МАТЕРИАЛЫ ВОРКШОПА

"Using Science Policy to Facilitate Innovation, Excellence and Global Cooperation". Part II

RC 23 ISA midterm workshop *"Using Science Policy to Facilitate Innovation, Excellence and Global Cooperation"* was held on 18—19 September, 2017 in St. Petersburg. It was organized by: Research Committee 23 (Sociology of Science and Technology) of the International Sociological Association and the St. Petersburg Branch for the Institute for History of Science and Technology of the Russian Academy of Sciences with the collaboration of the partners — St Petersburg Scientific Center of the Russian Academy of Sciences and House of Scientists — Palace of Grand Duke Vladimir.

RC 23 ISA midterm workshop received the favourable feedback from the participants and some also expressed interest in a publication of their papers presented at the workshop. In the 4 Issue of 2017 we've already published two papers written by *Leandro Raizer* "Society, Innovation and Energy Policy in Brazil" and *Sonia K Guimarae*s "Pathways to Technological Catching up: Relationship University-Business Relations in Brazil".

Journal *Sociology of Science and Technology* presents the second part of the RC 23 ISA-workshop's papers. This issue offers very interesting and attractive to STS community topics about "A Strategy for Scientific and Technological Development Geared to Innovation" *(Jaime Jiménez, Juan C. Escalante, Delfino Vargas, Rodolfo Ramírez, Leonardo Munguía, Brenda H. Molina),* "Adolescents and Scientific Careers. Interests, Scholastic Experiences and the Opinions of Italian Students" *(Giuseppe Pellegrini, Barbara Saracino),* "Russian-French Scientific Collaboration: Approaches and Mutual Attitudes" (*Irina Dezhina), "Youth's Interest in Science and Innovation and the Conditions for Leadership in Russia" (Galina P. Gvozdeva, Elena S. Gvozdeva),* "Sustainable professional career in science and technology: interdisciplinary perspective and the Russian context" *(Irina Popova),* "Journal of Molecular Biology's growth and content analysis" *(Jérôme Pierrel).*

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National Laboratories: a Strategy for Scientific and Technological Development Geared to Innovation

Abstract: The concept of governmental financing of science and technology was born in the Western World as early as the 17th Century. Both Great Britain and France became aware of the need to protect and enhance the scientific achievements of their scientists, mainly for reasons of international prestige. The USA witnessed a spectacular growth of its scientific facilities in the 20th Century. The number of National Laboratories expanded out of the massive scientific effort developed during WWII that produced innovative technologies such as the radar, the computer, the proximity fuse and, unfortunately, the atomic bomb. The scale and impact of the mobilization of science for military purposes during WW II was extraordinary and unprecedented. The concept of National Laboratory gradually extended in the USA to include research institutions dedicated to areas of national interest like atmosphere, soil, oceans and health of the population. Although not necessarily identified as National Laboratories, they conserved the characteristic of being financed by the national government. Countries in the process of development have put a lot of interest in the creation and support of National Laboratories, or equivalents, as a strategy to enhance productivity and reduce the gap between developed and developing countries. The chain science–technology–innovation–applications is to be encouraged for both international prestige and increase in revenues at national and international levels. The federal agency that is in charge of planning and implementing Mexican science, technology and innovation policy is the National Council for Science and Technology (Conacyt, in Spanish). In 2006, the institution launched a National Laboratories program through a call for national laboratory candidates that is still in effect today. The applicants submit a project to Conacyt, and commit to the joint development of projects with one or more similar Mexican research institutions. Those who are approved are supported with funds to acquire necessary equipment. Conacyt's ultimate aim is for the laboratories to become self-sufficient with the provision of services, as well as national and international referents in their field of knowledge. A preliminary presentation of a successful Mexican National Laboratory, the National Center of Imaging Studies and Medical Instrumentation (CI3M), is presented as a paradigmatic example of the track laboratories in the program should follow, aimed at accomplishing satisfactorily the objectives of human resource development, production of innovative technology, and provision of services. CI3M not only has fulfilled such areas but has become self-sufficient through the provision of services and the creation of their own enterprises.

