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Emergence, consolidation and main current challenges of India's National Innovation System: a historical interpretation from Latin America

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Emergence, consolidation and main current challenges of India's National Innovation System: a historical interpretation from Latin America[1]

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1 The development of India's National Innovation System, between successes and debts

India is undoubtedly a country of strong contrasts and historical ethnic, religious and regional heterogeneity, among other things (Metcalf and Metcalf, 2013; Parthasarathi, 2011). Broadly speaking, more than a third of its population is poor and unemployed or underemployed, yet the country has one of the highest GDP growth rates in the last three decades (Drèze and Sen, 2013; Joseph and Abrol, 2009). India is among the first ten countries with the highest current military expenditure in the world, with one of the most important nuclear programs of the world, however the pacifist movement led by Gandhi was one of the most significant of the last century (Cassiolato et al., 2008; Chaulia, 2011). A national socialist revolution brought to power two families, first the Nehru and then the Gandhi, that ruled the country for nearly three decades. From 1996 to 2006 India was positioned in the top-ten nations with more citations in the Science Citation Index (SCI), but R&D expenditure was around 0.80% of their GDP (Joseph, 2010) - this represents almost 30% lower than the Brazilian's one in 2012 (World Bank, 2014). An Indian company of information technology (IT), Tata Consultancy Services, which has more than 300,000 employees, is a worldwide leader in the sector, still the private sector only contributes 30% to the total expenditure on R&D (Joseph, 2011; Krishna, 2013, Joseph and Abraham, 2005).

These contrasts fit perfectly with the idea put forward by Nelson (1977) who highlighted the importance of understanding the innovation systems to explain and predict the direction -also add here the peculiarities- of change and technological asymmetries among –and within- different countries. There he introduced elements to understand why the man can reach the moon, but still cannot find a vaccine for HIV. Following this thought, to draw a technological perspective of a country with the characteristics of India, we need to recognize the historical molding process of the peculiar National Innovation System (NIS) that displays glittering achievements, but still has significant structural problems regarding the quality of life of its population and its geopolitical challenges.

Within the Globelics community the National System of Innovation of India has been subjected to extensive analysis. Particularly worth mentioning are the contributions of K J Joseph and Dinesh Abrol to several Globelics Conferences and the impressive coverage of different aspects of the NSI of India within the BRICS project by the team led by KJ

Joseph (Joseph and Abrol, 2009; Joseph et al, 2010; Joseph, 2011; Joseph, 2005; Lundvall et al, 2009; Krishnan, 2003; 2010; Kumar and Joseph, 2006, Abrol, 2010). In this paper we depart from this comprehensive effort to guide some research questions since a Latin American motivation and framework. In this sense, it is important to have in mind that both our societies and India started the post war years of mid XX century emphasizing the importance of self reliance in science and technology and are facing since the 80s the challenges of a more open external insertion, the emergence of a new techno-economic paradigm and the deepening in financial globalization (Perez, 2002; Erber & Cassiolato, 1997, Suzigan, 1996).

Thereby, the technological development is analyzed from the problems, bottlenecks and geopolitical, productive and social challenges faced by society and the consequent institutional efforts undertaken by it to answer challenges that lay ahead. As the Brazilian philosopher Álvaro Vieira Pinto points out in the his book The Concept of Technology - *O Conceito de Tecnologia* - (2005, p. 49):

> Men create nothing, invent nothing nor manufacture anything other than express their needs, having to solve the contradictions with reality… When we get in ecstasy before the miracles of modern technology and built a world view with the central concept of the infinite expandability of our creative power, the first thing to acknowledge, soon after our engineers moderated a little their candid enthusiasm, is that all possibility of technical progress is linked to the development of the productive forces of a society.[2]

At a society level, it is assumed that the State's action is a central element in the direction of technological efforts. That is why the nature and the way it happens the State intervention is a matter of ongoing discussion (Joseph, 2014, Mazzucato, 2014; Reinert, 1999; Stiglitz, 1989; Justman & Teubal, 1991; Krugman, 1997; Chang, 2005; Medeiros, 2013; Gadelha, 2003, Fiori, 1999; Wade, 1990). Regarding technological boundaries, Cassiolato et al., (2013, p. 21) in agreement with Rosemberg (1982), Medeiros (2003) and Fiori (2014), show how in The United States, China, Japan and Germany the evolutionary path of science and technology do not emerge

[2] From now on all quotations from texts that are not published in English or have a version in said language will be freely translated.

> Automatically or only from the concern arising out of a supposedly neutral speculations of science and technology. On the contrary, technological paths and hence the future trends in scientific and technological development are the product of complex interactions between different political, social and economic actors, conditioned by visions and national strategies linked to different nations' perceptions of their current role and future one in the global geopolitical context.

Particularly, when it comes to India, what is questioned in the evolution of forming their NIS and science and technology policies is, how they were affected by the passage of a linear innovation system, focused on big science, marked by State policies and interventions of technology-push type, to a scheme that seeks greater systemic integration, emphasizing the so-called inclusive innovation, all in a not so long period of time (Abrol, 2013, Joseph, 2013, Rothwell, 1974; Kline & Rosemberg, 1976; Cassiolato & Lastres, 2005). So, it is proposed that during this transition India managed to combine, in some areas such as IT, the scientific and institutional developments accumulated during the stage of State planning with the 'creative destruction' processes, first generated through the internal deregulation process and then after an opening to the foreign capital. However, despite the macroeconomic performance, they have not managed to solve many of the technological problems related to population basic needs, defense sector and public services and infrastructure in key areas such as health, education, transportation, energy, potable water, and so on. This paper will seek to show that these challenges together with the past, outlined the future outlook of the Indian technological development.

At the same time, the ability to align a society in favor of scientific and technological development is not a simple process. In this sense, for us Latin Americans it is appropriate to understand the evolution of NIS in India from Amilcar Herrera's (1971, p.7) perspective that pointed out the importance of distinguishing explicit and implicit science and technology policies[3]. To this author, the explicit science policy

[3] Amílcar Herrera was an Argentine geologist who made some of the most important contributions in the 1970s and 1980s to the Latin American literature in S&T policy. With the dictatorship in Argentina he was exiled in the UK where he spent some time at the Science Policy Research Unit where he collaborated extensively with Chris Freeman. Before that he led at the Bariloche Foundation in Argentine a team of Latin American scholars which provided the most important academic response to the Club of Rome dismal work on the limits to growth.

