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PUBLIC POLICY AND
TECHNOLOGICAL DEVELOPMENT

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"There are three roads to ruin:

Women, gambling and technology.

The most pleasant is with women.

The quickest is with gambling.

But the surest is with technology."

Georges Pompidou

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1 - INTRODUCTION

Change is one of the most compelling truths of living. Some changes reflect the inescapable and irrevocable stages of natural law. Biological aging is inevitable. Continental drift is uncontrollable. However, some elements of change are derived from calculated human endeavor. Fundamental and dramatic shifts in individual and social behavior have occurred with charismatic leadership, some of it religious, some ideological, some purely exploitative of the human condition.

In contemporary society, the most powerful engines of change are human invention, innovation, and applications of scientific knowledge. Collectively, we call these functions "technology".

Technology has always been a source of cultural transformation. The artifacts left by our predecessors have become treasures of insight as to how people cope with their strenuous, hostile and capricious natural environment. Indeed, we define these cultures by their tools and their material achievements. Technology was the springboard for change, from hunting and gathering to agriculture and videoconference, from use of fire and the arrow to the nuclear fission and ultrasonic aircraft. Once, the wheel was invented and became high-tech.

In the modern world, we continue to employ these instruments of human processing to gain control over our environment and to enhance the quality of life. The effects of many of these innovations influence almost every aspect of human existence.

We began to glorify technology over a century ago, with its cascade of inventions: the steam machine, electric lights, farm machinery, the sewing machine, even running water. Then came the automobile, radio, television, jet aircraft, modern medicine, nuclear energy, cellular phones and computers. Along with these inventions appeared a manufacturing and marketing infrastructure, modern management instruments and software technology to foster penetration into all of society.

A study shows us how the knowledge embodied in technology was the main device of change in the world. In 1850, around 79% of all the tasks were undertaken by animals, 15% by men and only 6% by machines. In 1900, this ratio shifted to 52%, 10% and 38%, respectively, and at last in 1946 to 4%, 4% and 92%.

Yet, since World War II, the rhythm of change is moving or functioning more rapidly. Just as the advances and applications of science and technology have changed social structures within nations, they have also shifted the international scene in a way that is substantial and accelerating.

Especially demanding is policy-making for international economic competition, which is increasingly defined in terms of technological competence. The diffusion of centers of technological excellence around the world and the progressive convergence of local markets in terms of consumer tastes and preferences have obliged economic agents to adopt a global outlook; not only to firms compete internationally but they also depend upon each other's technological, financial and marketing strengths to stay afloat.

This paper begins by introducing some definitions (item 2) and by offering reflections about government-technology connection (item 3). It evaluates the experiences of this issue, especially in the post World War II period, in large high-income nations with emphasis on the USA (item 4) and newly industrialized countries (item 5). The Brazilian public policy on science and technology deserves special attention (item 6), and finally there is a conclusion (item 7) about the actual role of the government in the technological development of firms.

2 - DEFINITIONS

Before beginning the subject of this work it is necessary for some agreement on basic terms and concepts. Definitions will be used following the National Science Foundation surveys and concepts of well-known authors.

The objective of basic research is to gain more knowledge that is comprehensive or understanding of the subject under study, without specific applications in mind. It is generic, non-appropiable and openly available. In industry is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be in fields of present potential commercial interest.

Applied research is aimed at gaining knowledge or understanding to determine the means by which a specific, recognize need may be met. It pays explicit attention to producing a technology or service. In industry includes investigations oriented to discovering new scientific knowledge that has specific commercial objectives with respect to products, processes or services.

Development is the systematic use of knowledge or understanding gained from research directed toward the production of useful materials, devices, systems or methods, including the design and development of prototypes and processes. It is of general interest to a sector or sectors, but full returns cannot be captured by any one company.

Innovation encompasses the processes by which firms master and get into practice products designs and manufacturing processes that are new to them, if not to the universe or even to the nation. It is characterized by its entrance into the market. The set of institutional actors that, together, plays the major role in influencing innovative performance is named system.

3 - TECHNOLOGY AND PUBLIC POLICY

The legends we live by include a common misconception about technology: that technological affairs are largely the providence of the private sector. Now we find that venue shared by government, with some major implications.

A brief view of history can help us to figure out the issue. Modern capitalism grew out of the nineteenth-century industrial revolution. Owner-entrepreneurs first engaged newly discovered techniques to concentrate energy; that was the innovative core of the revolution. Then they concentrated venture capital, for to exploit that innovative capacity to meet human needs and wants, money was also required. With both financial and technical resources, firms could then operate the mines and steel plants, build the railroads, manufacture automobiles, and, more recently, endow consumers with a supermarket of electronic gadgets and toys.

What was true one hundred years ago – that private enterprise produced most of the hardware – is true today, at least, in capitalism nations.

Government is now in the technological act as a silent partner with industry. Moreover, a case can be argued that as technology become more intimately twisted with society, the most crucial decisions as to both technological ends and means shifted from the traditional marketplace to government.

Government is involved with technology in different ways. Private entrepreneurship and investment are directly assisted by a galaxy of land grants, subsidies, tax incentives, import quotas and market guarantees. These inducements to stimulate technological activity go back almost to the nation's birth, so that over the intervening years, almost every sector has become a special pleader for handouts.

Otherwise, the private sector is indirectly assisted by government funding of social overhead. Included in this notion are supports for higher education, scholarships, specialized training and research and development – R&D; fiscal aids, services as launching of communication satellites and assistance to companies seeking business overseas.

In addition, by its deficit borrowing and its fiscal and tax policies, government heavily influences the capital market. Such manipulation impinges on interest rates, balance of payments and inflation; and thus on venture capital for new industrial starts and on industry's ability to compete overseas.

The government has been obliged to intervene through the regulatory process when technological activities of the private sector have been inimical to the public interest. Following World War II, when technological momentum increased sharply, government interceded in matters of air and water quality, occupational health, auto and aircraft safety, effectiveness of drugs, toxic waste disposal and a myriad of other problems ignited by freewheeling industries mediating new and powerful technologies.