Introduction

Mexico's Conacyt is the country's official science, technology, and innovation institution in charge of policy formulation and implementation. In its own terms, Conacyt's goals are:

"To consolidate a National Science and Technology System which responds to the prioritized demands of the country, solving specific problems and needs, thus contributing to the increase of both the standard of living and the well-being of the population. In order to accomplish such goals, we need:

To have an S&T State policy.

To increase the scientific and technological capability of the country.

To increase the quality, competitiveness and innovativeness of the enterprises" [*Conacyt*, 2017a].

Although not at a ministry level, the Council exerts considerable leverage, particularly on the allocation of the country's investment in science and technology, among the diverse spectrum of national science institutions throughout the country. Traditionally, the Council,

funded entirely by the Federal Government, allocates resources through many instruments: graduate studies scholarships, both in the country and abroad, direct funding of research projects, on an individual or team basis, as well as on an institutional or inter-institutional basis; and finally, a system of direct incentives to individual researchers, based on productivity. The Council has thus been instrumental in the creation, redesign and support of many scientific institutions. Among these stand out the specialized research institutions called Conacyt Centers, oriented to specific areas of research related to strategic needs of the country. The centers are grouped in three subsystems, namely Natural and Exact Sciences (10 centers); Social Sciences and Humanities (8 centers); Technological Development and services (8 centers); and one more specialized in financing graduate studies [*Conacyt*, 2017b].

The Council is also responsible for the National System of Researchers (SNI), instituted in 1986, which has been a pinnacle in innovative forms of stimuli to individual researchers based on their productivity [*Conacyt*, 2017c]. Another important program of Conacyt, launched in 2007, is the Retention and Repatriation Program destined to attract Mexican researchers with established academic trajectories abroad, to continue their academic careers in national higher education and research institutions [*Conacyt*, 2017d]. Likewise, in 2006 Conacyt launched the National Laboratories program in an effort to promote the preparation of high-level human resources, the creation of laboratory networks for mutual support, and the provision of high-quality technological services [*Conacyt*, 2017e].

In the following sections, we will provide a global view of National Laboratories or equivalent organizations, discuss the Mexican National Laboratories at a deeper level, describe at some detail a successful Mexican Laboratory, and provide some reflections and conclusions.

National Laboratories of the World

Western countries became aware of the need to protect and enhance their national science as early as the 17th Century. The first effort to support, enhance and control the scientific production of a country took place in Great Britain with the creation of the Royal Society in 1663. The first 'learned society' meeting took place as early as November 1660. The group received royal approval and from 1663 on was known as 'The Royal Society of London for Improving Natural Knowledge'. It is interesting to note that the first issue of *Philosophical Transactions* was published in 1665, the first scientific journal ever published. It established for the first time the concepts of scientific priority and peer review, being the oldest continuously published scientific journal in the world. Although the Royal Society is not the academic support of British national laboratories, it indeed was the inspiring intellectual founder of the enormous scientific apparatus of Great Britain, including the national laboratories [The Royal Society, 2017a].

The second oldest organization for the enhancement of science was born in Paris, France, in 1666. It emerged from the tradition of groups of scholars who used to meet around a patron or a learned personality to discuss advances of the science cultivated at the time. Jean-Baptiste Colbert created the Academy of Science of Paris by selecting a group of reputable scholars of general calling under the King's auspices. This reputable Académie was the founding block of the great scientific endeavor of France [Académie des sciences, 2017].

The examples that follow show the importance of investing in S&T for the material and social progress of the countries. Nations like Great Britain and France, which started recognizing the importance of cultivating science as early as the 17th Century, continue being not only scientific but economic global powers as well, regardless the immense tribulations they have endured along centuries. The USA, a colonial country who became independent as late as the end of the 18th Century, was able to build their scientific apparatus at a fast rate, in part urged by wars' exigencies. The three nations currently enjoy first class economies and are world technology leaders, see Figure 1.

