Brazil, Science, Technology: Some Dilemmas and Challenges

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The importance of the options that will be made in the field of science and technology for the development of Brazil is evident today. But the scope of this essay requires that I choose certain aspects of such a vast theme. Therefore, I chose to concisely describe some organizational dilemmas, instead of dealing with internal challenges to science and technology. One of these involves how to balance the scientist's freedom and society's need for knowledge; another is the tension between the individual pleasures of creation and the objective conditions of the structure wherein the scientist works. I will also consider alternatives between a centralized generation of science and technology, and regional imbalances. And I hope to propound alternative funding sources and examine the challenges that derive from the ongoing conflicts between public and private dimensions. Furthermore, it would be difficult to conceive this subject without analyzing the current relationship between science, technology and innovation. Lastly, although the ethical dilemmas of science pervade all the above issues, they are quite another matter and will not be dealt with here.

At this moment in time, when globalization is presented as inevitable even as its meaning or meanings remain unclear, writing about the challenges to science and technology in Brazil implies clarifying the alternatives that may be borne bout by recent history.

Since the Industrial Revolution, the evolvement of science has been inseparable from its applications in the developed world. The boom in science financing in the United States after Sputnik was launched is a classic example. In the late 1950s, political needs determined massive investment in science at all levels, from secondary schools to research centers, from universities to corporations. The State's procurement might, in what was the world's most capitalist country, enabled the military/industrial complex to exert a growing pressure on research organizations, which then expand to cover every field of knowledge. The result of such State-funded pressure was soon felt and the United States, both qualitatively and quantitatively, became the foremost center for the production of knowledge, technology and products in the ensuing decade. The Japanese interlude, as well as the short dance of the Asian tigers, without the sustenance of a corresponding knowledge base, were ephemeral and never actually threatened the actual supremacy of the United States.

In times of globalization, it also becomes clear all over the world that the State's procurement power plays a leading role in those areas where social needs are marked by public interventions. Health, education and security, among others, continue to be, even in Brazil, areas where the public sector is fundamental. The interrelationship between the State's procurement power and scientific/technological development is clear in the developed countries. Brazil's adoption of this relationship might become a determining factor for the future of our science/technology and innovation systems – and, consequently, for our development. Changing the State's procurement power into a tool for scientific and technological development is a possible but not assured decision, given the existing pressures to reduce the presence of the State. The regulatory nature of the State in several areas does not diminish its power to procure, while in others it is precisely the State's procurement power that determines market sizes and relationships. As has happened elsewhere, technological development and the basic science associated with these technologies could be enhanced if the State decided to exercise its procurement power.

In the developed countries, the means to sustain the science-producing system extend from areas that are directly related to applications to others that apparently bear no relation whatsoever. The increased density of the "frontier" areas, often defined as those closest to an application, has enabled the entire extent of science to expand continuously in countries where science is duly applied. And applications may appear from where one least expects them. Who could have foreseen,

for instance, that the observation of lotus leaves under a scanning electron microscope would lead to paints that, once applied, result in self-cleaning cars?[1]

In the developed countries, the results of this pressure to innovate extend from private interests to the State's procurement power. Particularly in recent times, this pressure has engendered a science-producing structure whose thematic density varies in time but, on average, grows inexorably.

And Brazil? Of course, evolution here is different. In this tropical country, whose very name derives from a tree, the export of brazilwood for dye extraction was not followed by a greater understanding of dyes or of how to conserve the trees that produced it.

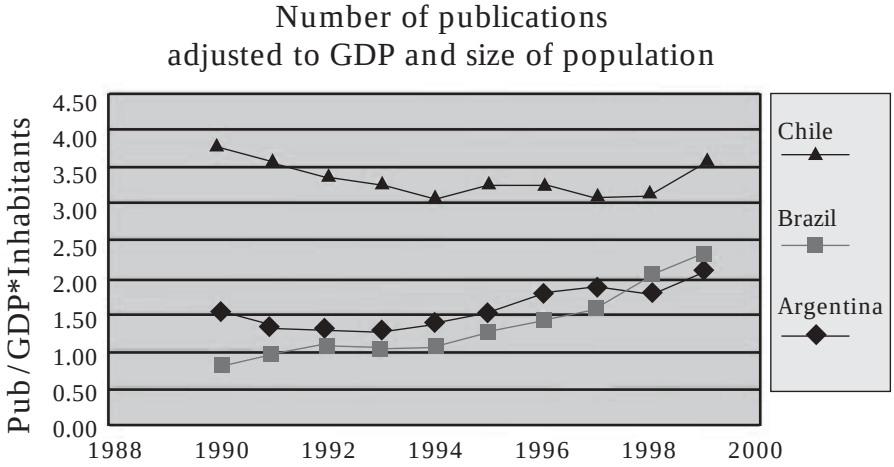
In Brazil, the organized production of science is a fairly recent event. To be sure, we have always had scientists and some major discoveries were made here. But how does one organize science if the Portuguese Crown avoided at all costs the establishment of universities in her colony? Where might scientists gather to exchange ideas if the Brazilian Academy of Sciences was founded less than eighty years ago? Some of our public research institutes, older than the universities, have had spurts of scientific creation and precious applications, followed by long periods in dire straits. The history of the professionalization of science in Brazil into a stable structure began with the founding of the University of São Paulo in 1934, introducing the concept of full-time dedication for faculty and researchers, which soon spread throughout Brazil. Because, as the saying goes, "everything planted here grows" the result of this seedling was possibly one of the most successful public initiatives of the last thirty years.