> It is expressed in the laws, statements and regulation of the organizations that are in charge of planning; in the development plans, in the government communications, etc. Summing up, they constitute the body of norms and statements usually known as the scientific and technological policy of a country.

But it is the implicit science and technology policy that really matters and is what impedes Latin American development in technology and innovation: "*Although it really establishes the role of the science in society, it is much more difficult of identify, because it does not have a formal structuration; in essence, it express the scientific and technological demand of dominant 'national project' in each country*". However the "national project" is defined as a set of goals and the country model aspired by the social sectors that have, directly or indirectly, the economic and political control of society. The main point is that this definition refers to concrete targets designed by the ruling elite with power to articulate and implement them.

Then, looking at the evolution of Indian S&T policy from Herrera´s lenses we could argue that the political partnership of key actors during the post-colonial period has been a relevant element to establish a national project where science have a principal role as a way of achieving self-affirmation. This partnership was between the political and religious elite, mainly represented by the Nehru family and later on with the Gandhi family and the scientific elite, establishing what Herrera calls an implicit explicit policy around science. Despite the opening and recent reforms and some clearly neoliberal policies, it is still possible to notice an umbrella around a "national project" that still aims to continue the development of science and technology in India. Nonetheless in the last decades the leadership of the development process is experimenting a reconfiguration with increasing participation of transnational and national private capital.

To sum up, on one hand, this paper aims to interpret the evolution of the Indian NIS since the geopolitical, productive and social challenges faced since the independence. On the other, it analyzes the extent to which explicit policies and especially the implicit ones developed by Nehru, despite having structural deficits, still work nowadays. The methodological background is the historical-structural approach characteristic of Latin American structuralism (Bielschowsky, 1998; Lopes Ribeiro, 2011).

2 The development stages of the Indian NIS

Next, there is a characterization of the NIS's development phases and the main industrial and technological policies implemented since the pre-independence to the present day based on the specialized literature.

a. Colonial science (before 1947): limiting and incentives from English rule

India was a British colony for about three centuries. During this period we can highlight some attempts and initiative regarding the scientific and technological development on Indian Territory and also some cultural heritage in relation to the language, the customs and possibilities of interaction mainly among the Indian elite with the Anglo-Saxon world. Nonetheless most authors are very critical in respect to the English extent of involvement in local technical scientific projects and even cultural heritage.

According to Rao (2008), there was nothing like technology policy in colonial India. There were few scientific institutions, and no obvious attempt to increase the scientific content of educational institutions or to crate institutional structures and agencies devoted to science and technology. Even more critical, Joseph (2008) reports that the English Heritage had a growth rate of the economy lower than 2% during the first half of the nineteenth century, with the growth rate of the GDP per capita less than 0.5%. Structurally speaking, India showed features of an underdeveloped economy: a) agriculture employed 85% of the population while the industrial sector only 10%, b) illiteracy reached 85% of Indians, c) child mortality was extremely high and they had a life expectancy of 30 years old.

The initiatives linked to scientific development during the colonial period, addressed by Krishna (2008) as "colonial science", relate to the railroads, geology, trigonometry, the botanical garden, questionnaires and information processed on jobs linked to the administrative and exploratory functions developed by England in India that time. There was a center-periphery type of division between England and India, where the role of the Indian establishment was oriented to search for information, with low degrees of processing and self-development. Therefore, the first three modern Indian universities[4],

[4] In fact, the first Indian "university" was located in Nalanda, between the 5th and the 12th century, although it was not a formal one, as we know nowadays.

Calcutta, Bombay and Madras, all of them created in 1857, had as its main task to train administrative and technical staff for the administration of the colony, offering this way few science courses. Among the main scientific institutions appear Survey of India, founded in 1867 and India Meteorological Department established in 1875.

The agricultural and railways development are interesting cases to reflect the colonial technological dynamic. As explained by Tucker (1988), the British Raj had a central role in the agricultural settings of the current India through the dismantling of indigenous forests, especially in the region of Kerala and Assam, and the introduction and expansion of certain crops such as tea, rice, rubber, opium, as well as different seeds for export. This modification of the original Indian subcontinent agrarian structure included some technology transfer in order to adapt these types of crops, but, at the same time, a loss of diversity of the local forest and in the living standards of farmers. In fact, the disconnection between the growth of the Indian population and the development of production for export resulted in different episodes of starvation deaths on a large scale, one of the most important occurred in 1877.

With regard to railways development in the second half of the twentieth century, they met both military and commercial interests. They facilitated the transfer of troops in Indian territory, such as business, expanding the market for English manufactures and ensuring the cotton supply. As developed in Metcalf and Metcalf (2013, p. 123)

> the construction of the railway offers a view of the workings of the British Indian rule in mid-century. The project was funded by British capital. The East India Company and after 1858 the Crown guarantee to investors, virtually all British, a return of 5% ... it was the first transfer of British capital to India... the construction of railroads provided a market for British goods. Rails, locomotives, wagons and other manufactured goods, and sometimes even English coal... were exported to India. this meant that a major public works project that could have served as a 'pioneering sector' to generate 'multiplier effects' for the industrialization of India did not have this effect.

However, according to Krishna (1997), from 1940 to 1980 it happened a break with dynamics of “colonial science” type and, in parallel, a series of structures in science and technology were created. These were the first efforts to shape a science and technology policy that attended the national needs and were linked with the relationship and partnership between the Indian scientific elite-many of them majored in England- and the local political elite. Thereby, within the scientific community appear M. N. Saha, who worked with stellar physics; J. C. Bose, who discovered radio waves propagation in 1905 and C. V. Raman, who discovered the so called Raman Effect. Most of them were grouped in the Indian Association for the Cultivation of Science in Kolkata and the Indian Institute of Science in Bangalore, where Raman was the first Indian director from 1933 to 1948. Among the group of political leaders gaining prominence appeared J. Nehru and M. Gandhi. This partnership would mark every step of independence and both Nehru and Gandhi governance, contributed to form the greater part of the NIS structure in India.