Finally, government is itself a major customer of technology. On behalf of the national security, it's purchased modern systems of defense. The government also sponsors research and development activities in university laboratories to benefit the health, communication, environment and control of its sovereignty.

All these activities reflect changes of a technological age. The government is expected to make the most fundamental decisions – to build the common defense, to rank social priorities, to allocate resources, to organize economic, social and political activity and to resolve conflicts among factions.

The vehicle of these decisions is public policy. Public policy defines both what governments do and what they may not do. In addition, particularly to technology policy, the issue is how extends the role of government in the technological development of private firms.

Perhaps no subject has received more debate and discussion than the appropriate division of responsibility between the private and public sectors for bearing of the technological development. While there is a general agreement that government should support R&D that is directly applicable to clearly public functions such as defense and health, there is much more uncertainty about R&D whose results are likely to be applied to the development of goods or services that have been traditionally sold in private markets.

In the next items, we will look into the experiences of different countries, concerning to the industrial and technological policies adopted in postwar time.

4 - EXPERIENCE OF LARGE HIGH-INCOME COUNTRIES

4.1 - USA

World War II produced the Age of Big Science. The atom bomb, radar, the proximity fuse, antibiotics, the digital electronic computer, and numerous new materials, theories, and analytical techniques all emerged from the concentrated efforts of university scientists brought together to address wartime needs.

The shibboleths of this new age were that basic science and well-funded scientists produced dramatic new technologies and that scientists knew better than generals, engineers, or industrialists what new science to pursue, which new technologies to develop, and how best to deploy those new technologies.

Thus, Great War transformed the United States R&D system. Federal government support for industrial and academic research expanded dramatically. The U.S. emerged from wartime as an unchallenged leader in a much broader range of technologies than was true at any point before 1940, and federal funding built a strong scientific research capability during the postwar years.

The success and the organizational structure of the massive federal wartime R&D program yielded several important legacies. The successful completion of the Manhattan Project, generated to develop weapons of unprecedented power, created a research and weapons production complex that eventually would usher in the age of truly "big science". Paradoxically, this Project contributed to rosy postwar perceptions of the constructive possibilities of large-scale science for the advance of societal welfare.

Science and technology had become an important segment of government, part of the missions of various operating agencies and departments. Initially those laboratories established during the war experienced peacetime declines in funding and exodus of personnel, and so the federal government concluded that would have to initiate new relationships with university scientists to further the development of R&D programs, most of them concerned with national security as nuclear weapons.

The huge increase in federal expenditures on university research had taken the form of contracts and grants for specific projects. Most of the demand for scientific research has emanated from a centralized federal authority, although a number of federal departments and agencies with distinctly separate missions and goals have contributed. On the supply side had been a heterogeneous range of institutions, public and private, committed to both research and education, dependent on the federal government for financial support but otherwise determined to maintain their autonomy.

As part of the science policy, in 1950 was created the NSF – National Science Foundation, the lead agency within the bureaucracy for sponsoring basic scientific research, which has assumed an important role on the development of the U.S. science.

After that time and until late 1960s, the Cold War played a fundamental role in shaping the course of R&D expenditure. The Korean conflict, the explosion of the Soviet hydrogen bomb and the launching of Sputnik combined to cast a long military shadow over all R&D activities. The nation’s scientists and universities found that they could even satisfy much of their own needs for basic research in the name of defense. Some of the last restrictive administrative procedures for basic research within the executive branch were those of the military agencies. At that time, annual federal R&D funding was increased at an accelerated pace. A major reason for the increase lay in the creation of NASA – National Aeronautics and Space Administration.

Thus, for more than a decade, there was constant growth in federal R&D. Funds for basic research and universities were plentiful, and government stimulated and paid for the training of thousands of new scientists and engineers.

Industry naturally was also affected by this development. The electronics industry in particular came to depend on the military for its R&D funding. In 1960, for instance, the federal government paid for 70% of the R&D conducted by the electronics industry.

However, the role of military-related projects in funding R&D became somewhat less dominant during the late 1960s and early 1970s because of the Vietnam conflict end, inflation rates and the growing political costs of those policies. The tenor of the nation gradually shifted from being supportive of the national Security State with all its scientific and technological trappings to being suspicious of it.

This decline was attended by a shift in spending among many of the largest industrial R&D investors, and even by the national innovation system.

The successive waves of new product technologies that have swept through the postwar U.S. economy, including semiconductors, computers, and biotechnology, have been commercialized in large part through the efforts of new firms. The large basic research establishments in universities, government, and a number of private firms served as important "incubators" for the development of innovations.

The venture capital market also played an especially important role in the establishment of many microelectronics firms and has contributed to the growth of the biotechnology and computer industries. Throughout the 1970s, US$ 100 – 200 million of funds annually flowed into this industry from the venture capital community and possibly in 1980s, flows of venture capital for high-technology firms may have been as US$ 2 – 4 billion annually. This abundant supply was gradually supplemented by public equity offerings.

During the 1980s, financial support from industry has established a number of research facilities on university campuses to conduct research with potential commercial value. Important initiatives are coming from the federal government as well as private industry. The NSF has embarked on a program to establish a number of interdisciplinary research centers in engineering and other scientific disciplines inside the universities. The financial structure of these centers combines "seed-money" support from the federal, state or local government with major contributions from private corporations that are affiliated with the centers.

Yet, federal spending for research performed by industrial firms again went up. Moreover, industry expenditures on research rose by 14% per year during much of the first half of the 1980s and at a lower but still healthy rate during much of the second half. The defense again, symbolized most clearly by "Star Wars" program, brought large-scale funding of military R&D to levels reminiscent of the earlier period.

From 1984 to 1990, NSF launched an extensive series of engineering, interdisciplinary research centers dedicated to building knowledge and capabilities that cut across firms, and industries and that were of direct commercial relevance. Similiarly, the industry-funded R&D spending were attended by another recognizable trend, big spending by firms on university research.

