Colombia’s National System of Innovation: A Multi-theoretical Assessment of Structure, Policy and Performance

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Introduction

Colombia is a Latin American country, medium in size, with about 46 million inhabitants and a GDP of 231 billion dollars³. Approximately 1% of total GDP is invested in science and technology. The country's activities in promoting science and technology are through the National System of Science, Technology and Innovation (NSSTI) which has been operating for more than 20 years. In recent years, there has developed a recognition that the country has great potential for innovative growth and development through the action of its national innovation system, but that more needs to be done.

Similar to most countries of the Latin American and Caribbean Region, Colombia has experienced challenges in developing its technical and scientific capabilities, resulting from factors that include infrastructure deficiencies, weak institutions, and low levels of articulation and engagement between the main actors of the NSI. One consequence has been a mismatch between demand and supply of knowledge and products to generate innovation. Further, the social and political problems faced since the early twentieth century have hampered the achievement of explicit goals set out by the Colombian National System of Science, Technology and Innovation (NSSTI).

The purpose of this paper is to describe and analyse the national system of innovation of Colombia using a multi-theoretical approach that includes: the Systems of Innovation (SI), Multi - Level Perspective on Socio - Technical Systems of Innovation; and particular perspectives relevant for the study of Latin American countries that include the Latin American School of Thought (LAST), from which derives the Latin American and Caribbean Structuralism Approach (LACSA). Most literature regarding NSSTI of Colombia, are official

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³ World Bank data for 2011.
documents, either political or public body recommendations. Although some academic papers have examined the sequential development of Science and Technology in the country, little is known on the nature of the system or how it operates. This paper intends to fill this gap by deploying a multi-theoretical approach to examine the structure of Colombia’s system of innovation and how it operates; the dynamics of its actors and subsystems and other factors that affect Colombia’s NSI; and to consider where and how Science and Technology (S&T) policy in Colombia can be improved.

In this paper, the use of multiple theoretical frameworks allows for a more comprehensive assessment of the NSSTI of Colombia, how it is performing and where gaps exist that can be improved. The approach is also reflexive in its deployment of documentary analysis in order to generate a broad sense of the system from different perspectives. The intention is to contribute new knowledge and recommendations related to Colombia’s innovation system but also offer new insights relates to the Latin American innovation literature.

We present the paper in three sections. In the first section a general description of the Colombian NSSTI is offered that includes an overview of the system, its structure, policy regimes, operation, and principal constraints. In the second section, the SI, LACSA, and LAST approaches will be used to understand the structure of the system and to state some hypotheses about its main failures. Finally, in the last section, some theoretical considerations about the study of SIs in developing countries will be given and some policy recommendations will be discussed to improve the long-term development path of the Colombian system.

National System of Science, Technology and Innovation of Colombia.

Overview

The process of institutional development of Science and Technology in Colombia has gone through three major stages. The first, between 1968 and 1989, focused on the formation of human resources and research groups, which resulted in the training of some scientists. In
the second stage, between 1990 and 1999, the Science and Technology Policy was promulgated and implemented. As part of this policy, the National System of Science, Technology and Innovation was instituted, following general guidelines from the SI Approach, and practical recommendations produced by the LAST. During this decade, the country built capabilities in ST&I through a strong compromise from the central government to encourage the formation of a support structure for the business, academic and public sector. This coincided with the LAC region impulse of S&T to generate economic development during the 90’s.

Finally from 2000 to date, efforts have been directed to consolidate the development of the economic and productive sectors, according to the objectives and strategies included in the definition of the NSSTI. Throughout these phases the system has acquired a stronger legal and political framework, which has contributed significantly to the construction and development of Science, Technology and Innovation in the country (Conpes, 2009, p. 7). Currently, the law that regulates scientific and technological activities in the country is Law 1286 of 2009⁴. This law modifies the Law 29 of 1990⁵, transforming the entity which regulates science and technology (Colciencias) into an administrative department, and strengthens the National System of Science, Technology and Innovation. Through this law, Colciencias has acquired greater budget independence to promulgate initiatives to promote ST&I as a central and transversal axis of the economic and social policy of Colombia.

The policy framework for the development of science and technology in Colombia was supported by several technical missions of science and technology from 1990 to 1993. Based on the recommendations of the resulting reports of the missions, the first National Council on Economic and Social Planning (CONPES - its acronym in Spanish) of Science and Technology was founded. After this advance, other documents have been developed to build the framework for science and technology policy, planning and long-term vision (for example, national development plans⁶, and the national vision to 2019 in science, technology and innovation⁷). These were complemented by documents about economic policy supported

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⁶ National Development Plans are the basis of the presidents of Colombian government policies. In this way, the plans are the legal instrument by which are disclosed the government objectives and their management.
by S&T such as the National Policy for the Promotion of Research and Innovation, “Colombia construye y siembra futuro”\(^8\), and the CONPES of competitiveness. Additionally, the National Competitiveness Commission has recognized that Science, Technology and Innovation (ST&I) are the base for productivity and competitiveness policy, and the 2006-2010 National Development Plan has identified ST&I as a special dimension of development.