Although both in Africa and in Latin America there were different independence movements, there is a particular stand out in the Indian case. It has to do with how the reaction to English domination formed a partnership between the political elite and the local scientific elite that ended up nurturing the industrial and technological policies of the post-independence phase.

Despite the general negative assessment of England’s contribution regarding the Indian technological and industrial development, more likely as a reaction than as a proposed objective, the English intervention paradoxically generated the necessary conditions for the emergence of the “national science”. Even more relevant, it contributed to the formation of a political partnership that would result in the greatest period of scientific development of India.

b. Nehruvian science (1947-1964): planning and conformation of Indian NIS

This period is characterized by Krishna (2013) as "*policies for the sciences*" since it has been marked by the creation of a basic infrastructure for science and technology. PJ Nehru, the first Prime Minister of India, who ruled for almost a decade and a half, shaped all this infrastructure. According to Parthasarathy and Baldev (1990), Nehru, who had studied natural sciences at Cambridge, was a liberal and a socialist. He believed planning was the right path to development, sympathized with the USSR and mistrusted the private sector. For example, to measure the importance that the development of science and technology had to Nehru, it can be pointed out that he created the Ministry of Scientific Research and Cultural Affairs in 1948, leaving himself in charge of the establishment of the entire network of universities, scientific agencies and national laboratories.

It is known that the science policy resolution proposed in 1958 by Nehru on the Indian parliament was a key event in the scientific history and Indian technology. From among the most outstanding paragraphs of the resolution, Rao (2008) highlights:

> The key to national prosperity, apart from the spirit of the people, in the modern age, is the effective combination of three factors, technology, raw materials and capital, of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can, in fact, make up for a deficiency in natural resources and reduce the demands on capital.

And he concludes: "It is an inherent obligation of a great country like India, with its traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today". This phrase is part of an implicit policy.

Overall, the pillars of Nehru's economic policy were: a) the pursuit of industrial and technological self-sufficiency, b) incredibility in the price mechanism and preferences for allocating resources, c) property or State control of the sectors considered strategic, d) The low participation of foreign capital, e) the regulation of the financial system and f) the preservation of small handcrafted production concentrated in consumer goods sectors (Joseph, 2008; Joseph, 2011; Prates, 2014; Cross, 2007, Abrol, 2010). In this background, the Industrial Policy Resolution let it clear the intentions of a rapid industrialization policy, starting with the heavy industry[5] and implemented through a five-year plan[6]. It was a "big push" type of strategy, characterized by Swamy (1995) as "a sort of local syncretism of Keynes, Prebisch, Soviet Style planning, and the 'spirit of caste'".

Specifically, in regards to the policies and decisions of State intervention it was clear that the control and ownership of the technology and capital would be manly in the State power and in second place in the hands of national business agents. As the inflow of foreign capital was restricted, companies that did not have an Indian partner were forced

[5] As indicates Prates (2014), a difference from the industrialization based on imports-substitution practiced by Latin America countries was the emphasis both in the speeches of Nehru, as in pragramatic documents from the time - As Bombay Plan prepared by entrepreneurs – and in the deployment of heavy industry with prior to frivolous industry.

[6] The Five-Year Plans have become the quintessential planning tool of the Indian state since the year 1951 to the present day.

to sell their products as imports or to establish partnerships with public companies or national companies. In this sense, during the first decade of the Era Nehru it was necessary to import technology from abroad, since the ability to develop machinery and local equipment was still limited, although already during the 60's the goal started to be the reduction of import of capital goods. This becomes clear in the third five-year plan developed by the Planning Commission in 1961: “A basic objective in the strategy of development is to create the conditions in which dependence on external assistance will disappear as early as possible and replacement of imports is essentially a question of developing the necessary capacity for production within the country”.

Regarding the institutional framework, the period between 1947 and 1964 had an impressive growth of the State’s organizational density. As emphasized by Rao (2008), the main agencies that were created were the Atomic Energy Commission in 1948, the University Grants Commission in 1956 and the Defence R&D Organization in 1958. Also, it was created in 1951 a science division, which answered directly to Nehru and the Indian Institute of Technology. A few years later it was generated, as detachments of the Atomic Energy Commission, the Space Commission and the Electronics Commission. Moreover, in relation to educational establishments of higher education, during the era of Nehru they passed from 30 to 95 universities.

Related to the Indian foreign relations during Nehru´s period, Pant (2011, p. 16) says:

> Jawaharlal Nehru dominated the Indian foreign and security policy landscape in the immediate aftermath of Indian independence till his death in 1964. It was his worldview that shaped Indian foreign policy priorities and Indian strategic culture can be viewed through the prism of Nehruvian predilections. Nehru was a strategic thinker and his non-alignment was a classic ‘balance of power’ policy in a bipolar world. He was and internationalist.

In the case of the conflicts with neighboring countries, the Indo-Palestinian war of 1947, which was originated with the independence of the two countries around the territorial dispute over the region of Kashmir and the conflict with China in 1962 around the border of the Himalayas have worked as a motive and stimulus for the development of the defense industry in India. In this sense, the aircrafts used by India in the conflict of 47 were British, which later led to the development of the Indian airline and aerospace industry (Wilson, 2003).

In relation to the conflict with China, the advance of Mao was so important that Nehru had to ask Kennedy in the United States for support, though unilaterally the Chinese had finally decided to stop the offensive and the advance of the army. This defeat was a military keystone for India´s geopolitics and for the defense sector. It highlighted the weakness of Nehru´s defense policy approach, it turned visible the geopolitical and territorial competition between China and India and it resulted in the beginning of the public debate about developing nuclear weapons (Pant, 2011; Cohen, 2002).

Making an assessment of the Indian industrial development, Tyabji’s (2000) points out that Indian industry has shown an impressive advance since the country’s independence, despite that, the industry had serious deficiencies to generate innovation in design, quality, reliability and reducing costs. On this line, the author emphasizes that there was a dichotomy between science policy and technology policy, prioritizing the former over the latter. In relation to economic performance, as highlighted by Prates (2014), the average of economy growth between 1947 and 1970 was only 3.5% , after that it was known as the standard Indian growth that was marginally higher than the population growth, making the benefits of technological development intangible for the whole society.