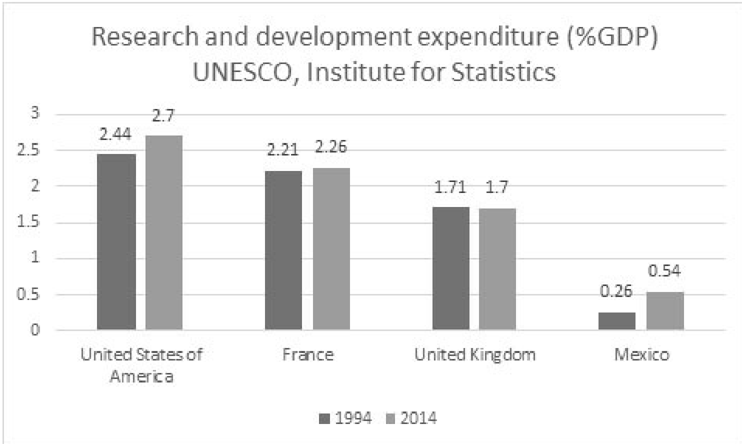

Figure 1. Per cent of GDP dedicated to S, T & I, in USA, France, the United Kingdom and Mexico. *Source:* https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?end=2014&start=1996&view=chart, accessed September 12, 2017.

United Kingdom National Laboratories

Government funded research in the UK is organized around eight Research Councils (RC). The RCs' annual investment is around £ 3 billion to cover all the academic disciplines from medical and biological sciences to astronomy, physics, chemistry, engineering, social sciences, economy, environmental sciences, arts and humanities. They look for excellence in research (they secure this by keeping benchmarks with other countries) that has an impact on the growth and social well-being of the UK. To keep their position in worldwide research they have different funding programs, first-class facilities and infrastructure. They also encourage young professionals to follow a scientific career, and work with the youth to inspire new talents, and also involve the public in research (The Royal Society, 2017b).

UK RCs seek to ensure that the UK remains as the best place in the world to do research, innovate and grow business. They know that to accomplish their goals, they must continue doing long term investment in world class research and innovation, take advantage and understand the full potential of the UK's research and innovation ecosystem, develop the right skills, leadership and infrastructure to feed a sustainable economy and create high quality jobs.

The Research Councils are key to deliver research and innovation for the economic growth and its social impact by creating new knowledge, funding excellence in basic research, responding to social challenges, developing skills, leadership and infrastructure, leading the research path of the UK, managing innovation, creating environments and brokerage companies, co-delivering research and innovation with 2,500 companies, 1,000 of which are subjected to situational method engineering (SME), and contributing to intelligence for defense policy [The Royal Society, 2017c].

The eight Research Councils are:

Biotechnology and Biological Sciences Research Council with 8 laboratories.

Science and Technology Facilities Council with 5 laboratories.

Department for Environment, Food and Rural Affairs with 4 laboratories.

Department for Business, Innovation and Skills with the National Physical Laboratory.

Ministry of Defense with 3 laboratories, one of them with 9 locations.

Medical Research Council with 5 laboratories.

Natural Environment Research Council with 6 laboratories.

Science and Technology Facilities Council, formerly Particle Physics and Astronomy Research Council with two laboratories (The Royal Society, 2017d).

French National Laboratories

The French achievements in science and technology have been significant throughout the past centuries, while the economic growth process and French industrialization was slow but continuous during the 18th and 19th centuries. The research and development efforts form an integral part of the country's economy. France is home to some of the oldest universities in the world (Montpellier, Paris) although in the moment of their foundation they were more centered on philosophy, theology and law rather than science.

The National Center for Scientific Research (Centre Nationale de la Recherche Scientifique, CNRS) is the public institution in charge of S&T in France. CNRS is organized around ten Institutes and dictates their scientific policy.

The National Center for Scientific Research: relevant characteristics.

CNRS is a public organization under the responsibility of the French Ministry of National Education, Higher Education and Research. CNRS is the largest French government organization for research and "the largest fundamental research organization in Europe" [CNRS Overview, 2017]. It employs 32,000 staff members (11,000+ researchers, 13,000+ engineers and 7,000+ administrative personnel). After the reorganization of 2009, the CNRS was divided into ten institutes:

Institute of Chemistry (INC).

Institute of Ecology and Environment (INEE).

Institute of Physics (INP).

Institute of Nuclear and Particle Physics (IN2P3).

