Argentina: the development of Science based Technology

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1. Science and Technology

It is necessary to distinguish between two concepts that we will use in what follows: *Science* and *Technology* [Dv-1996] y [Dv-1997].

Technology refers to the set of skills, knowledge, tools, instruments and organization that allows the production of a product or the provision of a service [Br-1993].

Following Bernal [Be-1986] we will attempt an approximation to the concept of Science:

a. We are familiar with the concept of the *scientific method*: to study a phenomenon we start by observing it and then we formulate hypotheses on the cause-consequence mechanism that drives the phenomenon (abstraction). The next step is to test the hypotheses via experimentation, which is the reproduction of the phenomenon in a controlled environment (see Fig.1)

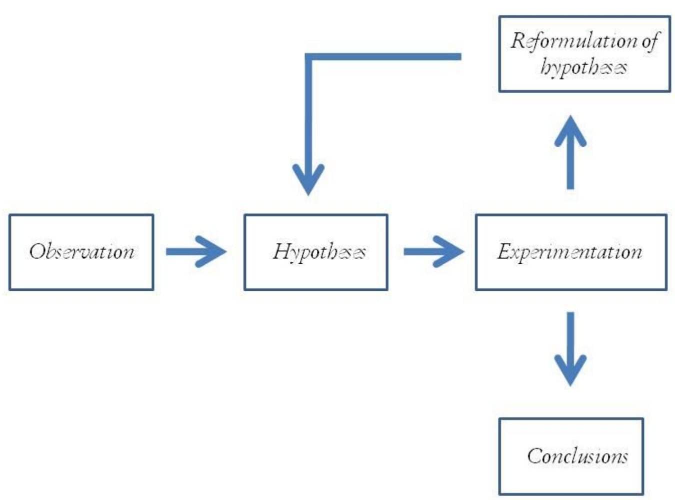

Figure 1. The Scientific Method

b. We can distinguish the *scientific instruments*, that is to say the measurement and analyses apparatus used for observation and experimentation when a phenomenon is studied via the scientific method.
c. We can identify a language, which is different from the language that it is used in normal life, and that is used by those that employing the scientific method as a tool work on similar topics. This is the *scientific language*.
d. Those who use the scientific method, the scientific apparatus and the scientific language form the *scientific community*. The people inside this community interchange experiences, evaluate the production of its own members (peers review), produce its own publications, etc. The members of the scientific community are called *scientists*.

Hence, following Bernal, we define the activity of the scientists as *Science*.

In the following table we highlight the most important differences and similarities between Science and Technology:

	SCIENCE	**TECHNOLOGY**
PROPERTY OF THE RESULTS	Social	Private (either a person, a company, a coop or a state)
ULTIMATE PURPOSE	Independent	Dependent
DIFUSSION	Irrestricted	Restricted
DEVELOPMENT	Accumulative *"If I have seen further it is only by standing on the shoulders of giants" Isaac Newton*	Uneven
METHODOLOGY	Scientific method	Indifferent
IMPACT IN TIME	Inmediate or deferred	Inmediate
LATERAL IMPACT	Ample	Ample

Table I. Science and Technology

In Fig. 2 we present a scheme of our vision of the relation between Science, Technology and production.

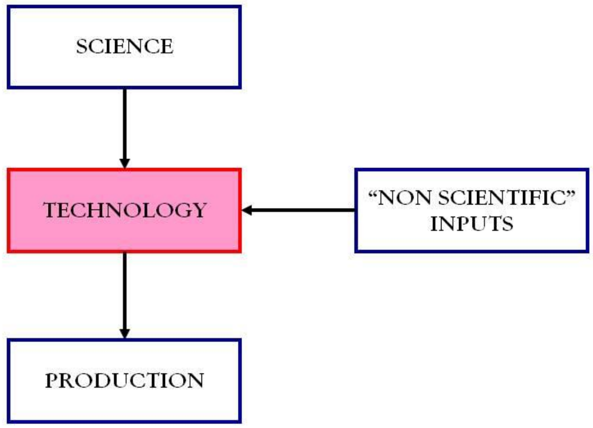

Figure 2. Science, Technology and Production

We should not interpret from the above figure that is necessary that science precedes technology. Bernal [Be-1986] provides the following counterexamples:

- Bows and scales were used much before Archimedes formulated the lever law. However, the lever law provided the basis for the a-posteriori development of technological developments more elaborated than bows and scales.
- The cathedral builders, in the middle age, did their constructions before the corresponding scientific knowledge was available [Be-1986].

Technological developments also impacted on the development of Science; e.g. the construction of precise clocks enabled the development of accurate scientific apparatus and also opened a research field on dynamics. The first mechanic clock can be traced to the year 1286 [Ca-1995] and the mechanics for understanding and improving the clock was much later developed by Galileo (1564-1642) and Newton (1643-1727).