Nevertheless, just to synthesize science and technology policy during the Nehru era, it can be said that during that time, this policy had been clearly thought alongside the supply side -technology push-, a strong State participation and economic planning, in order to form the basic Indian NIS. It was given a strong boost to heavy industry and science, developing among others, nuclear industry, aerospace, aircraft, steel, steelmaking, pharmaceutical, railways, etc. The development of these sectors was mainly connected to the pursuit of technological self-sufficiency. The main weakness of the period was the low priority given to infrastructure development and the relatively low GDP growth rates. Perhaps, the most important is that a political partnership between the scientific community and the political leadership was generated, in the words of Herrera (1971), it allowed an alignment between explicit and implicit science policy and as told by Nehru himself, synthesized in his famous phrase "*to burn incense at the altar of science*".

c. Selective self-sufficiency (1965-1989): institutional consolidation and internal deregulation with Indira and Rajiv Gandhi

Without Nehru, who died in 1964, the strongly protectionist strategy started to show some deficits. Among the main weaknesses appeared the previously mentioned low growth rate, the bottlenecks of the external sector and some kind of scientific's over-dimensioning sector, without the latter having a substantive impact on technological development and on the living conditions of the population. Moreover punctually, rising oil prices generated by the 1973 crisis fully impacted Indian industrial structure (Krishna, 2013).

However, projects and policies supporting science and technology continued, first during the "age of Gandhi", with Indira Gandhi, daughter of Nehru, and Prime Minister on two occasions between 1966 and 1977 and from 1980 to 1984. After her, there is Rajiv Gandhi, who since 1985 begins a process of a stronger economic opening. Regarding the scientific and technological policies, they aimed to systematize the planning processes and they changed from an almost total self-sufficiency scheme to a selective self-sufficiency one. At the sixth five-year plan it was declared:

> Self-reliance, as should be obvious, but often is not, does not necessarily means, self-sufficiency in all sections of the economy... however, self-reliance can no longer take the form of indiscriminate import substitution... export promotion is as much a part of the drive for self-reliance as efficient import-substitution.

On the institutional level stands out the creation of the National Commission of Science (NCST) in 1972 and the formulation of the first Science and Technology Plan for the period of 1974-1979. But even with the new institutions many of the technological trajectories elected and initiated by Nehru continued: in the early of the 80's, India joined the space and nuclear clubs. So the Indian Space Research Organization (ISRO) developed satellites to use at communications, meteorology, prospective, research in natural resources, cartography and more recently telemedicine, ocean resources, etc. As pointed out by Narasimha (2008), in 1975 the first Indian satellite called Aryabhata was released from the USSR, five years later Rohini was the first satellite sent into orbit from an Indian base.

As pointed out by Mani (2001), in 1983 the Technology Policy Statement (TPS) was launched, which had as its main objective to develop endogenously technology and to absorb and adapt technology from overseas. Although the actual impact of TPS has not been estimated, a relevant product was the creation of the Technology Information and Forecasting Assessment Council (TIFAC), which prepared the first technology foresight study in India, the *Technology Vision 2020.* This study focus on the future prospects of the following areas: food processing, civil aviation, electricity, agriculture, sea and road transport, health, life sciences and biotechnology, advanced sensors, industrial engineering, materials and processes, services, electronics and communication, processes and chemical industries, telecommunications and strategic industries.

Regarding higher education, 55 other universities were created, reaching 145 establishments in 1990. As a result, according to figures from the Department of Science and Technology, the number of graduates in technical and scientific disciplines increased significantly between 1970 and 1991: degrees in engineering went from 244,400 to 873,900, an increase of approximately 360%; the number of graduates in science more than tripled, from 139,200 to 482,000 and also it was multiplied by three the number of medical graduates, increasing from 97,800 to 310,300. Speaking of which, compared with China, India has achieved greater visibility in the world of scientific publications: in 1990 recorded 10,103 publications in the SCI while the current second in the world economy had 6,509. However, it was around this time that the phenomenon known as “brain drain” started in India, due to better payments and personal development opportunities, qualified personnel found themselves in foreign countries such as England and the United States (Narasimha, 2008).

In relation to the regulatory framework, the government’s presence remained visible. In 1969 the Monopolies and Restrictive Trade Practices (MRTP) was created followed by the Foreign Exchange Regulation Act (FERA) in 1973 to control the presence of foreign companies and the financial flows in order to avoid imbalances in the external economy sector. Moreover, in 1969 the banks were nationalized and in 1970 was enacted the Patent Act, which reduced the duration of patents from sixteen to fourteen years and for those drug and food related to seven years. Thereby, for more than three decades reverse engineering was the way India developed much of its technological capacity in the pharmaceutical industry, which has become with time one of the main export sectors.

Green revolution deserves a paragraph on its own (Harris, 2002). In mid-60's India was forced to import seed because of a sharp drop in production and the population's feeding problem became noticeable. Therefore, in the so called first cold-war, the Indian government, with technical and financial assistance from the United States[7], made a series of investments in irrigation, they introduced high-yield seeds and made use of fertilizers that allowed raising agricultural production from 70 million tons in 1966 to 130 million in 1978. Furthermore, the so-called 'yellow revolution' characterized by the production of oilseeds in semi-arid areas was also important and contributed to the gains in agricultural productivity. Both revolutions were important in different ways. On the positive side, they connected the scientific and technological developments and the population's needs and the raise in agricultural productivity impacted positively and significantly in the Indian GDP growth rates. On the negative side, Shiva (1991) argues that green revolution cause technological dependency on transnational corporations, ruin small peasants and produce environmental damage.

Concerning the defense industry, the conflict with Pakistan by exercising influence over Kashmir and a chance of conflict with China, resulted in a continued and even increased military spending during this period (Wilson, 2003). Specifically, in 1965 and 1971 were produced two wars with Pakistan over the Kashmir dispute. The latter one was the most important, killing about 9,000 Pakistani soldiers and 2,500 Indians. The Indian Navy has played a major role in this war. Indira Gandhi really encourage the development of military nuclear technology (Cohen, 2002; Pant, 2011). In 1974 India managed to detonate its first atomic bomb, which became the first nuclear power weapon of the Non-Aligned Movement.