Institute of Biological Sciences (INSB).

Institute for Humanities and Social Sciences (INSHS).

Institute for Computer Sciences (INS2I).

Institute for Engineering and Systems Sciences (INSIS).

Institute for Mathematical Sciences (INSMI).

Institute for Earth Sciences and Astronomy (INSU).

The National Committee for Scientific Research, that oversees the recruiting and evaluation of the researchers, is divided into 47 sections (e.g. section 1 is mathematics; section 7 is computer sciences and control). Researcher groups are affiliated to one primary institute and an optional secondary institute; all researchers belong to a section. For administrative purposes, the CNRS is divided in 19 regional divisions (including four for the Paris region) (CNRS, 2017a). CNRS laboratories, also called *research units,* are spread all over France and overseas. They are headed by tenured researchers, engineers and support personnel. A laboratory works on a renewable four-year contract, and is evaluated by the CNRS bi-annually. There are two types of labs:

Intramural labs, fully funded and managed by CNRS, and

Joint (or mixed) labs, in partnership with universities, other research organizations, or industry. They may be located in France or abroad.

Today, CNRS researchers are active in 1,256 research groups, 85 % are mixed and also include researchers that do not belong to the CNRS (most of the university professors); the mixed groups tend to be inside universities and other higher education institutions.

CNRS surpasses international rankings in all fields of knowledge. It features among the world's leading scientific organizations. In 2015, it heads *Nature's Index* with 4,939 refereed articles, ahead of the Chinese Academy of Sciences, Germany's Planck Institutes, Harvard University and the Spanish National Research Council. CNRS is also the world's leading research organization in terms of scientific publications, according to the rankings produced by the 2014 Scimago Institutions Rankings (SIR); again surpassing the Chinese Academy of Sciences, the Russian Academy of Sciences and Harvard University [CNRS, 2017a].

As the largest fundamental research organization in Europe, the CNRS carries out research in all fields of knowledge, through its ten institutes.

The role CNRS plays in innovation, technology transfer, spin off enterprises in France is of paramount importance to the French economy and development. It has a special agency that monitors and facilitates the innovation cycle. The Innovation and Business Relations Department (DIRE) is in charge of technology transfer specialists, 18 regional partnership and technology transfer departments, and an enterprise (FIST SA) dedicated to industrial applications, managing the patent portfolio and trading agreements with business partners. CNRS involvement with industry goes as far as being a part of 14 technology transfer companies (SATTs).

The CNRS Innovation and Business Relations Department (DIRE) monitors and facilitates the cycle of innovation (CNRS, 2017b).

It coordinates 300 technology transfer professionals, 18 CNRS regional partnership and technology transfer departments, and FIST SA, a subsidiary dedicated to industrial applications, managing the CNRS patent portfolio and negotiating operating agreements.

The CNRS also relies on the local action of the 14 technology transfer companies (SATTs) in which it is a shareholder.

USA National Laboratories

The origin of US National Laboratories can be traced back to the end of WW I when the US government started to invest in scientific research for national security purposes. However, the gigantic impulse for the creation of the laboratories took place during WW II because of the large scientific and technological requirements demanded by the war effort. This investment proved to be advantageous since the weapons that defeated the Axis

came out of the National Laboratories. The radar, the computer, the proximity fuse and the atomic bomb proved highly influential in the allied victory against the Third Reich and its allies, and so the technological advantage was also recognized as a proven asset.

After the War and due to its remarkable success, the new (at the time) Atomic Energy Commission took over the "temporary" war laboratories, extending their existence indefinitely. Funds and infrastructure were assigned to promote other national laboratories for both basic and classified research, especially in physics. Each national laboratory would be centered on one or several large and expensive equipment (such as particle accelerators or nuclear reactors). Most of the national laboratories are based on staffs of local researchers, allowing visiting researchers with different priorities according to each laboratory's policies. With this large resource centralization (monetary and intellectual), they are an example of what is known as Big Science [Weinberg, 1961].