However, the development process of the system has been slow and sometimes inadequate for the needs and demands of the country. This is evident, among other factors, in amount of scientific activity produced, which is measured by the number of academic publications, patents, the training of highly qualified personnel, as well as by the performance of the business sector. As a result, Colombia continues to lag behind other countries, not only from the developed world, but also behind those within the region\(^9\). According to the last indicators of S&T published by the Colombian Observatory of Science and Technology (OCyT – its acronym in Spanish) (Salazar et al., 2010), Colombia has one of the lowest investments in S&T when compared worldwide and within Latin America, which is one of the main factors that explains the failures of the system.

**Definition, structure, systemic relationships, constraints and challenges**

This section describes the system according to official laws and examines the system’s structure, the relationships between the actors and subsystems. Constraints and challenges of the system will then be discussed.

The National System of Science, Technology and Innovation of Colombia is defined in Law 1286 of 2009 dictated by the Congress of the Republic as follows:

“The National System of Science, Technology and Innovation (SNCTI - its acronym in Spanish) is an open system which contains the policies, strategies, programs, methodologies and mechanisms for the management, promotion, financing, protection and dissemination of scientific research and innovation technology, as well as public, private or mixed organizations that perform or promote the development of scientific, technological and

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\(^9\) Colombia continues to lag behind the international indexes as shown in the Competitiveness Ranking of the World Forum on Measuring 2010 - 2011, where between 139 countries Colombia ranked 68. The Global Competitiveness Report 2010-2011http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2010-11.pdf#
innovation activities” (Congress, 2009).

The system operates through Research and Development (R&D) inputs, and through Scientific, Technological and Innovation Activities (STIA). Colombia has made use of the Frascati Manual definitions of R&D and STIA. According to the Frascati Manual, “Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. The term R&D covers three activities: basic research, applied research and experimental development” (OECD, 2002, p. 31).

The definition of STIA is a bit more complex in the sense that it has different categories to define them. Basically, STIA are all other activities excluded from R&D. Those activities are classified in four subcategories: Education and Training; other related scientific and technological activities; other industrial activities; and administration and other supporting activities\(^\text{10}\).

Since 2005, in order to strengthen the system, public institutions have developed several studies\(^\text{11}\) to identify strategic areas and sectors to invest and to generate innovation in the productive sector. Although the studies have suggested diverse strategic sectors, what all of them have agreed upon is the productive sector must undergo a radical change in order to integrate learning processes to innovate. Taking this into account, the studies have been concentrated on satisfying the demand from the country and from the international market, and to identify the opportunity niches according to the knowledge, human resources and mineral and natural resources that Colombia has. In this sense, the National Policy for Promotion of Research and Innovation (Colciencias, 2008) considers four essential areas for the development of competitive advantage: Identification and sustainable use of biodiversity; use and conservation of water resources; development of research in the health sciences; and peace and social cohesion.

The government structure of the system is hierarchical. Figure 1 shows the general structure. At the head is the National Council of Science and Technology (NCST) as the

\(^{10}\)The definition of all subcategories into Science, Technology and Innovation Activities can be found in Frascati Manual (OECD, 2002, pp. 30-34).

\(^{11}\) The Ministry of Commerce, Industry and Tourism; the National Planning Department; Colciencias; and the State and Private Competitiveness Councils; made between 2005 and 2007 several studies and consultations to define these strategic sectors.
principal government advisor in S&T matters. This council directs and approves all initiatives, strategies and incentives to incorporate S&T into the plans of economic and social development of the country. The Administrative Department of ST&I – Colciencias – exercises technical secretary of the NCST, keeping records of its agreements and initiatives, and providing the coordination needed for achieving the NCST directions. The NSSTI acts through ten National Programs for the promotion of science and technology in particular areas of interest for the country. These programs are structured by objectives and tangible goals organized in projects executed by private or public organizations, communitarian organizations or natural persons. Each national program has its own council which is in charge of the promotion of cycles of knowledge, operation, and management of the national programs. On the bottom of the general structure are the departmental councils. Colombia is politically divided into departments, so each department has its own council for S&T to propose, organize, promote and approve local development programs. These are also the direct connection between the national interests and the regional ones. Through the nexus of them and the national councils, synergy is created within the system.

Figure 1. Political decision structure for ST&I in Colombia.