A 1994 report on some 1,100 university-industry research centers suggested that the federal government had been an active promoter of these centers (60% of which were formed in 1980s) by tying federal contributions to universities to industry participation. These centers represented roughly 70% of industry’s expenditures on academic R&D.

With the end of the Cold War, however, national security has lost its place at the top of the U.S. political agenda and the arguments for federal support for science and technology have lost some of their force. At the same time, the growing urgency of the federal government’s fiscal problems and the shifting political mood of the country toward cutting government spending and reducing the size of government have led some political leaders to raise questions about the affordability of increasingly expensive R&D programs.

Finally, there has been much discussion in Congress and in science policy circles of the need to link the nation's research efforts more directly to national goals, either by shifting away from research generally aimed at increasing knowledge toward strategic research or by establishing various institutional structures that would help provide this linkage.

Actually, the trend for the future of R&D activities in U.S. is to be supported and carried out each time more by private sector.

In recent years, nearly 60% of total R&D in U.S. is supported by industrial firms with their own company funds. Most of the balance, 36%, is supported by the federal government. Colleges, universities, and other nonprofit institutions provide the remainder. (See the evolution of the sources of funds for R&D between 1955 and 1994 in dollars million in Table 1 and percent in Table 2).

Table 1: Sources of Funds for R&D by Sector (Dollars in Millions - Real)*

YEAR	FEDERAL GOVERNMENT	INDUSTRY AND FIRMS	UNIVERSITIES & COLLEGES	OTHER NONPROFIT	U.S. TOTAL
1955	12,923	9,282	326	229	22,760
1960	28,191	14,591	479	387	43,648
1965	38,532	19,384	791	643	59,351
1970	35,636	24,851	1,111	807	62,405
1975	30,986	26,679	1,302	916	59,883
1980	34,548	36,067	1,565	1,057	73,237
1985	46,463	47,188	2,131	1,217	96,999
1990	54,274	73,592	3,821	2,067	133,754
1994	62,200	102,100	5,300	3,000	172,600

*Adapted and updated from Mowery and Rosenberg – National Innovation System

Table 2: Sources of Funds for R&D by Sector (percentage)*

YEAR	FEDERAL GOVERNMENT	INDUSTRY AND FIRMS	UNIVERSITIES & COLLEGES	OTHER NONPROFIT	U.S. TOTAL
1955	56.8	40.8	1.4	1.0	100
1960	64.6	33.4	1.1	0.9	100
1965	64.9	32.7	1.3	1.1	100
1970	57.1	39.8	1.8	1.3	100
1975	51.7	44.6	2.2	1.5	100
1980	47.2	49.3	2.1	1.4	100
1985	47.9	48.7	2.2	1.2	100
1990	40.6	55.0	2.9	1.5	100
1994	36.0	59.2	3.1	1.7	100

*Calculated from the Table 1

It is important to stress that only a small part of the R&D supported by the federal government is actually carried out in government's own laboratories. The largest share of federally funded R&D is performed by industrial firms under contracts, and a significant amount is also conducted under federal grants in colleges and universities as well as other nonprofit institutions, including FFRDCs – Federally-Funded R&D Centers, operated by contractors. (See Table 3).

Table 3: Research and Developments Performers in 1994 (Dollars in Millions and %)*

PERFORMERS	AMOUNT	PERCENT
Government Labs	17,200	10.0
Industrial Labs	123,700	71.7
Universities and Colleges	20,600	11.9
FFRDCs	5,100	2.9
Others	6,000	3.5
TOTAL	172,600	100

*Adapted from Rycroft – lecture in class

In conclusion, the powerful role of the federal government within the postwar U.S. innovation system was not linked to any economic strategy, however, instead being motivated largely by national security concerns. Whether or not the policy was based on a comprehensive strategy, the interaction between federal and private R&D expenditures significantly influenced the performance of U.S. technological development. A large, well-financed federal defense R&D program increased the demand and expanded the supply of professional engineers and scientists. In addition, privately financed R&D is growing and gaining an important role in supporting the U.S. science and technology system.

4.2 - JAPAN

The impact of World War II on the Japanese economy was, needless to say, devastating. Many of the plants and equipment had been destroyed by bombing and others were spoiled or taken away by the Allied Forces. Still, more than two-thirds of the production capacity had been left intact in most of the heavy industries. The R&D knowledge that had been increased before and during the war returned to civilian production, although some of them obsolete. Yet, as Japan's military spending after the war was practically zero, most of these resources could be transferred for the purpose of improving production.

Then, the process of catching up started following a dual tracking: encouraging the importation of advanced technology and promoting a domestic technology base. To make an effective technology transfer, the government allocated its scarce foreign currency selectively to those firms capable of adapting and improving imported technology. This gave the government, notably the MITI – Ministry of International Trade and Industry, a strong power over the industries.

Nevertheless, despite the effect this control undoubtedly had on individual firms, it unlikely has affected the overall pattern and pace of technology importation in a major way. A more profound influence was provided by the restriction of import and direct investment because the only way for foreign firms to exploit their technological superiority was to sell their technology, even though they might have preferred to export the product or start their own manufacturing in Japan.

Another important consequence of this policy was that the Japanese industries, as automobile, electric equipment and steel plants remained mostly in the hands of Japanese shareholders, and the stakes foreign firms in fact decreased during the postwar period. Thus, even after the capital liberalization in the 1970's, the management of most Japanese firms has been not exposed to the pressure of the international capital market.

In evaluating the role of imported technology and restricted imports and investments policy played in Japan's development, one should also stress two facts. First, trade in technology increased worldwide and Japan, even recently, is the largest among major countries in payment to technology importation, and undoubtedly, it was one of the major beneficiaries of this trend.

Second, technology transfer would not have succeeded without a rapid increase in R&D expenditures. As mentioned early, when the war ended, a large number of researchers, engineers and skilled workers were released to be utilized in civilian production. Moreover, domestic R&D were essential to enable firms to evaluate, adapt, and improved imported technology.

Moreover, since the 1960's Japan became a serious competitor in the international market, its industries advanced technologically and grew world-class, and the backlog of technologies available for import decreased. Consequently, the need for improved efforts to develop its own technology again became urgent and government policies to promote domestic R&D began to be emphasized.