Elements of competition and cooperation are promoted among laboratories. Frequently there are two laboratories with a similar mission (i. e., Lawrence Livermore was designed to compete with Los Alamos) hoping competition for resources will create a high-quality working culture. The Department of Energy of the USA, is one of the largest (if not the largest) scientific research system in the world. It provides funding for more than 40 % of the national total for physics, chemistry, materials science and other areas of physical sciences. Many are locally managed by private companies, while others are managed by universities. As a system, it forms one of the components of, what is called, the "iron triangle" (military, academy, industry).

USA national laboratories have served as leaders of scientific innovation for more than seventy years. This fact is clearly explained in the introduction to the description of each: "An outgrowth of immense investment in scientific research initiated by the U. S. Government during World War II, the National Laboratories have served as the leading institutions for scientific innovation in the United States for more than seventy years. The Energy Department's 17 National Labs tackle the critical scientific challenges of our time — from combating climate change to discovering the origins of our universe — and possess unique instruments and facilities, many of which are found nowhere else in the world. They address large scale, complex research and development challenges with a multidisciplinary approach that places an emphasis on translating basic science to innovation" [US Department of Energy, 2017].

Their general objectives are:

- Conduct research of the highest caliber.
- Advance the USA energy independence and the leadership in clean and accessible energy.
- Improve global and national security.
- Design, build, and operate distinctive scientific instrumentation and facilities and make them available to the scientific community.

Relevant characteristics

Today, all of them are mega institutions that provide services both to the public sector as well as the private sector, covering all fields of knowledge, and are grouped as follows:

17 National Laboratories from the Department of Energy (DOE), a set of research centers funded by the federal government and spread all over the country, with the purpose of advancing science and technology as well as fulfilling DOE's mission.

The National Institute of Standards and Technology, an agency of the Commerce Department. It operates six research laboratory programs, headquartered in Gaithersburg, Maryland.

The National Health Institutes is a research installation on biomedical and health related fields located in Bethesda, Maryland. It has five National Laboratories.

The University-National Oceanographic Laboratory System, a group of academic institutions and National Laboratories that are government funded organized to coordinate the use of research vessels to investigate the ocean.

The Center for the Advancement of Science in Space, a National Laboratory whose main research facilities are located in the USA portion of the International Space Station.

The USA sponsors its National ST&I system in different forms. It is difficult to assess the number of scientific laboratories operating since small and big universities, private or public, have each one of them research installations of considerable caliber, difficult to enumerate. Additionally, many industries carry out scientific research for their own purposes in well-equipped laboratories, like the pharmaceutical, food, machine tool, vehicle construction, and many other industries. In sum, the scientific and technological infrastructure of the USA generates countless scientific and technological results that eventually are incorporated to their products and sold not only in the USA but also in the rest of the world as well.

Mexican National Laboratories

In 2006, Conacyt instituted the National Laboratories Program. These laboratories are specialized research units for scientific development and innovation in fundamental subjects. They fulfill three main functions: research, human resources formation, and provision

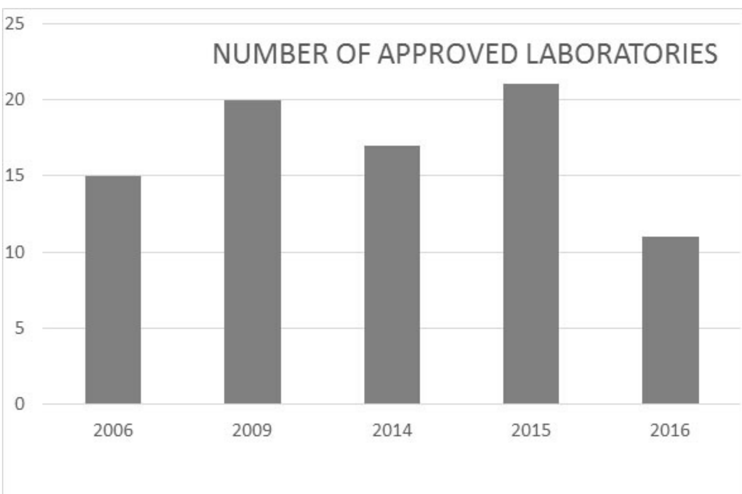

Figure 2. Number of approved laboratories per year.
Source: Conacyt (2017f). National Laboratories prior to 2016.