Source: Data gathered from Decree 585 of 1991 (Colombia, 1991) and in the National Policy of Science, Technology and Innovation (Conpes, 2009)
In spite of all the mechanisms and strategies drawn to operate the NSSTI, the development process of the country with support of ST&I has been slow and insufficient which can be seen in national indicators of S&T, which are far from the set goals exposed in the system for every year\textsuperscript{12}. This is clearly exposed in the diagnostics included in the National Policy of Science, Technology and Innovation (Conpes, 2009). Table 1 summarizes the principal strategies of the system, with an assessment of the results achieved in the application of each one of them up to 2009:

<table>
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<th>Strategy</th>
<th>Findings/Issues</th>
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<td>Promoting innovation in productive systems</td>
<td>• Low investment in STIA and R&amp;D (0.41% and 0.16% respectively). The goal to 2010 was to invest 1% of annual GDP in STIA and R&amp;D.</td>
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<td>• Disproportionate investment between the public and private sector (56% vs. 39% respectively)</td>
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<td>• Low appropriation of S&amp;T results. Only 20.5% of businessmen perceive STIA and R&amp;D as lucrative and important for their companies.</td>
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\textsuperscript{12} Last National S&T indicators can be found in the Colombian Science and Technology indicators 2010 (Salazar et al., 2010). Basically investment in STIA and R&D, scientific and technological formation, academic and patent production, and number and quality of research groups in the country, are behind what was expected for this particular time point time in the evolution of the system.
| Consolidation of the institutional framework of the NSSTI | • The National Council of S&T is not effective because it does not have enough political power and there are insufficient legal resources to materialize its decisions.  
  
  • Unbalanced relationships between actors in Councils of the National Programs of S&T. There is a strong academic sector, practically non-existent productive sector and low commitment of the state. Also, few Departmental Councils of S&T are operative.  
  
  • Low articulation of National budget planning and execution for ST&I. Budget sectorization and disarticulation has failed to focus on the achievement of common goals.  
  
  • The financial instruments are not effective and the distribution of resources is inefficient.  
  
  • Lack of systematic assessment of the NSSTI. |
|---|---|
| Strengthen the training of human resources for research and innovation | • The educational system has an incipient promotion of scientific skills  
  
  • Insufficient and no pertinent work education (lack of Technicians)  
  
  • Scarcity of human resources with advanced training (PhD and Masters) |
### Promoting the social appropriation of knowledge

- Lack of commitment of the private and public sector.
- Scientific community not interested in activities of divulgence of products and results from science
- Low public understanding of science
- Low diffusion in the national media of the results of science and technology.

### Focus on strategic areas through public action

- Limited studies about strategic sectors for the country
- Dispersion of financial resources in several sectors which causes lack of focalization in the national investment for ST&I

### Develop and strengthen of capabilities in Science, Technology and Innovation

- Regional disparities in scientific and technological capabilities
- Concentration around the four large metropolitan areas such as Bogotá, Medellin, Barranquilla and Cali
- Areas as such Biodiversity and Natural Resources do not follow agglomeration patterns, so there is lack of research and innovation capabilities where the resources actually are located
- Low insertion of the country in international scientific networks

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<th>Table 1. Strategies and problematic results found in the assessment of the National System of Science, Technology and Innovation of Colombia up to 2009. Source: Data and evidence found in the National Policy of Science, Technology and Innovation (Conpes, 2009)</th>
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One of the main topics of discussion about the performance of the system is the investment in STIA and R&D, since investment is a key variable for the well-functioning of
the system. From 2000 to 2010, levels of investment as a percentage of the GDP have increased slowly and insufficiently, as it can be observed in Figure 2. The national goal, stated in the National Development Plan 2006 – 2010 was to invest 1% of the GDP in R&D and STIA, and according to the Vision 2019 of the country, this percentage must rise to 2% in 2019. Currently, the aggregate investment of R&D and STIA accounts for 0.57% of GDP, which is almost half of what was planned for 2010.

![Figure 2. Evolution of the investment in STIA and R&D as a percentage of GDP 2000 – 2010](image)

The investment proportion of the public sector (central government units, public universities, public research centres, public hospitals), private sector (enterprises, private universities, private research centres, NGOs, professional associations and unions), and international funding is highly unequal as well. In 2010, according to OCyT (Salazar, et al., 2010, p. 23), the proportion of investment for STIA was: 56.01% from Public Sector; 39.26% from private sector; and 4.73% from international resources. Whilst for R&D was: 63.45% from public sector; 32.33% from private sector; and 4.22% from international resources. This goes against the international trend, where the highest proportion of investment is made by the private sector, and is directly related to the poor perception employers have about the impact S&T has to generate innovation in industry.

The following section will examine the general framework of the Colombian NSSTI from different theoretical approaches such as SI, LAST and therefore LACSA, and to some extent the Multi – Level Perspective on SIs. The Colombian National System was designed

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13 This figure was taken from the book “Indicadores de Ciencia y Tecnologia 2010” (Salazar, et al., 2010, p. 22)
taking into account the Latin American 90’s context on S&T and some structural principles of SI. We are going to look into the system using these theoretical frameworks, not only to understand and describe the nature of the system, but also to provide some indications about possible paths to respond to the challenges the country is facing currently and may face in the future.