However, the government support to industrial R&D and the size of the incentives provided through tax breaks, subsidies and low-interest loans were modest (see Table 4). In 1983, it represented, respectively, only 2.6% and 1.3% of industrial R&D expenditure. These financial incentives to the private sector have been moderate and smaller than in other countries where as much as a one-third of industrial R&D is financed by the government.

Indeed, Table 4 reveals a clear downward trend in the importance of the role of government and its subsidies in the R&D expenditures. Private firms, under increased competition from other Japanese firms and from American and European companies in overseas and domestic markets felt an imperative need to enhance their technological capability and more than tripled their R&D expenditure in the latter half of the 1960's.

Table 4: Government Support to Industrial R&D in Japan* (in billion yen)

YEAR	(A) TOTAL	SUBSIDIES	(B) R&D EXPENDITURE BY INDUSTRY	(A):(B) %
1960	9.8	0.7	124.4	7.88
1965	16.4	3.1	252.4	6.50
1970	31.0	11.0	823.3	3.77
1975	64.7	29.8	1,684.8	3.84
1980	101.0	60.8	3,142.3	3.21
1983	117.7	58.7	4,560.1	2.58

*Adapted from Goto and Wakasugi (1988) – National Innovation Systems

The R&D activity and its aftermath in Japan has displayed different features facing other countries: because postwar Japan's Peace Constitution meant that the military was no longer a significant customer to business, defense-related R&D expenditures are less significant; in 1989, the number of research persons working in industry represented 64% of all researchers and with a relatively larger proportion of engineers (42%) than scientists (16%); they worked more in development than in research; and the number of patent application is increasing rapidly.

The features of the Japanese firms also abide innovation. It has often been argued that Japanese firms are more growth oriented and have more long-run objectives than American and European enterprises. Rotation of workers from R&D to production and sales are more common, helping them acquire a company-wide view and gain flexibility to changing work environment. Furthermore, long-term employment naturally leads the workers to develop personal linkages across departments, facilitating to discuss problems of mutual concern and to introduce new product into manufacturing and marketing stages. Other feature is a close link with suppliers and subcontractors; consequently, they tend to share the threat of market competition as well as the need for innovation.

Thus, the role of Japanese government policy in the technological development can be summarized as: the amount of funding to industries, including subsidies, tax credits and low-interest loans was rather modest; there is a clear tendency that such government funding has decreased in amount and importance over time; the restriction on imports, foreign investment in Japan and on the growing domestic market was the most important policy, obliging the firms to compete among themselves and to strengthen the investments in plants, equipment and R&D.

4.3 - FRANCE

In 1945, France's industrial base was small and often extremely backward technologically. The industry, the coal and iron mines and the basic economic infrastructures bore the scars of two earlier decades of chronic underinvestment, the impact of the Slump of the 1930's and the destruction of the war. Finally, 40% of the French population was still engaged in agriculture.

The first phase of institution building began in a significant and spectacular manner with the creation of a capacity for R&D and production in nuclear energy, and subsequently for military purposes, lodged in a major agency, the CEA – Commissariat à l'Energie. It also included the reorganization and expansion of the CNRS – National Centre for Scientific Research. Its initial mandate piled up the responsibility to develop, orient and coordinate all French science. Although this objective was never to be achieved, the CNRS was to have a profound impact on the organization and development of basic and long-term research, the availability of scientific and technologic personnel, and the overall support of science.

Inside the technological policy of fostering R&D activities, the CNRS established numerous laboratories and research facilities, supported university research by providing services, assistants and equipment required by scientists, financed the attendance of French scientists at international conferences and subvened technical publication and the purchase of instrumentation.

During the 1945-1958 period, the production and diffusion of technology were driven almost exclusively by the State and innovation capacity sheltered principally in nationalized or publicly owned firms. Even in the setting up of the Fifth Republic, from 1958 to 1966, the R&D was accomplished strongly by the government, but policies start to be enacted to lodge at least a part of innovation within the industry's national champions, it means, the large public or private firms with which the State has decided to build up in order to work in close partnership.

The same pattern of State-industry relationship, based on procurement and often involving firms, was adopted for the arms industry, aeronautic, and atomic and space programs. Between 1959 and 1966 these programs accounted for about 65% of public R&D expenditure. It shows us the importance of military research in the French industrial policy.

The 1970's and 1980's have essentially brought about only shifts in emphasis in the area of overall R&D resource allocation and the location of entrepreneurial capacity, along with a clearer spelling out of features that were already contained within the system as it had been built previously. Therefore, two measures warrant special attention.

The first has been the development of a large military-industrial complex, which encompasses those parts of space program that fall outside the European programs, a part of the activity in telecommunications, and the efforts made to maintain a computer and components industry. The industrial elements of the complex now represent France's most powerful and at least in appear most successful high-technology corporations.

The second novel but totally logical development concerned the steps taken first to build new links or bridges between the research capacity accumulated within the public sector and all firms that are ready to carry the innovations to market. The measure was the creation of ANVAR – Agence Nationale pour la Valorisation de la Recherche, which is a fairly classical type of agency for technology transfer from government and university research laboratories to industry. ANVAR manages a portfolio of patents that files 1000-1200 applications at home and abroad on average a year, finances innovative enterprises, and even grants R&D.

Notwithstanding the changes are still far from a full scale privatization of public sector R&D, the technology policy adopted certainly represents a step in that direction. The status of the R&D laboratories was changed from administrative public institutions to a new generic type with some attributes of private law, and so, they have been empowered to establish subsidiaries, acquire shares, and seek cooperation around specific projects with scientific and industrial partners. In practice, marketing will generally be undertaken by private law subsidiaries that can more appropriately act as entrepreneurs than the research agencies themselves.

Since 1980's, the government has also fostered the set up of incubators of small high-tech companies, where these innovative firms have facilities, and technological, business and legal support to create and launch new products in the market.