A society that is willing to transition from scientific knowledge to technological applications needs to construct the *"knowledge development chain"* pictured in Fig. 3.

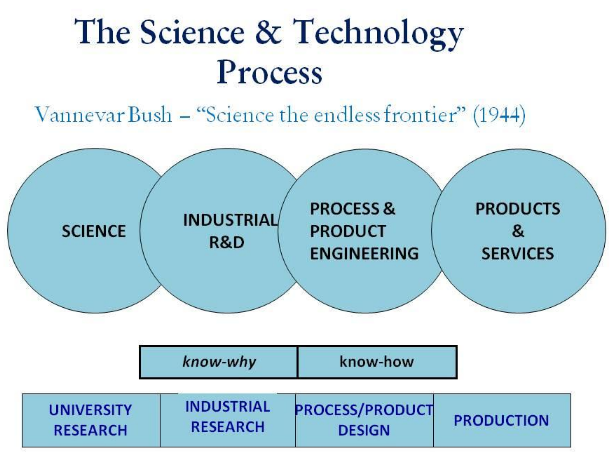

Figure 3. Science and Technology Chain

However, neither is the above scheme the only way for a society to develop Technology nor is it the mandatory route for Science.
We can conclude that,

- Technology is not the mandatory objective for developing Science.
- Science is not the necessary prerequisite for developing Technology[1].
- BUT ... when they are matched they can produce high benefits for the society.

In this sense, it is important to remark that two important news of the XX century were Engineering Sciences and Applied Scientific Research.
The Vannevar Bush vision in the US [VB-1944]:

> Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited national resources, and will assure means of defense against aggression. But to achieve these objectives - to secure a high level of employment, to maintain a position of world leadership - the flow of new scientific knowledge must be both continuous and substantial.

The Bernardo Houssay vision in Argentina [Ho-1960]:

> Some people believe that Science is a luxurious item and that the most developed countries spend in Science because they are rich.
>
> Big mistake; they spend in Science because it is an excellent investment and in that way they get even richer.
>
> They do not spend in Science because they are rich and prosperous but they are rich and prosperous because they invest in Science.
>
> Nothing gives higher revenues than the scientific and technological research.

2. Innovation

Absolute *innovation* is doing what has not been done before by anybody.

In Science the concept of innovation is absolute and it is also absolute in the very competitive high tech industries.

[1] A powerful technological development does not necessarily require a solid scientific establishment and the Korean case is a very illustrative example [WL-1999].

In other more traditional industries (e.g. the steel industry) we can distinguish the *local innovation*: the process through which a company provides a product or service new to that company or even to its country [Br-1993].

The MIT mathematician Norbert Wiener defined in the '50s four conditions for innovation [Wi-1994]:

1. ***The generation of a new concept***
2. ***A technological environment that makes possible the development of the new concept.***
3. ***The integration between scientists and producers.***
4. ***The innovation stimulus.***

3. Science and/or Technology: motivations

In Fig. 4 [St-1997], the research and development activities are classified according to their scientific and/or technological motivations.

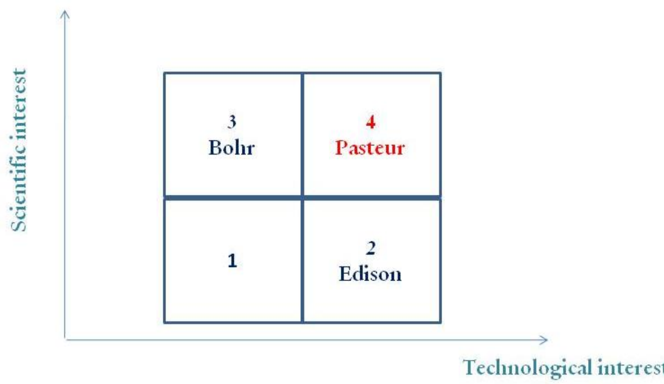

Figure 4. Stoke's four quadrants diagram

In the first quadrant we localize the routine engineering activities.
In the second quadrant (*Edison's quadrant*) we localize the very innovative technological activities with low scientific interest.
In the third quadrant (*Bohr's quadrant*) we localize the activities that have a high scientific interest and do not lead to technological developments.
In the fourth quadrant (*Pasteur's quadrant*) we localize the activities with high scientific interest and high potential for technological innovation.
The desideratum is to evolve the country S&T system to the Pasteur's Quadrant.

How to evolve?
Pushing from the side of the scientific offer is good for the scientific system; but, as it is schematized in Fig. 5, we may end up incrementing only the Bohr quadrant without any actual impact on technological development.