Analytical view of the Colombian National System of Science, Technology and Innovation

Theoretical approaches in context: System of Innovation Approach (SI), Latin American School of Thought (LAST) and Latin American Structuralism Approach (LACSA), and Multi – Level Perspective on Socio – Technical Systems of Innovation (MLP)

The concept of System of Innovation (SI) emerged in the late 1980s to early 1990s, and has been developed since that time by different authors coming from different disciplines and traditions. When reading principal authors which have written about SI ((B.-A. k. Lundvall, 1988, 1992), (B.-Å. Lundvall, Johnson, Andersen, & Dalum, 2002), (Dosi, 1988), (Nelson, 1993), (Carlsson & Jacobsson, 1997; Carlsson, Jacobsson, Holmén, & Rickne, 2002), (Freeman, 2002), (Edquist, 1997b), (Johnson, 1997)), the core theory came from an (evolutionary) economic dimension. Later on, the approach was strengthened with studies and considerations of the central role of the institutions, social dimension of the systems and the context of the historical path – dependences of the case studies ((Carlsson & Jacobsson, 1997), (Cassiolato, Lastres, & Maciel, 2003), (Cohendet & Llerena, 1997), (Filippetti & Archibugi, 2011), (Galli & Teubal, 1997), (Teubal, 2002)).

The Latin American Structuralism Approach (LACSA) is another attempt to focus on the particularities of the Latin American and Caribbean Countries (LAC). From the LACSA perspective, underdevelopment is not a stage in the evolution of countries, but a historical dependent process which is attached to cultural, political, social and economic variables (Furtado, 1960). This is why, from this approach, it is fundamental to go into the particular structures of systems of Less Developed Countries (LDC) to understand the particular regimes inside their National Systems of Innovation (NSI). It implies the need to go beyond
the application of recipe models derived from developed countries to solve the structural failures in LDCs. Finally, the Latin American School of Thought (LAST) is important here to understand the evolution of the National Systems of Innovation in LAC, and how the region shifted from importing foreign technology and exporting natural resources, to building economic, social, and political capacity in order to generate development with support of Science, Technology and Innovation (ST&I).\textsuperscript{14}

Innovation and learning processes are fundamental in the SI approach. Innovation is the final aim to bring transformation into the system in order to produce economic benefits. But this transformation cannot be achieved without the combination of existing and new learning processes to produce knowledge as the main element to build technical and economical capacity into the system ((Edquist, 1997a), (B.-A. k. Lundvall, 1992), (Cassiolato, et al., 2003)). To complement these key issues, the Latin American Structuralism Approach has developed a contextual reading of the dynamics of the insertion of S&T in Less Developed Countries (LDCs), recognizing that these countries have different innovation paths according to the particularities of the regimes ((Furtado, 1960), (Cassiolato & Lastres, 2010)). The Latin American School of Thought contributed with practical recommendations about the insertion of S&T in Latin America in the productive processes. LAST gave aims about the use of international resources to develop technological capacity in the region, the introduction of technology as an important element in the development of macroeconomic policy, and the creation of S&T institutes to operationalize polices.

One of the fundamental theoretical and practical aspects of LACSA is the centrality of history when studying the development trajectory of developing countries. In order to understand the structure of the economic, social, political, and innovation systems of LAC countries, it is fundamental to explore the historical patterns which determines the current situation of the region. Although the level of development and innovation processes of the regional countries is different, there has been a common path followed by LAC.

Since colonialism, peripheral countries have specialized in the production of raw materials to export to central countries, pushing them to be economically dependent on

\textsuperscript{14} Jorge Sábato, one of the founders of LAST, led in 1957 the construction of an experimental reactor in Argentina instead of buying it. This was one of the first concrete actions to build capacity and knowledge capacity in LAC, and allows us to see the spirit of the School. “In April 1957, the issue was raised to buy an experimental reactor. And one of the first reactions of our group was: Why to buy and not to build an experimental reactor? We thought it would be more important to the experience we could acquire in its construction because we could be fully immersed in the nuclear technology problems, not only in the use of an instrument. So we decided to build an experimental reactor in Argentina” [Translated from Spanish to English] (Martínez Vidal & Mari, 2002, p. 5).
agriculture. This dependence joined by the periodic economic crisis of the central countries, intensified the underdevelopment of LAC countries, making them dependent not only on the export of agricultural products, but also on the import of scientific and technological goods and capabilities of developed countries. Raúl Prebisch, the first General Secretary of the Economic Commission of Latin American and the Caribbean (ECLAC) and one of the precursors of LACSA, emphasised these common aspects of the Latin American region to propose alternatives for LDCs to generate innovation through S&T (Prebish, R. 1949).