Thus, we can remark on some evidences from the French technology policy: the military programs had important role in the technological development of the country; despite the government has shifted the R&D activities to private sector it funded approximately 50% in 1985; ANVAR carries out an effective function in technology transfer; and the government has spurred the blossoming of innovative enterprises.

5 - EXPERIENCE OF NEWLY INDUSTRIALIZED COUNTRIES

5.1 - AUSTRALIA

Immediately after World War II, when the Australian government began to plan for economic development, it could have acted to foster private research centers but the traditional of "colonial socialism", the satisfactory experience of war-time planning, and the lack of a technologically sophisticated private sector naturally guided to the belief that government should take the lead. Hence the creation of CSIRO – Commonwealth Scientific and Industrial Research Organization, in 1949, which was an independent statutory authority to serve the R&D needs of the rural sector, the Institute of Advanced Studies at the Australian National University, and a number of government research organizations.

From that period until middle 1960's, the Australian socioeconomic objectives were mainly aimed to agriculture production and rural exports. The government therefore had a dominant expenditure on agricultural research. Nevertheless, over the last 30 years rural sector has declined. The rural export share has fallen from around 85% during the early 1950's to approximately 35% at the end of the 1980's and the GDP share from 15 to 4%. This change has been particularly marked for CSIRO, which during the early 1970's accounted for more than a quarter of the government research budget and has now been reduced to 16%.

The development of the industrial policy adopted by the government was to be based on augmenting Australian endowments with immigrants to provide labor and foreign companies to provide capital and technology. The major policy instruments were a liberalized immigration program, including paid passages, and import protection for companies that began Australian production.

However the criticism of protection had become widespread and even the development policy failed to generate large increases in manufactured exports, which were less than 7% of manufacturing turnover for 1968-1969, and largely confined to processing of foodstuffs and basic minerals. In addition, a new industry policy of lower tariffs embarked in 1973 was no successful.

Thus, the government was aware of the need to restructure and revitalize its manufacturing and service industries. The long-term decline in prices for agriculture and mineral commodities together with rising domestic demand for imports of manufactures has led to a large and persistent trade deficit. This has been particularly pronounced in high technology goods. For the high technology industries in Australia to grow would require increased expenditures on R&D and technologically sophisticated machinery, as well as innovations in organizational structure.

Since the early 1980's the government science and technologies policies have placed an increasing emphasis on improving research agencies responsiveness to national economic objectives, particularly the need to promote a more open and internationally competitive economy and to facilitate structural adjustment.

As in most countries, there has been some concern as to the shortage of venture capital and the Australian response was to establish the MIC – Management Investment Company Program in 1984. There are 11 MICs that can raise a limited amount of capital, fully tax deductible in the year of the investment. Most of the portfolio went to activities in electronic equipment, robotics, computer software, scientific and technical services, and biomedical products.

In May 1985, the government announced a 150% taxation concession for R&D expenditure until 1993 to be phased down to 125%. At the present company tax rate of 39%, the concession provides for an additional 19.5 cents of R&D expenditure to be recouped from normal tax liability. Current cost is estimated to be $200 million, about one-seventh as large as all private sectors R&D expenditure.

In 1985-1986, federal and state governments purchased high technology products at a cost of $3.6 billion, mainly imported from multinationals. For some time government has used this purchasing power, within an offsets program, as an industry development instrument. Under this program major overseas supplier must direct activities of technological significance to Australian industry, including manufacturing, export marketing and R&D.

Therefore the distinctive characteristics of the Australian national innovation system are a low level of science and technology expenditure (1.2% of GDP in 1989), a high level of government involvement in financing and researching, a low level of private sector R&D, and exceptionally high dependence on foreign technology.

5.2 - SOUTH KOREA

The Korean War, which took place between 1945 and 1953, destroyed the majority of industrial and infrastructure facilities South Korea (hereafter Korea) inherited from Japanese colonization. When the Armistice was signed in 1953, the net commodity product decreased by 26% compared to the figure 10 years before, while net commodity product per capita dropped 44%. Ironically, the Korean War also served positively to a certain extent for the subsequent economic development, having completely transformed a traditional rigid society into a highly mobile one by forcing geographical mobility and contributed to the rapid formation of basic skills among the male labor force, most of who served compulsory military service.

Korea's rapid economic progress may be attributed to many economic, social, and technical factors. The most important of all may be technological capabilities, which is a combined outcome of various inputs. It is the ability to make effective use of technical knowledge in production, investment, and innovation. Technological capability enables one to assimilate, use, adapt, change, or create technology and to develop new products and processes in response to a changing economic environment. To achieve it, Korean government undertook some important public policies.

First, human resource development may be a most basic and crucial determinant. The Korean government's modernization strategy can be seen in the growth of government investment in education: the share of education in the total government budget, for instance, rose from 2.5% in 1951 to over 22% in the 1980's. Therefore, enrollment in the various levels of the formal education system has increased rapidly. For example, enrollment in colleges and universities increased by almost 150 times between 1945 and 1980.

Overseas training and observation were also characteristic of human resource development. As an aftermath, there were over 360,000 scientists and engineers in Korea in 1987, most of them trained abroad.

Second, lacking technological capability at the outset of its economic development, Korea had to rely on foreign technology imports. However, Korea's policies concerning direct foreign investment (DFI) and foreign licensing (FL) were quite restrictive in the early years of industrialization, when technology was not a critical element and the mature technologies needed could be easily acquired through mechanisms other than DFI or FL (e.g. reverse engineering).

Consequently, Korea promoted technology transfer through the procurement of turnkey plants. Nevertheless, Korean firms assimilated imported technologies so rapidly that they managed to undertake subsequent expansions and upgrading with little assistance from foreigners. Moreover, government policy had been biased in favor of the importation of foreign capital goods and against the development of a rudimentary local industry as a way to strengthen international competitiveness of the capital goods user industries. Such a policy became a major source of learning through reverse engineering by Korean firms.