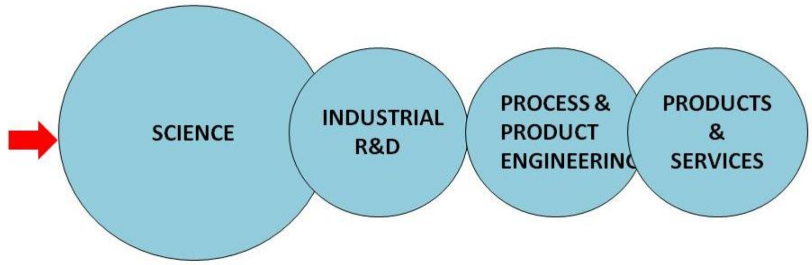

Figure 5. Pushing from the scientific end

It is necessary to pull from the side of the industrial demand.
But, who can drive a powerful industrial demand?
In table II we present some international examples:

Country	Main demand drivers for R&D
US	DOE, DOD, NIH, etc.
EU	European Programs
Japan	MITI
Brazil	Petrobras, Embraer, etc.

Table II. R&D Drivers

Only the governments can undertake long term and risky research projects.
To evolve to the Pasteur's Quadrant, Argentina needs to urgently rebuild its public sector.
In the following picture we show the well known Sabato Triangle, a scheme of the desirable interaction between the main stakeholders in the technological development process.

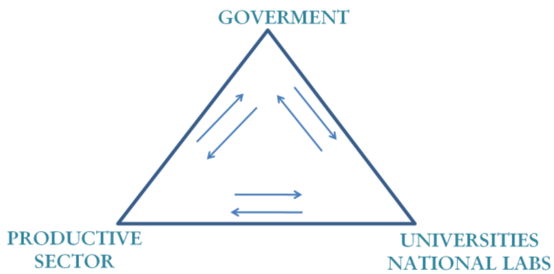

Figure 6. The Sabato triangle

4. Is Argentina investing in S&T?

The answer is yes; and also, as a result, the Argentine scientific production is increasing.

