (U.S. Government Printing Office, Washington, DC, 1945). [3]H. Brooks, *What We Know and Do Not Know About Technology Transfer. Linking Knowledge to Action in Marshalling Technology for Development*, from a symposium held in Irvine, California, 28-30 November 1994 (National Academy Press, Washington, DC, 1995), pp. 83-96. [4]J.-J. Salomon, in *Strategies for the National Support of Basic Research: An International Comparison*, proceedings of a conference sponsored by the Israel Academy of Sciences and Humanities, Jerusalem, 23-26 October 1994 (Israel Academy of Sciences and Humanities, Jerusalem, 1995), pp. 23-41.

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