But beyond that, it was also important the direct military intervention within India itself, mostly because of disputes between the central government and states governments. As indicated by Cassiolato et al. (2008):

> The social, cultural and ethnic diversity among the different states has motivated various attempts at insurrection against the control exercised by the central government since the 60's. We can highlight the uprisings in the state

[7] It is interesting to highlight, in line with Cohen (2002), that during the cold-war, despite its non-alignment position, India received financial and technical assistance both from the United States and from the URSS.

> of Tamil Nadu and several movements in the states of northwestern region, as in the states of Punjab, Jammu and Kashmir. In other states, such as Kerala and West Bengal, the rise of communist parties, with a strong tendency to independence on the Government has also enhanced inter-regional conflicts. To solve these conflicts it has been recurrent the use of force and military weapons by the central government.

In this regard, the oldest conflict, focusing on seven states of the country, is with the Maoist armed group CPI-M, which opposes the land ownership system and parliamentary democracy.

After the assassination of Indira Gandhi in 1984, Rajiv Gandhi took over as Prime Minister. He was also very passionate about science, so he was the first ruler to strongly promote the use of computers in the public sector and by the whole population, besides that he started talking about India's twenty-first century. On this line, he created a new Science Advisory Council formed by scientists and technologists who had no connections with the government, giving them more freedom and autonomy to provide feedback and step in. Also, it was during his administration that the decision to start with a bigger economic and technological opening was made. Rodrick and Subramanian (2008) point out that it was Rajiv Gandhi who abandoned the speech and the hostile attitude towards the business sector and began a policy in favor of the existing business companies, which meant the pregnancy of Indian's future national champions.

The emergence of new technologies such as ICT, biotechnology and nanotechnology have led to a challenge that prompted the authorities to make the decision to open the imports and allow the implementation of foreign enterprises to try to absorb and disseminate processes and knowledge in a local scale. As stated in the Technology Policy Statement from 1983 "there shall be a firm commitment for absorption, adaptation and subsequent development of imported know-how through adequate investment in research and development to which importers of technology will be expected to contribute". As said by Joseph (2008), there was an attempt to stimulate the training and upgrading of the local private sector via tax incentives, credits, subsidies etc., and through the incorporation of new technologies and R & D in-house activities. Also it was allowed and encouraged the growth of the corporate sector at the base in the internal market, this was the origin of Indian "national champions".

On the other hand, during the 80's the criticism regarding the impact of science on people's living conditions were even harder. As a response, the government implemented, still in the mid-80s, the "Technology Missions", in the words of Krishna (1997), they were "time-bounded regulated schemes for tackling the basics needs through redirection of science and technology inputs in water, immunization, oil-seeds, telecommunications, leather and literacy". So, they tried to shape the technology policy to new global challenges and population needs. Finally, in terms of sectors, between 1970 and 1990 the share of agriculture in the Indian GDP fell from 39% to 27%, the industry increased from 23% to 26.5% and services increased notably from 38.5% to 46%.

In summary, the governments of Gandhi can be characterized by the continuity of the linear view of the innovation process initiated by Nehru, either by attempts to link the scientific development to the population's needs or, already in the 80's, by rewarding the private sector and starting the commercial and technological opening process. Furthermore, both armed conflicts and the need to solve basic problems for the population, such as food security, influenced the choices and technological developments of the time. However, the State participation in the economy continued to be important both in terms of direct intervention, through public companies, as well as in the regulatory area.

d. Since the New Economic Policy (1990-20??): internationalization and decentralization

The current account crisis in 1989 marked the need to balance the external sector of the economy. The New Economic Policy (NEP), which began in 1990, meant a strong deepening openness and decentralization policies in S&T. More in line with the neoliberal times, with N. Rao as Prime Minister and M. Singh as Minister of Finance, they introduced policies focused on: promoting exports and FDI, selective privatization of public enterprises, the encouragement to competition and investment in the transport sector, mining, electronic, telecommunications, pharmaceutical and ICT. Partnerships between the State, through public companies, and the private sector acted as an instrument to stimulate investment, especially in infrastructure and in several technology development programs. However, the governments' participation and investments in key sectors and areas such as aerospace, nuclear and defense, remained present.

Analyzing more deeply the last few years or R. Gandhi government, Krishna (2013), points out that in 1991 a Planning Commission of the Ministry of Industry stated:

While the government would continue to follow the policy of self-reliance, there would be greater emphasis placed on building up India´s ability to pay for imports through its own foreign exchange earnings. At the same time, foreign collaboration would be welcomed in investment and technology in order to increase exports and expand the production base requiring higher technology.

The investments of Indian companies abroad were stimulated and that facilitated not only the access to technology and qualified human resources but also the access to international markets. So, according to Ribeiro (2014), the flow of direct investments conducted abroad by Indian companies went from only $ 6 million, in 1990, to 514 million in 2000. Much of these investments were made in neighboring countries such as Bangladesh, Bhutan, Nepal and Sri Lanka. The main companies making foreign investments were Tata Group, NTPC Limited, Mahindra Group and GMR Group.

But the incentives were not only for national business players, but also for transnationals that have decided to invest in India. As put by Prates (2014) the liberalization of the 1990's led to two major decisions: 1) direct investment from abroad with more than 51% of capital control began to receive automatic approval in sectors considered of "high priority" and 2) it was created a council for the promotion of foreign investment (Foreign Investment Promotion Board) to assess the FDI proposals that had not been approved by the predetermined parameters and procedures. The first case covers investments for technological and industrial parks linked to computing services that attracted large multinational conglomerates such as Motorola, Hewlett-Packard and Cisco System and the second is focused on infrastructure projects such as generation, transmission and distribution of electricity, roads and ports, since they needed to sustain the high growth rates of the decade.