Basically, what is proposed is to shift from the external introduction of economic and political models from developed countries, to a deeper study of the specific structure of the systems of S&T in LAC, and how, through the construction of internal capabilities, the insertion of S&T can bring innovation into the production systems of the region. This structuralism has its origin in what is called the Latin American School of Thought. Although this agglomeration of academics, technicians and politicians is called LAST, it was more a set of practical recommendations according to the political circumstances of LAC in 1950. The Latin American School of Thought (LAST) was instituted in the early 1960s by a group of Latin American politicians, academics and technicians. Its principal claim was to develop endogenous technology, instead of importing technology from developed countries. The principal achievements of the school were practical impacts on the definition of public policy, and international relationships with transnational organizations such as ECLAC, UNESCO, IFM and WB. Through the action of its members, most of the National Departments in charge of S&T were created in each country. The central aim was to generate technological recommendations to change the productive patterns of the region and to propose sectoral and national public policies of S&T as fundamental to produce economic and social development. In this sense, it is a school of thought not as a corpus of theoretical premises defined by a group of academics in order to create a new discipline with a specific methodology and context, but as a common thought about the impact and successful generation and insertion of scientific and technological knowledge for innovation in LAC.

The main shared aspects of the school were technological autonomy, local and endogenous development of technology and an integral development of LAC countries according to peculiarities of the region. Some of the principal members of LAST are Jorge Sábato, Carlos Martínez, Raúl Prebisch and Máximo Halty. Colombia was not exempted of the political and economic situation of LAC during the 1950 to 1990, and so its historical
trajectory was determined by Latin American movements. Thus, the development stages of
ST&I of the country are in accordance to the fluctuations and initiatives followed by LAC
countries.

Another relevant yet broader approximation to Systems of Innovation is given in
several papers by Geels, including not only economic features in the analysis of SIs, but also
taking into account social and political systems which interact with the technical ones (Elzen,
Geels, Leeuwis, & van Mierlo, 2011; Geels, 2001, 2004; Geels & Schot, 2007). This
approach emerges as a complement to the SI approach and it gives a central role to the
interaction between technology and user environment and to the social infrastructure
necessary to develop, commercialise, and use innovations. Then, according to Geels (Geels,
2004), there are four main differences between the SI approach which mainly focus on the
production side where innovations emerge, and the MLP approach: (1) Socio – Technical
systems encompass production, diffusion, and use of technology, considering the supply side
(innovations) and the demand side (user environment). Then, dynamics in ST-systems
involve a dynamic process of mutual adaptations and feedbacks between technology and user
environment; (2) In order to have a clearer analytical approach to the understanding of the
systems, there is a distinction between systems (resources, material aspects), actors involved
in maintaining and changing the system, and the rules and institutions which guide actor’s
perceptions and activities; (3) Institutions are explicitly taken into account. In this approach,
it is explained how institutions play a role in dynamic developments, rather than explaining
inertia and stability; (4) The change from one system or sub – system to another is analysed.
The focus is on the changes between sectoral systems and its dynamics, rather than in its
economic performance. Then, questions like “How new sectoral systems emerge, and what is
the link with the previous sectoral system?” are considered in the analytical framework.

We suggest that this is a powerful approach, although it is mainly focused on sectoral
systems of innovation. However, a National SI can be understood from the dynamics and
functioning of its sub – units which can be characterized from its sectoral SIs. This is why we
insert this framework here, to zoom in the structural components of the big system and to
emphasize the importance of the social infrastructure needed for an effective operation of the
system.
The Colombian NSSTI analysed through SI, LAST, LACSA and MLP approaches

Learning and knowledge processes

Following these approaches, an analytical study of the economic, political and social trajectories of ST&I of Colombia will be made. In first instance it will explore, how the NSSTI integrates and manages learning processes to generate knowledge and innovation. Learning processes are central in the well working of the system structurally and operationally speaking. As was mentioned in the last section, independent of the chosen strategic sectors, if the country does not have the capabilities to absorb, appropriate, reproduce, and introduce learning into the productive sector to generate competitiveness in industry, all political attempts to impulse key sectors will not be successful, mainly with the geo – political patterns of inequality in the global markets which make it more difficult to compete with strong competitors. Then, as it is mentioned by Lastres et al “...the emphasis is in the capacity to learn (as well as to forget) and to innovate as being crucial to the productivity and competitiveness of economic agents, rather than on the capacity to acquire and use new technical means’’ (Lastres, Cassiolato, & Maciel, 2003, p. 3). Unfortunately, the weak links between the academic and research sector and the industry sector in the system, affect directly the way knowledge flows and is used to innovate. This can be viewed in the low appropriation and generation of knowledge in the business sector; the imperfect information flows and market entry barriers are translated into late insertion of technology and high costs to acquire infrastructure; and, as a result, high uncertainty about the costs and benefits of research and its results. There are some successful cases of partnership between universities and industry15, but they are not the typical ones. Another major constraint in the system is that although there is a National Council of S&T through which the main decisions are made, there are not effective links between the national programs to constitute joined