To analyze the recent evolution of science in Brazil, I have resorted to a system of organizing scientific information that compiles titles and summaries of works published in international journals: the Institute for Scientific Information (ISI). The use of this database has been sufficiently discussed and I will not attempt to justify it here[2].

1. Barthlott W. and C. Neinhuis. "Purity of the Sacred Lotus or Escape from Contamination in Biological Interfaces", *Planta* 202, nº 1, 1997. See also www.botanik.uni-bonn.de/system/bionics.htm.
2. Meis, L. de, and J. Leta. *O Perfil da Ciência Brasileira*, Rio de Janeiro, Ed. UFRJ, 1996, p. 104.

Patents, which are an indicator of innovation, now increasingly display on their title page references to the same works indexed at the ISI. In more technologically active areas, the number of indexed scientific publications is becoming similar to the number of references to other patents – not to mention that these references have a strong national bias, that is, one country's patents tend to mention scientists from the same country more frequently than from other countries. Thus falls another myth, that countries that do not produce science may innovate with the science of others. [3] One of our most glaring challenges is a joint effort by universities, companies and government to assure that Brazil's modest contribution to patents will grow at rates comparable to the production of science, without impairing the different nature of each partner.

Brazil's contribution to indexed science has increased from 0.4% in 1990 to more than 1.2% in 1999. This ten-year increase reflects deliberate decisions that have more to do with funding science and postgraduate courses than with a corresponding increase in per capita GDP. Few countries in the world made this leap – a result of decisions and not determinist changes in per capita GDP in this part of the continent. Comparative data for some Latin American countries suggest this is a sustainable assertion. See Figure 1.



Source: ISI and InterAmerican Development Bank

3. Narin e Olivastro, Hamilton. *Research Policy,* 26, 317, 1997.

In Brazil, the ratio between number of publications, per capita GDP and total population has increased significantly over the last decade, notwithstanding the fact that the growth of Brazil's per capita GDP was the lowest in the period. The growth of per capita GDP during this period in Chile, Argentina and Brazil was 56%, 36% and 8%, respectively, according to the InterAmerican Development Bank. Using the same ratios, the rate of scientific production in the United States in 1999 was 5.89, and its per capita GDP ten times that of Brazil.

Thus, after adjusting the number of Brazilian scientific publications to the growth of the population, and even if our economic performance in the decade was poor when measured by per capita wealth, the performance of the small segment of the population that produced science deserves mention. The participating of public universities in the national development effort cannot be overstressed, notwithstanding the current fancy of stubbornly insisting on the bankruptcy of every public service. In Brazil, practically all production of science takes place in public universities, where undergraduate admissions remain stable but graduate and postgraduate courses are expanding. The expansion of higher education, which today embraces more than 2 million students, occurs mainly in a private system that contributes little to the national production of science and technology.

Thus, the central issue is the sustainability and growth potential of this hard fact. Consequently, decisions must be made to assure the sustainability. Or, alternatively, we must become aware that other decisions may quickly deter this spectacular growth. Such matters must be considered in the light of social convenience, and not merely as something that arises from the dynamics of the production of science.

We are sufficiently aware that, one, science and technology do not promote socially equitable development and that, two, no development is possible nowadays without an adequate science and technology system. Thus, when considering the need to consolidate our science and technology system, we must not go as far as believing that it is the system that determines development. There is no sustainable future if a country's science system is not related to its innovation system – adding value to export products, solving the serious income distribution problems and providing access to health services.