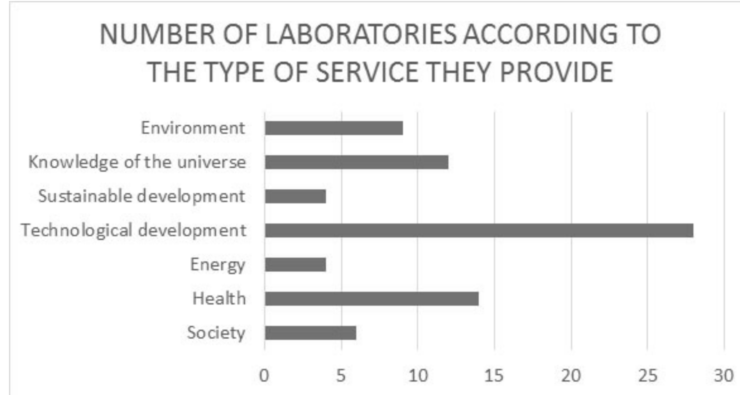

Figure 3. Number of laboratories according to the service provided.
Source: Conacyt, Boletín de Servicios (2017)

of services. The laboratories are composed by at least two research institutions, either public or private, with common or complementary research activities. The aim is to expand their S&T capabilities and provide high quality services to other laboratories, research centers, public and private corporations located in Mexico or abroad. Conacyt's pretention is that the laboratories eventually become self-financed by virtue of their role as services providers. Through calls for participation, Conacyt supports the creation of the laboratories to encourage the formation of high quality personnel, optimize resources, and generate synergies among institutions and organizations. The program provides funding for infrastructure; equipment and conditioning of a physical space within one of the participating institutions [*Conacyt*, 2017e].

So far there had been six calls for participation to laboratories to be recognized as national. Figure 2 shows the year and number of laboratories approved until 2016.

Not all laboratories selected remain as national. Some delete themselves for internal reasons, some are removed by Conacyt because they did not fulfill appropriately the plans they were supposed to carry out. Currently there are 66 laboratories in operation [*Sánchez, Verenise*, 2016], although a total of 84 institutions have been granted the status of National Laboratories at one time or another. One useful classification is referred to the field of knowledge they specialize in. Figure 3 shows the service category and the number of laboratories listed in each category, according to Conacyt's classification [*Conacyt, Boletín de Servicios*, 2017].

The national center of imaging studies and medical instrumentation (ci3m): an experience to follow

The CI3M is a unique project both in Mexico and Latin America. Its mother institution is the Metropolitan Autonomous University-Iztapalapa in Mexico City, which signed an agreement with Conacyt in 2004 for funding of the laboratory's infrastructure. It became a National Laboratory in 2007.

Figure 4. The National Center of Imaging Studies and Medical Instrumentation (CI3M), at The Metropolitan Autonomous University (UAM) in Mexico City

It is equipped with two magnetic resonance apparatus, one of 7 Tesla for small species research, and another one of 3 Tesla for humans, both for research and clinical use. The Laboratory's staff is composed of highly competent professionals. It is ranked as the most important imaging studies laboratory in Latin America and one of the best twelve laboratories globally [CI3M, 2017].

CI3M is in the field of Biomedical Engineering research. They seek new linkage methods and mutual support between all those involved in the discipline i. e. patients, physicians, clinical researchers, engineers, health institutions, entrepreneurs, investors, and government officials. The central idea is to put the infrastructure of this laboratory at the service of any scientist requesting it, to facilitate technology development of the interested community in the field of Biomedical Engineering. CI3M's objective is: "Our approach name is *Translational Engineering.* The objective is to facilitate the transformation of an idea or local solution of a problem into an application in the clinical media that not only solves the local problem, but with the potential of solving similar problems all over the world" [CI3M, Reporte Anual 2014–2015. (2016)].

In terms of human resources formation CI3M oversaw 160 internal students in special courses, 80 external students in courses and residencies, 100 external students in practices, and collaborates with several graduate programs, one internal and the rest external, by 2015. The core staff is composed by six renowned scientists.