Third, continued relations with USA in the national defense have served an important role in enabling Korean firms to accumulate experience and capability. The U.S. military procurement program afforded many producers in a number of sectors with occasions for assisted learning by doing to meet exacting product specifications. Parallely, Korea had to maintain one of the largest military forces in the free world and acquired capability for defense production. The threat of northeast neighbor has put enormous pressure on both the government and private entrepreneurs to upgrade technological capability mainly in heavy machine and electronic industries.

Fourth, the Korean government intentionally created large firms, *chaebols*, as an instrument to bring about the economy of scale in mature technologies and in turn to develop these "strategic industries" and to lead exports and economy. The government helped the capital formation of the *chaebols*, gave them large import-substitution projects and boosted their diversification.

And fifth, as science and technology infrastructure played little role in promoting the development of industries and there was a absence of R&D capability in universities, the government established in 1966 the KIST – Korea Institute of Science and Technology, as an integrated technical center and subsequently its spin-offs to meet industry's technical needs. However, R&D in the formal sense of the term were not important for Korea during the stage of imitating mature technologies. Industries in fact reversed the sequence of R, D&E: it started with engineering for products and processes imported from abroad, and then progressively evolved into the position of undertaking substantial development. However, research was not relevant to Korea's industrialization through the 1970's.

In 1980's, Korea's R&D efforts began to succeed and between 1981 and 1987 the R&D expenditure had increased 541%, one of the world's fastest growth rates. R&D expenditure rose faster than GNP, increasing its shares of GNP from 0.65 to 1.93% during the same period.

Government statistics indicate that basic research accounted for 16.6%, applied research for 19.6%, and development for the remaining 63.8% of the nation's total R&D expenditure in 1987. The statistics also show that the private sector accounted for 40% of the total, while universities accounted for only

28% and public R&D institutes for 32%. The share of public funds in R&D expenditure was for only 20% while the private sector responded for 80% in the same year.

The Korean government has played a significant role in helping the corporate sector secure funds for R&D activities mainly through three mechanisms: direct R&D subsidy, preferential financing and tax incentives.

First, the government introduced two schemes for direct funding of private R&D. The one is "National R&D Projects" in new technology areas focusing primarily on future problems, and the other is "Industrial Base Technology Development Projects" in existing technology areas aiming primarily on current problems. Both schemes designate targets technologies and offer direct R&D subsidy to R&D organizations.

Second, the most important mechanism for funding corporate R&D, the preferential financing offered by state-controlled banks and public funds. In 1987, it accounted for 94.3% of total corporate R&D financing (about US$ 900 millions) by state.

Third, tax incentives are a major indirect mechanism in making funds available for promoting corporate R&D investment. They are reduced tariffs on import of R&D equipment and supplies, the deduction of annual noncapital R&D expenditures and human resource development costs from taxable income, accelerated depreciation on industrial R&D facilities, and the exemption of real state tax on R&D-related properties. The incentives also include a tax reduce scheme, whereby an enterprise can set aside up to 20% (30% for high-technology industries) of profits before tax in any one year to be used for its R&D work in the following 4 years.

Therefore, we may remark that the Korean government played a relevant role in the technological development of the firms. The most significant factors are: the formation of skilled workers in the 1950's for the subsequent development, the military programs performed with U.S. partner, the reverse engineering, the import of technology and capital goods, the creation of the *chaebols*, and during the 1980's the technology policy of supporting R&D activities through grants as direct subsidies, preferential financing and tax incentives.

5.3 - ARGENTINA

In the 1940's, the inconvertibility of the British pound and the outbreak of World War, induced the military government in power into a domestically oriented import substitution industrialization that was to have long lasting consequences on the country's social and economic performance.

From 1945 onward, the nationalization of foreign trade and the expropriation of agricultural profits allowed the government to transfer resources from rural landlords to the rapidly growing urban-industrial sector. The sector developed in those days under the incentives of an expanding real wage rate and of an industrial policy that promoted various so-called "industries of national interest". The role of Argentina's highly nationalistic military forces became central to the country's macroeconomic policy formulation mechanism during those years.

However, the end of the war and the rapid technological reconstruction of the developed countries during the 1950's brought about an increasing technological gap between local manufacturing industries and their international counterparts.

Hence, the government began to revise its antagonistic attitude toward foreign capital and accepted the idea that foreign investment and technology could become major sources of economic growth.

Paralelly the Argentine government started the creation of R&D agencies as the CNEA – Atomic Energy Commission (1951), to develop technological self-sufficiency in the atomic energy field, the INTA – National Institute for Agricultural Technology (1956) with the purpose of strengthening agricultural research and extension activities, and the CONICET – National Council for Science and Technology (1958) with the target of promoting, coordinating and carrying out research both in applied and pure sciences.

The late 1950's and early 1960's clearly constituted the starting point of a period of rapid expansion in manufacturing output and in the productivity of labor. Both the functioning of the agencies and institutions supporting technical change and innovation, and the massive arrival of foreign firms, were mainly responsible for that economic and technological growth.

The industrialization process lasted until middle 1970's. During this period, a study documented that some US$ 20 millions per year were spent by the largest 200 industrial firms in Argentina in "adaptive" R&D and engineering activities as well as in production planning and organization.

Nonetheless, the development process encountered limitations both domestic and external. On the domestic side, it was clear that many consumer durable markets became highly saturated. The import substitution industrialization strategy became increasingly criticized for its overprotected nature as well as for its lack of a stronger export drive.

On the external side, the rapid diffusion of microprocessors and microelectronic technology quickly eroded the competitive advantage many local firms had managed to attain in Latin America markets for tools, electrical instruments, and capital goods in general. Local entrepreneurs were not able to follow the pace of the international technological frontier.

In addition to these economic circumstances, it should also be taken into consideration that the domestic institutional atmosphere became rather tense with militant trade unions and students groups increasingly challenging the political status quo. Argentina was at that point entering into a turbulent period from which it has not yet completely recovered.

Shortly after, in early 1976, a new military takeover occurred, and in the context of a massive process of social repression, the authorities attempted to deregulate and open the local economy to foreign competition. Among their initial economic policy, actions were found a major reduction in tariff protection, a revaluation of the local currency of approximately 40% in real terms, and the deregulation of the financial sector of the economy.