Besides that, other measures that have been adopted in relation to FDI were: to grant absolute monopoly on patents of foreign companies that develop new products or processes locally, lifting the ban on using foreign brands in the Indian market and the progressive abolition of restrictions on remittances abroad. Thus, according to United Nations Conference on Trade and Development (UNCTAD), between 1920 and 1989, 22 million dollars in concept of FDI entered in the country, between 1990 and 1999 the figure amounted to 92 billion and between 2000 and 2007, 71 billion. In 2007 there was a real boom in FDI flows and they reached a record high of 32.4 billion dollars, which was equivalent to 1.3% of the world total amount (Prates, 2014).

With the purpose of guiding the NIS in problem solving logic and to overcome the linear focus of "offer", the breakthrough came in the decentralization policy. As stressed by Prates (2014), in 2003 a new technology policy was launched and it had as main goals: i) to increase the national expenditure on R & D to 2% of the GDP (this percentage was 0.82% in 2002); ii) to increase the ratio between the number of scientists and engineers in the country and the total workforce; iii) raising the deposit of patents at home and abroad; and iv) to reduce the brain drain (according to the United States Patent and Trademark Office (USPTO) in the late 1990's India was the foreign country with the largest number of scientists and engineers in the United States, which amounted to 184,900). In institutional terms, the Indian state is based on a complex and extensive network of over 200 government institutions: ministries, committees, agencies, R&D institutes, laboratories and universities. All of them are members of the NIS. According to The Economist (2008), in 2007 there were in India 348 universities and about 18,000 colleges.

In this context, with decentralization, a major change is highlighted by Krishna (2013), which was the end of the domain that physicists had in the formulation of S&T policy during the decades of 50 and 70. So technocrats as S. Pitroda, chemicals such as R. Mashelkar, biologists as P. Balram, P. Bhargava and S. Bhan and bureaucrats as K. Subrahmanyam, among others, occupied influential positions during the 90's. Nonetheless this movement to decentralize the areas related to social and defense such as climate exchange, human development, national security, etc. remained in the orbit of the Prime Minister's Office (PMO).

Therefore the panorama of actors who participated in the political agenda of the discussion in S&T undoubtedly widened during the NEP. The corporate sector began to occupy a more important place in the design and formulation of policies, in order to improve coordination between the S &T institutions and the industry. A shift happened in this scenario, from a partnership between the political elite and the scientific elite, which ran smoothly since the independence to a scheme in which, according to Krishna (2013), did not have a defined "center of gravity". In this case, new actors emerged in the bureaucracy as well in the business community: the national champions become consolidated. They had already appeared in the previous decade, although it is in the new century they had remarkably set impressive conglomerates in India and to a lesser extent, abroad. In this list of 'captains of industry' appear R. Bajaj, R. and K. Tata Mahindra Automotive sector, N. Murthy and the software association NASSCOM, the Ambani brothers petrochemical and communications, Mittal brothers telecommunications and B. Kalyani machinery and equipment.

As studied in Joseph (2011), Kumar and Joseph (2006) and Joseph and Abraham (2005), Information Technology (IT) industry deserve a paragraph of their own: this became the star sector of the Indian economy since the 90’s. Taking advantage of the complementarity time difference with the United States, the good qualification of a segment of the population and the low international relative wages, the sector has become the strongest case of the opportunity to create wealth from knowledge. Therefore, there is a view that this sector’s boom was almost exclusive responsibility of the private one. However, still without being unaware of the process of "creative destruction" carried by local entrepreneurs and transnationals, the State had a relevant role in the sector emergence and evolution. The role of education policies implemented by the Indian state for the training of technicians, engineers and other profiles with good qualification to be within the sector is principal (Joseph, 2009). There has been a formative role of laboratories and public research centers, where these qualified workforce was working prior to the industry boom, including defense laboratories. Besides, the encouragement given by Rajiv Gandhi to the use of computers in the public sector and in the population at large by the end of the 80’s was also important. Besides private investment in IT training since the early 1980s has played an important role too.

In 2014, the IT sector and the service sector related to it, represented 15% of Indian exports, 5% of Indian GDP but the employment generation was below 3%. In this sense, Joseph (2009) and D´Costa (2003) highlight the highly concentrate export destination and regional distribution of the IT sector: more than 60% of the exports go to the US and almost 70% of the value generation came from the city of Bangalore. Both authors describe the sector dynamic as an productive 'enclave', without much linkages with the rest of indian economy and low employment generation.

It is also important to emphasize the development of supercomputers. The Centre for Development of Advanced Computing (C-DAC) was established in 1987 and in 1991 the first Indian supercomputer, the PARAM 8,000, was given as a present. All the hardware and the majority of the computer's software were developed in India. The evolutionary history of the supercomputer is an interesting process since, in short, from the beginning in 1991, the Indian processing architecture was different from the standards used worldwide and as a result was rejected in most of the world. But already in 1994, with 10,000 PARAM, India had imposed itself, being accepted in the United States and Germany, converting the country into a valuable player in the supercomputer industry. All this development began with government investment, which still remains relevant.

Continuing with other sectorial developments, biotechnology, pharmaceutical and others not so dynamic sectors in terms of technology as jewelry and gemstones, also had a strong export insertion. In particular, the pharmaceutical industry had a remarkable advance, from an innovative type of reverse engineering to develop locally drugs, mostly generic. In fact, in this industry the role played by venture capital and the process of company acquisitions by national laboratories was important such as Nicholas Piramal India Ranbaxy.

In the new century, India's share in the global competitive process was underway. In 1995, Singh claimed "*India's tryst with globalization has become irreversible -no matter which government come to power after the elections of 1996*". Thus, in 2003 a new direction of policy and discourse in S & T was stablished. First, the Department of Science and Technology (DST) conducted a technology foresight assignment in 20 sectors which resulted in the publication of *India 2020 - Vision for the New Millennium*. This book explores the strengths and weaknesses of India as a nation and offers insight on how India can emerge between the four main countries of the world in 2020. Secondly, it was published the Science and Technology Policy Statement 2003 (S&T Policy 2003) which establishes the need to integrate S&T programs promoting a strong interaction between public and private stakeholders. This marked an advancement in understanding the innovation process as a systemic phenomenon and not simply as a supply problem:

The transformation of new ideas into commercial successes is of vital importance to the nation´s ability to achieve high economic growth and global competitiveness. Accordingly, special emphasis will be given not only to R&D and technological factors of innovation, but also to the other equally important social, institutional and market factors needed for adoption, diffusion and transfer of innovation to productive sectors...