CI3CM reports the following accomplishments by 2015:

- Research:

Lines of research: medical instrumentation, imaging, artificial organs and technical support.

30 projects, 50 % external collaborations,

13 international patents,

1 national patent 2010–2015.

- External services:

38 employees,

6 international and national enterprises,

7 universities,

3 research centers, international and national,

6 health institutes.

Figure 5. Part of the staff at the CI3M

In addition, CI3CM reported the creation of the first Mexican artificial heart Vitacor-UVAD, currently being used under informed consent [IMMX, 2017]. One of the most remarkable features of CI3CM is the fact that it is self-sustainable, which is the most cherished objective of the Conacyt's National Laboratories Program [CIM3M carteles, 2016].

Conclusions

The urgency to speed up the production of scientific and technological results in the economic south may be illustrated by the fact that *knowledge* is being produced by advanced countries at a rate impossible to catch up, therefore economic south countries should make the maximum effort to not to let the gap be enlarged but, if possible, reduced. *Knowledge* grows at a rate ever faster; Linowes puts it in the following terms:

It took from the time of Christ to the mid-eighteenth century for knowledge to double. It doubled again 150 years later and then again in only 50 years. Today it doubles every 4 or 5 years. More new information has been produced in the last 30 years than in the previous 5,000 [Linowes, 1990].

It is clear that the protection and enhancement of science by national authorities at an early stage have had a positive effect in the material well-being of countries. Those nations which supported modern science became global powers and controlled much of the international affairs. Countries in the process of development arrived late in the science scenery and therefore are making efforts to catch up. Those countries in the economic south became interested in science as a tool for development as late as the middle of the 20^{th} Century.

Although there were a number of official efforts before, the Mexican government took the responsibility of promoting science — through the creation of Conacyt — in the direction the country badly needed it, since 1970. The foundation of the National Laboratories in 2006 has been the most recent major strategic plan to orient and encourage the science, technology, and innovation potential to speed up the technological progress of Mexico.

Many of the National Laboratories have positively responded to the expectations deposited in them. We have identified the following characteristics common to the successful laboratories:

Experience. Laboratories with vast experience have a better chance to succeed in their new role as National Laboratories. Many of the labs which were awarded the national nomination have been in existence from 3 to 10 years earlier; therefore they have the prestige, tradition and the networking to perform successfully.

Network. Laboratories with an ample network have the advantage to strengthen the already made connections as opposed to labs which have to start from scratch the construction of a robust network.

Team expertise. It plays a crucial role for the performance of National Laboratories. Those labs equipped with expert teams carry out innovative and frontier research, innovating with unique new products based on the knowledge and expertise of their research teams.

Leadership. Perhaps this is the most important feature for laboratories to succeed. In fact, it's not necessary to count with "many" scientific leaders. One or two would be enough to make the lab a successful endeavor. The leader has to be an internationally recognized scientist, in addition to count not only with the acceptance of the group, but also the desire and courage to work together, as a well-oiled engine.

The National Center of Imaging Studies and Medical Instrumentation (CI3M) may be taken as a benchmark for the rest of laboratories. It abundantly fulfilled the four conditions suggested above. The laboratory was founded in 2003 as a response of university professors who were convinced of the need to develop research projects and programs in the area of medical imaging. At the time, the equipment they had was primarily used for clinical imaging purposes due to the great demand the population had for these services. By 2006 CI3M was prepared to answer Conacyt's call to become a national laboratory since it comprehensively met the required conditions. CI3M was awarded the distinction in 2007 together with a seed capital of 4 million US dollars. The capital was used to purchase up-to-date imaging equipment.

CI3M fulfills all the conditions Conacyt "dreams" of achieving for all the national laboratories. In the words of Dr. Bunge, Head of Scientific Development "we hope all the laboratories become national referents" [*Bunge*, 2017]. CI3M is not only a national referent but an international referent as well.

In conclusion, nations concerned with the cultivation of S&T+I at an early time in history, have improved the living standards of their peoples and have become the current global economic powers. In contrast, nations lagging behind and just entering the global economy have to make a substantial effort to reduce the S&T+I gap to really approach living standards of the economic powers.

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