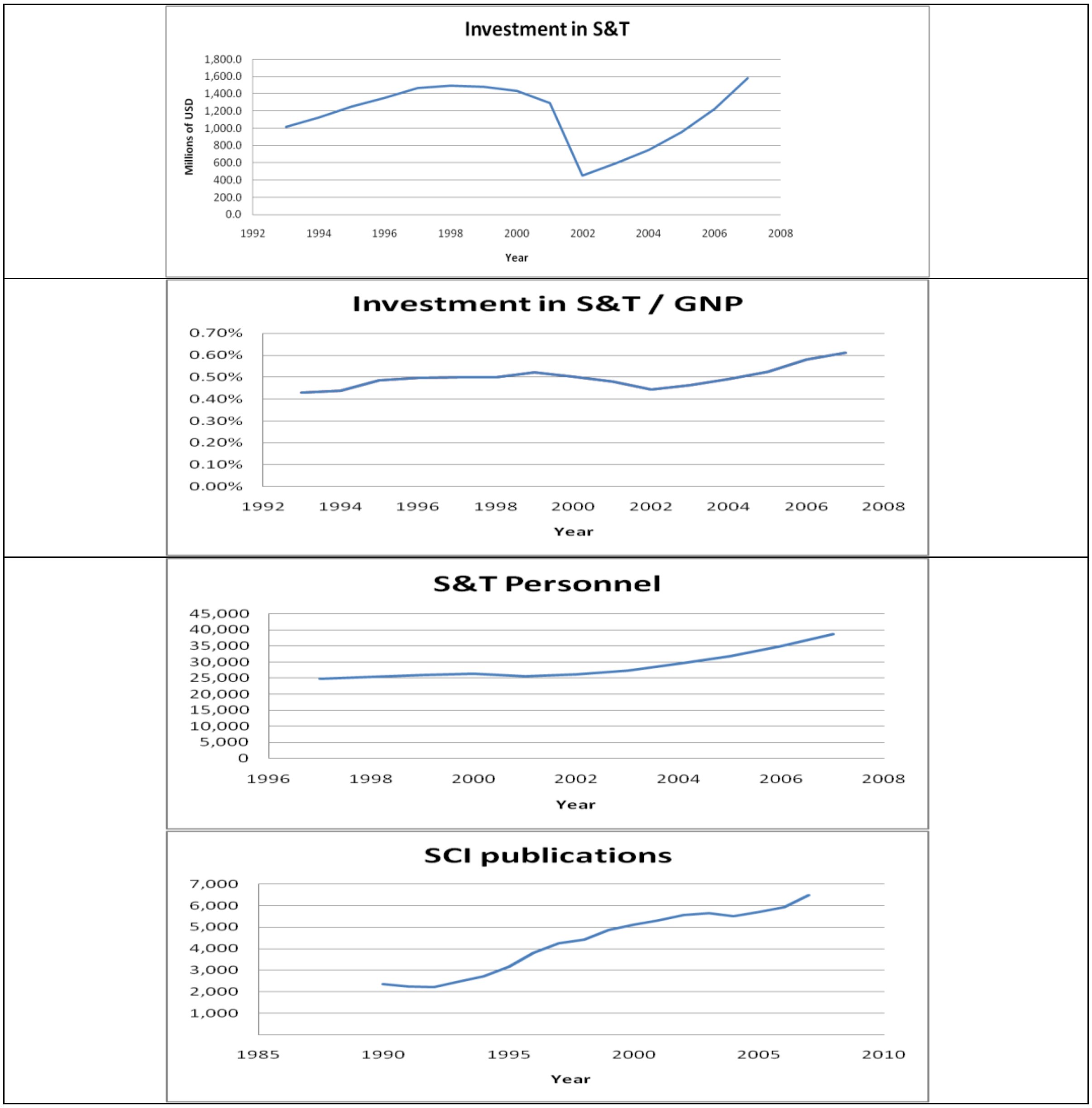

Figure 7. S&T Investment in Argentina

However, we are still not spending enough resources in the field as it can be seen from the international comparison in Fig. 8.

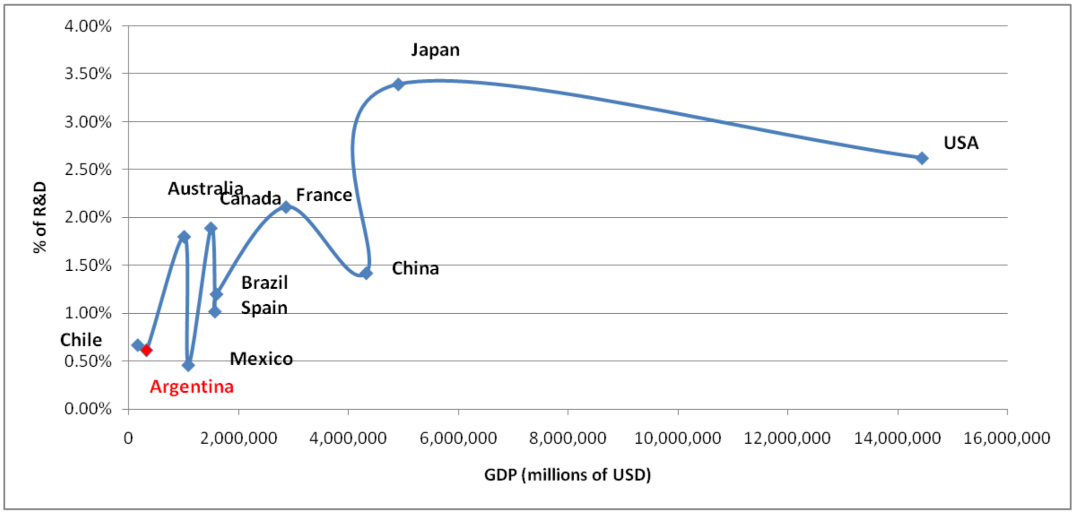

Figure 8. Expenditures in R&D as part of the GNP

It is important to point out that this growth in the Argentine Science, has not yet had an equivalent impact on the Argentine Technology production.

5. Argentina successful cases of Science and Technology interaction

In this Section we are going to very briefly summarize some of the successful Argentine cases of S&T interaction.

Company	Owner	Fields
INVAP S.E.	State owned	Nuclear, satellites, radars, industrial equipments, medical systems
CONAE / VENG S.A.	State owned	Satellites and launching vehicles
TENARIS - Siderca	Private company	Seamless steel pipes
IMPSA	Private company	Hydraulic turbines, wind generators
INTA - Bioceres	Public – Private cooperation	Transgenic species
INTA and various agricultural machine manufacturers	Public – Private cooperation	Precision agriculture
INTI	State owned	Development of “enhanced cheese”; development of paintings with bactericide properties
CONICET - SANCOR	Public – Private cooperation	Development of “enhanced milk”
BIOSIDUS	Private company	Development of human proteins in genetically engineered organisms
Laboratorios Beta-IBYME-CONICET	Public – Private cooperation	Development of human recombinant insulin
UBA-CONICET-INTA-BIOSIDUS	Public – Private cooperation	Cows cloning for the production of medicines

6. Conclusions

The importance of Science for the development of the country is well recognized in Argentina.

The transition from Scientific Knowledge to Technological Applications needs more pulling from the public sector.

7. References

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