These policies, together with the fiscal incentives for raw material processing industries approved earlier, had a major impact on the rate and nature of the industrialization process as well as on the behavior of the national system of innovation supporting technical advance in industry.

As an aftermath of these policies in the innovation system, there was an absolute contraction in the industrial R&D and engineering efforts that militated against long-term technological and innovative commitments on the part of the local entrepreneurial community. Firms had turned more to the search for subsidies and special privileges than to investment and technological change.

Since 1980's, the government has attempted to increase the expenditure in R&D activities. Public R&D expenditure and knowledge generation efforts came close to US$ 380 millions per annum in 1988. However, these activities were highly concentrated. Eight agencies and institutions, including CONICET, CNEA and INTA, absorbed 90% of the total budget.

Argentine universities do not constitute an important source of new technology. Basic research is normally performed for the "advancement of science". They have just been marginally contributing to the national system of innovation.

Thus, we can observe that the Argentina's innovation system was mainly harmed by the lack of a consistent technological public policy, a scientific and technological sector that has lacked in sense of purpose and direction, a rent-seeking activities rather than in technological and innovative efforts, and a concentrated and oligopolistic industry that developed in an overprotected environment.

6 - BRAZILIAN TECHNOLOGY PUBLIC POLICY

6.1 - TECHNOLOGICAL POLICY EVOLUTION

The period between 1947 and 1964 was characterized by a strong drive toward industrialization. This period was built around ambitious projects in energy, transportation, steel and petroleum refining, chemicals and petrochemicals, capital goods, automobiles, and pharmaceuticals.

One of the essential elements of the industrial development strategy was to induce foreign firms to set up manufacturing facilities in Brazil. This consisted of not only protecting the local market, but also of offering significant subsidies and special treatment for foreign investors. At the same time, important steps were taken in the science and technology – S&T area. The National Research Council – CNPq was established in 1951 to promote research in all areas, mainly to prepare Brazil to use its mineral resources for the production of atomic energy.

The creation of CNPq has to be seen in the context of postwar polarization, competition, and conflict. Harnessing atomic energy was perceived as the key to military power and a crucial step for accelerating the process of economic development. The emphasis on S&T during this period was also a matter of national prestige. There was an important demonstration effect from the scientific and technological activities of the advanced economies that drove countries such as Brazil to try to keep up in order to gain international stature. Much of the effort was driven by the military. A number of institutions were set up by the armed forces during this period. Possibly the most successful was the Aerospace Research Center – CTA established in 1947, which played a major role in the development of the Brazilian aviation industry as well as the gasohol program.

In the early 1960s the Brazilian economy lost steam as ambitious projects, including the building of the new capital Brasilia, and subsequent poor economic management led to growing macroeconomic imbalances. The deterioration in economic and political stability eventually led to a military coup in 1964 and to 21 years of military rule.

That period saw many changes in the structure of the Brazilian economy and in policy-making. Greater efforts were directed toward planning for development and formalizing essential programs, and increased resources were allocated to S&T.

Three important institutions relating to S&T were created during the first 3 years of the military period: the FUNTEC, a special fund to finance the training of specialized technical personnel for research and related activities in the universities, the FINAME, a fund for the acquisition of machinery and industrial equipment, and the Agency for Financing Studies and Projects – FINEP. In 1970 the National Institute of Industrial Property – INPI was created. Among other responsibilities, it was to regulate transfer of technology.

Brazil’s competitive position in the 1970s improved significantly. It had expanded its world market share in industrial segments with positive manufactured exports, and had an impressive record of market diversification and product differentiation. In many categories, such as office machinery, boats and ships, aircraft, and textiles, the export composition shifted to higher value-added products.

Financial incentives had been the main instrument for encouraging the development of technological capabilities at the firm level. Since 1973, FINEP had used subsidized loans, risk-sharing instruments, and, to a lesser extent, equity participation to foster national firms to undertake technological activities. The focus had been on the development of import substitutes and products that would allow national firms to compete with foreign-owned producers in the domestic market. There had been a growing emphasis on establishing R&D and quality control labs, developing, and improving products, processes, and tools.

However, in the 1980s, the competitive dynamics of the Brazilian economy had changed substantially, with constant or declining market shares, including technologically sophisticated areas. Virtually all-nontraditional and nonnatural resource-based manufactured products had their gains reversed.

Several factors explain the country's inability to sustain its competitive position. After the second oil shock, macroeconomic adjustment was postponed, and consequently Brazil's growth became increasingly debt dependent. International interest rates rose rapidly, and economies driven by debt-led growth strategies became unacceptably risky for lenders once countries began to default on sovereign debt. The ratio of investment to GDP fell dramatically.

Moreover, efforts to deepen the industrial base were based on restricting imports. Such policies also shielded producers from domestic and international competition. As the industrial sector matured, these protective barriers solidified, and firms became increasingly secure in their market position. Protection from competition made firms less resilient and management less responsive to the rapid shifts in the international economy: an accelerated rate of innovation and intense technological and commercial rivalry were accompanied by increased protectionism in developed countries.

The most comprehensive attempt to block imports and foreign investment, and promote domestic firms' capabilities had been in informatics, broadly defined to include computers and peripherals, professional and industrial electronics, and microelectronics. Brazil's informatics policies reserved the domestic market exclusively for national producers, fostering the establishment and growth of a sizable number of firms. However, they had not brought adequate levels of production efficiency, while design efforts had resulted at most in incremental innovations within well-known and relatively open technologies. Thus, there was a backwardness in the Brazilian's informatic area, and consequently in the updating of the industrial sector.

In regards to R&D expenditure, the public sector had been dominant not only in scope but in resources allocated. A complex and differentiated government institutional network carries out the majority of R&D activities. Although there were no firms' estimates of total R&D expenditure in Brazil until 1993, most sources estimate that public sector expenditures account for between 80 to 90% of total R&D outlays during the 3 last decades.