All over the world, the most significant funding source for science systems is the government. Basic science is developed almost entirely in universities and research institutes. In spite of all that has been said about the importance of private

financing of basic science, all available data in the world show that this subsystem is overwhelmingly financed by public funds. Some areas may be temporarily more benefited than others in terms of funds for basic science development, but the system depends on harmonious financing that must essentially cover all fields of knowledge. Political decisions concerning this line of funding derive from an understanding by the State of the correlation between the production of basic science and the other systems that contribute to socially equitable development.

It is well known that science cannot be planned; however, investment in science must be planned[4]. The dilemma between the individual will of scientists (workbench) and the need to invest in priority areas (program) is a longstanding concern. The recent history of FAPESP shows how this dilemma may be solved in practice. The recent increase in the significance of FAPESP's programs has not inhibited, nor diminished, the balcony. Quality assessment is a common referential for the workbenches and for the programs.

The challenge, however, is extending this policy to Brazil as a whole. When the long-awaited Sectorial Funds finally emerge to finance specific research fields with new public resources, it is essential to continue funding the individual initiatives of researchers in every field of knowledge. Every federal funding agency must be aware that the workbench/program equilibrium must not entail workbench financing only for projects with a high probability of success. We would then run the risk of abating the central component of creation in science, namely, the quest for the truly unknown. In this sense, an additional challenge in planning science investments is to determine which undeveloped areas are avowedly a hindrance to the development of science itself – increasingly interdisciplinary nowadays. An example is the acknowledgement that the post-genomic age is entirely dependent on the development of so-called bioinformatics.

In Brazil, considering that the generation of science and most technological development takes place in public universities, access to higher education and the preservation of the research structure are a particularly crucial challenge today. The number of graduates in the secondary school system increases much quicker than the number of openings in the current university system. Thus, the dilemma also

4. Chaimovich, H. "Sobre Planejamento e Ciência", *Jornal da USP*, Jun. 1998.

comprises the challenge of increasing the number of students admitted to institutions of higher learning. However, increasing the number of enrolled students in public universities without expanding the faculties and the infrastructure may destabilize the entire production of science in Brazil.

To face this dilemma, we must consider that perhaps not all higher teaching should necessarily take place in research universities. Without going into technological details, including distance learning, an bird's-eye view of the world will show us that in every country where more than 50% of 17- to 25-year old population is enrolled in institutions of higher learning (in Brazil the figure is 11%) the system is highly differentiated, i.e., we find the coexistence of research universities, universities that don't grant doctoral degrees, professional establishments, junior colleges, post-secondary technical schools and a wide variety of forms and structures of learning.

One of the cultural characteristics of our milieu is the reproduction of a single form of teaching, the university, wherein the relationship between teaching and research, more than an organizational trait, is a way of responding to laws that, formally, should be obeyed. Public universities will be hard put to survive as producers of knowledge if the higher education system in Brazil is not differentiated, if the number of student admissions does not increase and if there is no massive investment in personnel and infrastructure. As we are unlikely to see public investments of such magnitude, this dilemma might only be solved by differentiating the higher education system. Of course, the public sector is likewise responsible for this initiative, inasmuch as the expansion of the private system has resulted in organizations that, although formally replicating the public universities, lack the ability, or the interest, to provide alternatives. Thus, it is possible that with investments commensurate with our current situation, the creation of a differentiated system of public higher learning will result in more and better educated youths, in the consolidation of the research universities and – why not? – in the private sector providing alternative forms of post-secondary education.

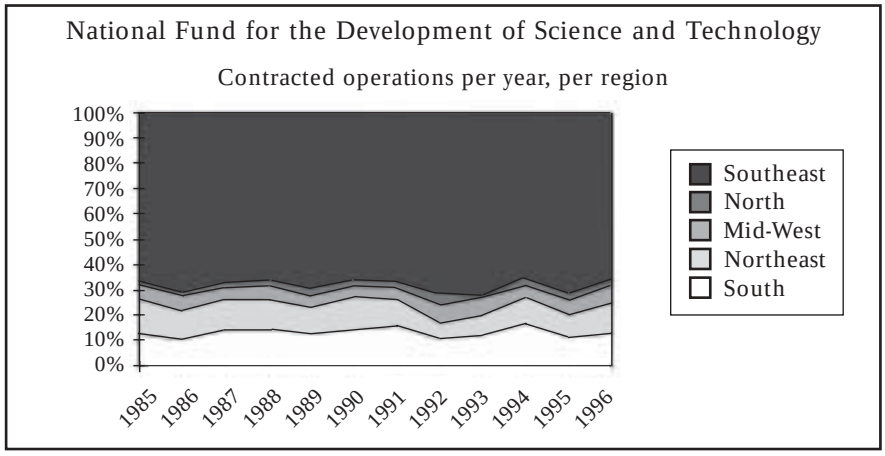
Other dilemmas concern the structure of public research universities and the geographic concentration of knowledge production in Brazil.