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15 The project PROMIGAS, was developed between La Universidad del Norte with enterprises of the Colombian Caribe to develop innovation projects. As a result several products were developed for the companies, as an intelligent system for the detection of failures in gas network operations. La Universidad de Antioquia developed with SOFASA a design for an anticorrosive phosphate bodywork production plant. Another example is the partnership between the International Physics Center with the Power Enterprise of Cundinamarca for the development of specialized equipment that analyses the quality of the electric power delivered to final users, and then sends the information on time to the Regulatory Commission of Energy and Gas. These are some of the successful relationships between the academic and industry sectors.
projects. This means that valuable knowledge produced in one sector that could be beneficial to S&T projects for others sectors, never flows. This is also visible in the unequal development of S&T capabilities between regions.

**Specialization, distribution and dynamics between actors**

Unless there have been identified strategic areas and sectors to invest nationally, resources are still unfocused, which means lack of specialization and lack of proper long budget planning. This is problematic in the structure of the system because the institutional regime is in many cases unlinked with sectoral and regional systems. This has implications on two levels: it deepens the gap between different regions of the country which already have very unbalanced development, and on the other hand, it makes the country less competitive in the international market, because dispersion of resources in several sectors jeopardize strengthening critical industries in which the country has the greatest potential. This is not only a problem in Colombia, but a common problem faces by LAC, as it is expressed by Alcorta and Peres in regards to the lack of specialization in Brazil: “This diversity and fragmentation did not allow firms to concentrate their limited technological, marketing and financial resources in a smaller set of key products that could have been competitive in international markets and would have allowed them to reap economies of scale. Indeed, the lack of firm, industry and intra-industry specialization seems to be one of the major limitations to Brazil’s industrial development” (Alcorta and Peres: 871).

Actors in the system are central. If one of the vertices of the triangle Government, Academic Organizations and Research Centres, and industry fails, the whole system is affected. One of the main weaknesses of the system is the different level of commitment by individual actors. Changes in government plans affect investment priorities causing the cancellation of successful projects without the capitalization of learning lessons and knowledge acquisition. In many cases, the local, sectoral, regional and national policies do not have synergy, which means bureaucratic delays and the formation of obstacles that impede productive innovation. Besides the problems with the political framework and

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16 In 1968 to define and materialize the fundamental relationships inside the National Systems of Innovation, Jorge Sábato, one of the thinkers of LAST, proposed the theoretical Sábato Triangle, which was used by most LAC countries and is still used in the Colombian NSSTI. The components of the triangle are: the productive sector, the government sector and the scientific – technologic sector. This predates the golden helix model.
government actors, there is an uncommitted industrial sector with the development of S&T inside business. Most large and multinational companies import their technology without the generation of local capabilities and learning processes, so it is impossible for knowledge to transfer in local practices. Small and Medium Enterprises (SMEs) in most cases do not have the resources to produce local technology, and innovation through the acquisition of foreign technology is very expensive.

Additionally, businessmen do not perceive the academic sector as an effective allied for the generation of wealth through the improvement of productive processes or the creation of new products\textsuperscript{17}. The academic sector is the strongest of the triad\textsuperscript{18}. There are instituted regional university – industry – state committees in which universities and research centres are the protagonist proposing practical projects for state and industry, but most of times governmental actors are not present, while the industry sector is incredulous and does not perceive the practical benefits to insert scientific and technological knowledge in their business. As a result, Colombia, as many countries in LAC, has an industrial sector with low levels of technological culture, which is translated into low levels of investment in R&D and STIA, and a diversification of policies which have failed to tackle the needs of S&T according to internal and external supply and demand\textsuperscript{19}.

\textbf{Assessment and Performance of the System}

Another problematic issue to address, specifically in developing countries, is the measure of the performance of the system. Appropriate and contextual indicators must be used in order to assess properly the evolution and level of development and consistency of the system. As it has been said before, the SI approach focuses on the technical innovation and the production and flowing of knowledge, being it new or incremental from prior discoveries. Knowledge is naturally inscribed in the centre of all R&D, institutional development, market conditions, channels of distribution, and in a broader sense, in all the

\textsuperscript{17} In 2010 the National Administrative Department of Statistics (DANE) published the results of the Third Survey of Development and Technological Innovation (EDIT III). The survey collects statistics on STIA and technological development carried out by Colombian industrial firms during 2005 – 2006. A total of 6,080 of 6,957 enterprises identified in the directory of the Annual Manufacturing Survey (EAM) completed the survey. According to the results of the EDIT III, 57.12% of the enterprises are not innovative, 9.16% potentially innovative; 11.81% innovative in strict sense; and 21.91% widely innovative. Only 12.32% of technological innovation had its origin in alliances with universities and/or research centres, whilst 41.40% comes from internal ideas of the enterprise. More information about the EDIT III is available on http://www.dane.gov.co/daneweb_V09/index.php?option=com_content&view=article&cid=104&Itemid=61