However, government-undertaken industrial R&D had not been very effective due to generally weak linkages with the productive sector. A 1989 survey of sources of technology in Brazilian industry noted that less than 5% of product designs, tool designs and manufacturing processes had originated in research institutes.

According to an earlier confident estimate in 1993, S&T expenditures were about US$ 4.7 billions, performed 81.8% by public sector, and representing 0.77% of the GDP.

To summarize, the technology policy regime adopted during the last decades in Brazil had been characterized by objectives other than the acquisition of technological capabilities that would allow firms to become internationally competitive. Government interventions had been oriented instead toward enabling domestic firms to operate in new areas, design import substitutes with their own or acquired means, achieve a measure of technological autonomy, and displace multinational firms from certain key industrial segments. Therefore, the country failed to attract best-practice technology via direct foreign investment or arms-length transactions. A combination of weak domestic technological efforts and restrictive access to the most valuable foreign technology appeared to have hampered the modernization efforts of Brazilian firms.

6.2 - THE CURRENT SITUATION

A combination of limited technological involvement by domestic producers, regulatory and policy restrictions on both embodied and disembodied forms of technology imports, and weak institutional support to industrial firms increased Brazilian firms distance from the price-performance frontier. In addition, major gaps in the educational system, particularly low enrollment level in secondary school and in science and engineering, compromised the supply of technical labor force and the acquisition of technological capabilities in the future.

Hence in the early 1990s, the government began to intensify the efforts to strengthen the public infrastructure of R&D by recovering and equipping laboratories and research centers, fostering the private sector's investment in R&D activities, creating incentives and subsidies, and improving the graduation and specialization of the labor force through giving scholarships and grants to students and professionals.

During this period, four laws were approved to achieve those goals. First, the Law 8,010/90 that dispenses with the formalities for non-profit institutions to import equipment addressed to research. Second the Law 8,032/90 that concedes exemption from taxation for research institutions to import machinery and goods for R&D activities. Third, the Law 8,248/93, named "Informatic Law", which allows the deduction of 50% of the income tax for informatic firms that invest at least 5% of their gross revenue in R&D activities. Until 1996, the results of this law were investments of US$ 1.2 billion in R&D and fiscal renunciation about US$ 1.1 billion. Around 290 enterprises have enjoyed the benefits of this law. And fourth, the Law 8,661/93 that concedes deduction until 8% of the proper income tax for any agriculture or industrial firms that undertake R&D activities in-house or with the participation of universities or research centers. This law, also grants exemption from taxation to import equipment addressed to research. Recent information (September, 97) shows us that 120 firms have used these benefits, generating US$ 430 millions of incentives and providing investments of US$ 1.7 billion in new R&D activities.

Paralelly, the government financing agents have expanded the funds for enterprises to be used in improving management, quality and productivity, machinery modernization, technology transfer, and technological development.

In regards to education, the government has increased the resources to graduate and to specialize the labor force. In 1996, the CNPq yielded 30,000 scholarships for graduation, 9,500 grants for researching, and 2,500 scholarships for the technological formation of professionals.

The aftermath of this technology policy regime can be seen in the last statistics which indicate that Brazil's R&D expenditure advanced to roughly 1% of its GDP, and the private sector enlarged to 25% its participation in all R&D activities undertaken in Brazil.

The current Brazilian S&T program forecasts to 1999 the growth of the resources for S&T to US$ 13.1 billions, with participation of 40% from the private sector. It means that these investments will represent 1.5% of the GDP. Priorities will be given to the information area, automation, airspace, environment, nuclear, healthy, and sea resources.

7 – CONCLUSION

Technology and science interact in complex ways. Both private for profit and public institutions play roles in virtually all arenas of technological advance, but the efficient way of dividing this labor is not obvious. Arguments that private enterprise does industrial innovation and that public institutions have a little useful role in it are simple minded. In this area it is not totally clear what one should call subsidy or protection, as contrasted with legitimate public spending, coordination or regulation.

In this study, we highlighted the technological development of the innovative system of six different countries, after World War II. When we analyze the technological evolution of each country, the public policy adopted in regards to R&D activities, the role of the private sector in the technological development, and the results obtained, we can conclude that actually there is not a standard procedure to be followed.

For example, the national security concerns and the military programs performed during the Cold War had a very important role in the technological development of the USA, France, Korea, and to a minor level in Japan. Otherwise, it was not too relevant for Argentina and Brazil, whose military programs reflected more the ambitions of their military elites.

In Japan, the role of the government's R&D expenditures was always low compared to R&D activities carried out by the private sector. In the USA, the sources of governmental funds for R&D reached 65% in 1965, and decreased to 36% in 1994. The French government supported 50% of R&D activities until 1992, and Australia still has a high level of government involvement in financing and undertaking research. Korea adopted during the 1980s a technology policy of offering subsidies, preferential financing and tax incentives for R&D activities, and Brazil has also supported R&D in the 1990s with grants and tax incentives. Argentina did not have a consistent technological public policy until 1993.

Economic policies also had different and important roles in the technological development of these countries. The Japanese government bore the restriction on imports and foreign investments, and the protection of domestic markets. Korea fostered the import of technology and capital goods, and the creation of the *chaebols*, the Korean big companies. Brazil adopted the policy of import substitution and protection of its market, but it was not very successful in the technological feature. Australia focused its economic policy on agriculture and natural resource exploration, and has had a high dependence on foreign technology.

However, we can emphasize the relevance of education in the technological development. The countries that achieved a higher level of industrialization had in education an important tool. This is the cause for USA, Japan, France and more recently, Korea. The formation of skilled workers, professional engineers, researchers and scientists has been crucial to the technological and economic development of these countries.

Finally, it is important to stress that if the Cold War had a strong role in the technological development of most of these countries, from the 1950s until the 1990s, we believe that the new challenge at the end of this century and beyond will be the globalization and internationalization of these markets. Technology is changing rapidly, the Internet is becoming the world small, the capital is shifting toward all countries, the labor force is improving its specialization, so each country, and particularly Brazil, must search for its technological development by using any different policies and tools to guarantee the welfare of its population and a relevant role in the world economy of the next century.

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