The swift changes in society and in the systems of production, the growing urbanization, the deterioration of the social fabric in Brazil, the increasing concentration of income and the dissemination of violence have placed greater demands on the public research universities. The growing clamor for knowledge, transparen-

cy of the social impact of investments, and alternatives to public policies deriving from academic analyses is incompatible with the current structure of public universities in Brazil.

The structure of research universities in developed countries has evolved alongside with changes in the social clamor for knowledge. In Brazil, structural changes in public universities were not determined by any kind of structural adjustment to social changes. Therefore, the challenge consists in reconciling the multiple social pressures upon the research university with the preservation of a knowledge-producing academic structure that, while having the world as reference, remains focused on Brazil. This accommodation must include an analysis of how generic concepts – such as equality under the law and power – relate to this type of focus. While the academic dignity of everyone must be maintained as a fundamental principle, in practice personal and institutional objectives must be taken into account if they attain the assented goals of social impact. Such acknowledgement may dispense with equal treatment under the law. Power and the structures of power should be adjusted to stimulate the development of collective academic competence and the transference of knowledge thus acquired.

The dramatic regional disparities in the production of knowledge are one of the core challenges when one examines the situation of science and technology in Brazil. Although abundantly well-known, due to a weakness in my upbringing I cannot resist the temptation of presenting a graph that illustrates this disparity. See Figure 2.



Source: Ministery of Science and Technology

Reiterating, as public universities are largely responsible for the production of the knowledge that derives from investment in science and technology, it is within these institutions that the decisions to change must be considered. To be sure, a region-by-region analysis is an oversimplification, and may even be misguiding, because each region has centers that produce knowledge of comparable quality to that of anywhere else in the world. Nevertheless, the overall disparity persists. And as has been demonstrated in the state of São Paulo, the existence of research-producing public universities can lead to changes in the chains of production and result in improvements in the quality of life.

I believe we have no other alternative but to assuage regional disparities, taking local vocations into account. This challenge certainly involves providing an adequate structure for public universities, but we must also assess the reasons for the failure of so many initiatives that attempted to reduce regional differences. A determining factor in failed past initiatives was a disregard for basic rules that indicate that academic quality is essential for the absorption of investments. It must also be stressed that if scientists do not participate in managing priorities, investments are rarely, if ever, successful. The existence of competitive fields of knowledge in a region with a low-density generation of science shows the correlation between faculty involvement in decision-making and the success of the change. By choosing physics and chemistry at the Federal University of Pernambuco as example, I had to discard many others – but any analysis will confirm this assertion. The challenge consists in harmonizing this awareness with career and power structures in federal universities that often deprive the academy of the power to make major decisions. The success of such investments, which have already been earmarked for the region by the Ministry of Science and Technology's new Sectorial Funds, depends overwhelmingly on detailing this type of reflection.

Today, the distance between basic science, technology and innovation is uniquely related to the product. If we accept that innovation is something that takes place in a business firm, the requisite prior technological development may, or may not, have occurred in that company. As this issue is somewhat diversified, I will limit myself to providing an example. The sequence of certain genes (an element of basic science) may lead to the almost immediate launching of new methods for diagnosis, inasmuch as the passage from a datum of basic science (the sequence) to the product (the diagnosis kit) requires the incorporation of several well-known

technologies – product manufacturing, product operation, marketing strategies, distribution. The introduction of a new drug, on the other hand, traverses a much longer path from the discovery (basic science) and the invention (usable drug), requiring the creation of new technologies and massive investment. It is the chain of production, not knowledge, that determines the option for public investment in technology and innovation. The limits of public investment for research in universities – and, therefore, the separation of knowledge (public) and innovation – imply challenges that, being dependent on the chain of production, have to be thoroughly discussed with the universities to define investment policies.

While the production of science and technology in universities fulfilled the dual role of cultural resistance and tool for personnel development, the structure of the university bore little relation with the needs of the groups responsible for this production. But today's multiple challenges – including, among other healthy pressures, the social use of knowledge, the increase in the number of university admissions, multiple relationships with the systems of production, and the deconcentration of the production of knowledge – require structural adjustments, particularly in the research universities, in order to face up to the demands and establish structural relationships that are compatible with explicit missions. In Brazil, for the system of production of science and technology in public universities to have a more central role in the country's socially equitable development, the requisite funding and planning decisions must include the academy as a significant and irreplaceable player.

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