\textsuperscript{18} This does not mean that the academic sector does not have profound deficiencies. The academic production in basic sciences is very low comparing with humanities and the social sciences, and the number of professionals with postgraduate education in core areas of basic sciences, agriculture and life sciences, is as well low. The average percentage of master degree graduates in natural and exact sciences, and agricultural sciences from 2000 to 2009 is 10.28% and 1.89% respectively, whilst 61.82% of the master degree graduates are from the social sciences and humanities.

\textsuperscript{19} To have more references to specific cases of LAC, see (Alcorta & Peres, 1998)
operation and dynamics of the system. Then, in order to estimate how learning processes are
developing and how well they are inscribed inside the blocks, linkages and actors, it is central
to assess the success of the strategies implemented in the system. However, the main
indicator to measure the production of new knowledge and how well the system is
performing is the number of new patents produced annually. There is no doubt that this is a
good indicator for developed countries such as United States, Japan and United Kingdom, but
what happens with developing countries such as Colombia? Colombia has a low level of
patent production even when compared with other LAC. Although, most countries in Latin
America with a successful record of patent production such as Brazil, Mexico, Chile and
Argentina, are as well significantly behind countries like the U.S. So, does it mean that these
Innovation Systems do not have enough or good learning processes? Historical reasons,
institutions and industrial hegemonies which are different for developed and developing
countries must be taken into account. Therefore, it is important to enhance the actual theories
and models for the assessment of SI with more contextual and systemic indicators. Attempts
to build more complex indexes like the Index of Technological Specialization (ITS)\(^{20}\) could
improve analysis to compare the evolution and performance of LAC countries.

Historical trajectory is important to establish the performance of SIs in less developed
countries and it is central to studying the social, political and economic regimes for every
case, because their understanding is fundamental to catch the level of insertion of science and
technology into the systems to produce innovation. This, at the same time, produces policies
coherent with the social framework and it especially takes into consideration the internal and
external constraints faced by developing countries. In this context, approaches such as the
Latin American Structuralism are better to study the non-economic factors of development to
build technical and scientific capabilities. LASA recognises differences between developed
and less developed countries, but not as a linear process where the latter is a pre – state of the
former. This means that there are not unique solutions to apply to public policies in order to
succeed and catch up, on the contrary, the social and economic structures determine the way
in which technical change occurs and how it can be boosted. “Therefore, development –
resulted from the introduction and diffusion of new technologies – may be considered as the
outcome of cumulative trajectories historically built-up according to institutional specificities
and specialization patterns inherent to a determined country, region or sector”(Cassiolato &

\(^{20}\) The ITS is proposed by Alcorta and Peres, and it shows, from a dynamic perspective, how a country’s relative market shares in high and
low technology change. To see the index, how can it be measured and calculations of it for LAC countries, go to (Alcorta & Peres, 1998).
Relationship between the components of the system

Using the MLP approach in order to have an analytical approach towards the Colombian NSSTI makes it important to have a closer approximation of the dynamics of the sub – components of the system, particularly of the emergent niches of opportunity in which the country has a competitive advantage. Figure 3 shows the outside political and institutional framework that contextually affects the system or in MLP terminology, the landscape. Then, the regime or set of internal institutions, actors and instituted strategies and objectives of the system are drawn, showing supply and demand sides. Finally, the opportunity sectors or niches are shown intermediating between actors and expected results, as potential breakers of inertia of the system.

![Socio-technical configuration of the Colombian National System of Innovation](image)

**Figure 3.** Socio-technical configuration of the Colombian National System of Innovation.

*Source: Analytical considerations from the authors.*

Institutions at the top of the system are central because they provide the stability and regulatory boundaries in which the system operates. The dynamics of economic, social and environmental development are the context in which the system performs. Changes in the...
development landscape have effects on the evolution of the system. The regime of the macro system of science, technology and innovation of the country is concentrated under the coordination of Colciencias, the official entity responsible for ensuring the best performance of the system. Colciencias, in turn, is regulated by the central government through the policies and mandate of the executive branch. Therefore, changes in the central government have an immediate effect on the stability of the regime. Strategic sectors of the system are protected within the regime, which have special policies to impel them. Coupled with this, the way the system is put into action is through the so called STIA and R&D inputs. The opportunity niches, regimes and landscape are part of the whole framework of the system.