However, the involvement of the State in sectors considered strategic, continued to be significant. As described by Cassiolato et al. (2008), in 2005 India had three State companies among the world's 100 largest armament producers: the Ordnance Factories, dedicated to the manufacture of artillery and small arms, Hindustan Aeronautics, dedicated to produce aeronautical equipment, and Bharat Electronics, dedicated to the production of electronic components for the defense industry. These companies employed in 2004 about 160,000 workers, generating revenues from the sale of weapons in the order of $ 3 billion. In addition to these, the Indian government is seeking to stimulate a small group of big private companies - referred to as *Raksha udyog ratnas* or literally "defense industry jewels" - to also conduct part of their production to the military sector. This group includes large specialized companies in the ICT sector, such as the Tata group, Larsen & Toubro (L & T), Godrej and Mahindra & Mahindra, operating in the supply of components for the defense industry, including parts for the production of rockets and nuclear submarines.

As stated by Pant (2011, p. 42) in military terms

> India has embarked upon a massive military development programme. Much of this military development is focused upon projecting power throughout the Indian Ocean. It includes the addition of a sea-based leg to its nuclear posture, substantial air force development... and major investment in the expansion of its surface and submarine naval capacities. Most significantly, it awaits delivery of the refurbished Kiev-class Admiral Gorshkov aircraft carrier (renamed INS Vikramaditya), due in late 2012, and it is building an indigenous 40,000- ton Vikrant-class aircraft carrier, due to be launched by the end of 2010 and commissioned by 2014, a development picked up in China.

In geopolitical terms, in the 2000’s Kashmir once again is the center of the conflict. Strengthening the deployment of troops at the border, India has even carried out successful tests of Agni nuclear missile. Furthermore, after 30 years of sanctions, in 2007, India signed with the United States a nuclear cooperation partnership with civil purposes although still nowadays India haven´t signed the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). Nuclear power implied a more general change in Indian foreign policy, going from a '*soft power*' strategy, characteristic of the *'Neruvian approach*' to a much more hard power strategy, typical of the Bharatiya Janata Party (BJP). This is clear since the words of *BJP Prime Minister Atal Behari Vajpayee* quated by Font (2011, p. 9) "*India is now a nuclear weapon state […] it is not a conferment that we seek; nor is it a status for others to grant […] it is India's due, the right of one sixth of humankind*".

The evolution of the Indian financial system is a good reflection of the time: although initiated a deregulation process the State participation and direction remained relevant. In 1991 the Committee on Financial Systems was created and recommended an improvement of banks' supervisory standards in parallel to the deregulation process of the system. As explained by Prates (2013), banks had more freedom in the composition of its assets since the controls were diluted to the entry of new banks and institutional investors (pension funds, investment, hedge funds, etc.). National banks were allowed to sell shares to the private sector and transformed the development banks - fusing them with other banks - in universal banks, subject to the same rules as other banks. Nevertheless, in 2008 the assets of public sector banks reached 70% of total assets of the system, private banks 22% and foreigners only 8%.

In summary, the NEP deepened the process of deregulation and opening to the foreign capital that began to sketch since mid 80's. In terms of growth, according to figures from the World Bank, the average rate during the 90's was 5% and during the first decade of the new century was 7.5%. This period introduced the transnational enterprises and national champions in the productive and political local scene. The State continued to have a strong role, mainly at the defense, nuclear and aerospace sectors. Besides, tentative policies trying to articulate and decentralize the NIS around different actors involved in the innovation process, striving to leverage the skills accumulated during the previous stages, were implemented. However, social indicators do not show much improvement, as we will see in the next section.

3 The current challenges of the Indian NIS

After the first decade of this century India combines in its productive structure the participation of: **a)** sectors linked to the new post-Fordist technological paradigm (primarily information technology and biotechnology), **b)** intermediate technology intensive sectors (such as pharmaceutical, chemical, machinery and equipment, etc.) and more traditional industrial sectors (as automotive, equipment, etc.), **c)** others sectors related to big science as defense, nuclear, and aerospace and **d)** a huge informal and subsistence economy.

Following the same line, the corporate structure is also mixed. Even after the beginning of the privatization process the government continues to have control of much of public companies (currently there are 7 Maharatnas, 17 and 71 Navratnas Miniratnas), from which it establishes partnerships with the private and it directs the sector dynamics. But, besides the State, 'captains of industry' and transnational enterprises, also became important stakeholders in the Indian business community. In these circumstances, the production scenario today has a distinctly greater diversity than the one initiated by Nehru, taking into consideration the sector, origin and capital size. So, thinking about the Indian NIS potential, Narasimha (2008) says that

> India has an elite educational system that produces a small number of excellent engineering graduates... at a fraction of the costs in the US, an R&D system that produces international publications at the lowest unit cost among major nations, and the largest and best space programme in the world... More than 300 MNCs have established large R&D centers in India and make use of Indian talent. The country has a youthful demographic profile: more than half the population is under the age of 30. Young people in India still like to study science and engineering.

Yet, contrasts in India are still extremely strong. Today, according to The United Nations Educational, Scientific and Cultural Organization (UNESCO), about 300 million people are illiterate in India, which is equivalent to 35% of global illiteracy. In addition, only 7% of the population has access to the university system. The university infrastructure is still poor and in the last decade, according to their own Prime Minister, M Singh, it was observed a decline in the level of training of the university graduates. Recruitment schemes and retaining talent in the scientific system are still underdeveloped, contributing to the brain drain. R&D investment is one of the lowest for a nation that aspires to be among the top five economies in the world: 0.8% of GDP, against 2.6% in South Korea and the United States and 1.3 % from China. Besides, private R&D investment is less than 30%.

Socially, the country also registers strong deficits. According to Joseph et al. (2013) 350 million people or one-third of the Indian population still lives in poverty, another third of the population is unemployed or underemployed and not more than 45% have access to drinking water. Food is no longer scarce, although deaths from starvation still happens (Drèze and Sen, 2013). Besides, public services and infrastructure suffer of chronically under-investment, as stated by Font (2011, p. 29):

> The other big lacuna that holds India's economy back is the substandard condition of its infrastructure... India's roads, bridges, airports, seaports, electricity grids and clean water utilities are chronically under-supplied, deficient, crumbling or outright non-existent, especially in rural areas. Economist Jagdish Bhagwati has calculated that GDP growth could easily go two percentage points higher if the country built up 'decent roads, railways and power'. Chronic paucity of electricity is a blight that brooks no short-term solution because of surging demand, depleting coal resources and limited hydro-electric power potential.

Generally speaking, thinking about the future of the Indian NIS, the main challenges arise in forming an articulated dynamic around three areas: **1)** it is necessary to deepen the bond between the institutions of S&T and the population's needs, **2)** it is central to take advantage of the skills accumulated in the scientific sector and transform them into technological development and innovation and **3)** given India´s geopolitical location and scale, two interrelates areas will constantly be in the agenda: the modernization of Indian defense capabilities, trying to develop dual use technologies and the need to advance in a regional agenda focused in energy integration and development, in order to sustain a high growth economy.

Regarding the first area, which could be called "innovation for inclusion", it is necessary to make the NIS work for "poor" India by creating affordable products for the most popular sectors of the population. Indian domestic market is potentially huge. For example, as reported by Mashelkar (2008) discovery, development, and delivery of drugs and therapeutic vaccines that are available, affordable, and accessible to the poor is one example. The recent launch of the Nano automobile by Tatas, a low-cost (U$S 2.500) vehicle for the lower-middle class could be another example.

Investment in agricultural and rural development remains essential: rural routes, rural energy and agro processing are priority areas, just like the diversification of seeds and biotechnology. However, health is also a key area, especially the expansion of health care services for the entire population it is a strong and unresolved challenge, deepening a dual system: a private one, for the rich people and healthcare medicine and a public one, for most of the population, with limited access and quality (Joseph et al, 2013). Finally, experiences and projects related to the so-called grassroots innovation, social innovation, frugal innovation or pro-poor innovation, which has the common denominator of connecting technology developments and innovation with the needs, resources and capacities of locals, came to occupy a major spot in the Indian NIS agenda (Gupta, 2012; Iizuka & SadreGhazi, 2011; Bound e Thornton, 2012). In this case, it is important to articulate effective demand, wealth distribution and technology capabilities. This is not just a technological issue.

Turning to the second area, especially during the last decades, the Indian government efforts were oriented to move from a linear approach to the innovative process, technology push style type to a more systemic and interactive approach (Rothwell, 1994, Cassiolato and Lastres, 2005). Here, the challenge is to take advantage of the accumulation of scientific and technological capabilities developed during the "offer" stage and connect to the exploiting processes of the different agents of the ecosystem. In other words, as the report entitled *Creating a Roadmap for a 'Decade of Innovation'* by the Office of Adviser to the Prime Minister (2011) says, to develop an innovative, complex, integrated, Indian ecosystem, for the whole society is the challenge of the twenty-first century. improving agriculture and industrial productivity is still a key issue.

Third, with respect to the geopolitical needs, it is a general consensus that China and India will push the growth of -at least- the first half of XXI century. China has emerged as the only candidate to dispute the United State hegemony as the main world ruler. In this global dispute, India will play a central role. Only to give an example, the Indic ocean have a principal place both because of its commercial flux (more than half of China´s petroleum imports are transported through Indic water) and because of its military importance (Diego Garcia island houses US military bases, that are actively use for any NATO attack to the Middle East and the Persian Gulf). In this context, India´s presence and projection trough the Indic appears as a main geopolitical challenge that will imply several technological efforts, mainly in the naval sector (Pant, 2011; Kaplan, 2013; Gonzalo, 2016). Besides, currently, both India and China are competing to sustain high growth rates particularly related to energy. So, conventional and non-conventional energy development projects will configure the Indian NIS.

4 Final comments on the evolutionary path the Indian NIS

In this paper we tried to make a first effort to interpret the evolution of the Indian NIS since its main geopolitical, productive and social challenges since the independence and to analyze the extent to which explicit policies and especially the implicit ones developed by Nehru still work nowadays.

It is necessary to highlight some key events or historical trajectories. With respect to the colonial period, it is interesting to think that, despite the lack of England encouragement to the development of indigenous science and technology in India, it fulfilled the role of generating a counter-reaction that led to Gandhi, Nehru and the scientific community at the time to organize themselves and think the scientific challenges of independent India. In this context, the 'nehruvian science' appears as a way to affirm a sovereignty demand. In this matter, the partnership between Gandhi, Nehru and the scientific community, which will mark all future technological trajectory of India, has its roots in the colonial period. In terms of Herrera (1971), implicit policy, and an explicit one, based mainly on the formation of a scientific and institutional system oriented to “big science”, were the constituent events of the Indian NIS, that are still present nowadays.

Already with Indira and Rajiv Gandhi, between mid-60 and 80’s, there was a transition from an almost total self-sufficiency to a selective self-sufficiency model. In this sense, it could be said that India had accumulated capabilities in certain areas and the focus was to consolidate these and start a partial process of opening those sectors where the technological gap was very marked and the technology (and the market) was controlled by transnational corporations. In fact, the so-called “underutilization” of the scientific system, began to turn an opportunity for exploration and investment by the private sector. In this sense, no doubt, with the NEP, it was adopted explicit policies of greater openness, deregulation of markets, promotion to the FDI installation and exports drives.

The sustainability of a NIS needs both diversity and scale. But the construction of a national project supposes to build hegemony around certain objectives established by the elite through political partnerships and the explicit -or implicit- acceptance of most of society. In the last decades, in the search of diversity and scale, the Indian economic and political arena has been opened to other actors: transnational enterprises, captains of industry and the new profile of the State bureaucracy. Certainly, the Indian national project today, even listening to the mantra of Nehru's background, is subjected to a new political partnerships scheme that is still under construction, in a different geopolitical context. From the conformation of these partnerships will depend the balance between sovereignty and financial globalization, big science and inclusive innovation, indigenous and foreign technology development. One-third of the Indian population, almost half billion people, is still waiting to be part of this national project. Will they?

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