Finally, it is important to analyse the emerged impact and competitive sectors or niches in the system. Albeit within the objectives of the system is the support for SMEs, incubators, technological parks and University-Industry-State alliances — the ideal environment for innovation — the maturity of these niches, in most cases, is very low. As a result, when pressure from external markets and political conditions are pushed on institutions, the niches are not prepared to take advantage of these disruptions and so on, allowing only moderate changes to be produced. This kind of situation is defined by Geels and Schot as Transformation Path “[i]f there is moderate landscape pressure (‘disruptive change’) at a moment when niche-innovations have not been yet sufficiently developed, then regime actors will respond by modifying the direction of development paths and innovation activities” (Geels & Schot, 2007, p. 406). For more advanced sectors, such as the biodiversity sector, in which the country has gained knowledge and expertise, the niches have a higher level of maturity. However, the inertia maintained by the institutions within the regime is strong enough to not allow significant changes; therefore, the country loses competitiveness in the international context. For instance, biodiversity has become a central topic in global discussions and Colombia is one of the most biodiverse countries in the world, so there is great external and internal pressure to explore and to promote its development. However, innovation in this sector is still low and its potential has not been exploited completely yet. Thereupon sectoral inertia in biosciences, agriculture, and industrial policies to patent, must be broken in order to change idle practices and reap the maximum benefit from this market opportunity.

Then, although the NSSTI of Colombia has evolved and institutionalized the insertion of S&T to generate innovation, it still has several structural and political shortcomings to
overcome. The SI approach and Latin American contextual studies are a good support to understand the evolution, performance, and possible successful trajectories. Having this theoretical and practical ground, it is possible to build development models taking S&T variables as core to development. Colombia has internal capabilities to obtain effective learning flows between the blocks and subsystems of the NSI, as well as to be competitive in specific sectors in which are already human and productive resources, and a strong institutionally to support the system, although the legal instruments are still insufficient. Then, it is necessary to intervene structural blocks of the system and dynamize the action of the actors in such a way that all components and strategies will be more balanced and effective on all levels; macro, micro and meso.

Innovation and technology policies for the NSSTI. Some features and recommendations

In the last section some theoretical approximations applied to the Colombian NSSTI were discussed and although some general recommendations were given, we want to look into the rationale of theories to give practical aims to policy makers. It is difficult to extract from theory and academic discussions answers to political dilemmas policy makers have when trying to construct sustainable solutions for development within countries ((Teubal 2002), (Laranja, Urraya, Flanagan)). Science and Technology Studies, Evolutionary Economics, Systems of Innovation Approach and even Latin American Structuralism Approach seldom give any straight indications to policy makers. The process of constructing Innovation and Technology Policies (ITP) requires from the policy makers the capacity to assess the current scenario and to build new ones. This means, to create through policy strategies possible pathways to achieve system goals. Albeit Colombia lately has involved the participation of specific technical experts for the construction of policies, it still requires a stronger presence and cooperation from the academic sector. But in order for this to happen, it is necessary to deconstruct heavy theoretical blocks into practical strategies. It is important then, to identify the different theoretical approaches used to structure the Colombian NSI, understand its implications, and choose a set of practical directions to promote the well-functioning of it in the Colombian social context.

The governability of the Colombian NSSTI is to some extend difficult to manage,
because of the lack of resources to follow the performance of the existing policies and in some cases, even when policies have been promulgated, there are not legal mechanisms to apply the objectives raised in them. Related to this concern, Alcorta and Peres, discuss how in LAC a great number of S&T policies have failed because of the great level of detail when trying to regulate the insertion of S&T in the national system. For example, they mention how in Mexico the National Program for Industry Promotion and Foreign Trade failed because to operate 274 regulations had to be changed, because of the specificity of the strategies, which required structural changes in all public organizations (Alcorta & Peres, 1998). The last law regulating S&T in Colombia (Law 1286 of 2009) tries to overcome the problems of the previous law (Law 29 of 1990), giving specific strategies and proposing specific objectives to operate the system. In this Law, all regulatory changes were taken into account, in order to make it feasible. It is still too early to assess the performance of this law, but up to now, Colciencias, as the National Administrative Department of S&T, has gained more power and independence to plan and execute the national budget for S&T in the short, mid and long term. One successful strategy in the policies about S&T in Colombia has been to build over the constructed; this means, to make incremental policies, not changing the fundamental vision and direction of the previous policies, but improving the instruments to apply the laws. However, it is necessary to make assessments of the programs implemented to materialize policies.

Since the NSSTI is a socio-technical network, which must tend towards synergy, it is fundamental for policy makers, to direct specific instruments to improve the connexions, links, articulations, between the subsystems and levels of the system. This is a structural failure that undermines the well-functioning of the entire system. Although there are National Programs to insert S&T in different productive sectors, there is not enough articulation between the national proposals and the necessities of the particular sectors of the country. This becomes worse when national and sectoral policies are articulated with the regional ones, which can be seen in the unequal development of the expenditure, investment and development of the Departments\textsuperscript{21} of Colombia. According to the 2010 indicators published by the OCyT (Salazar, et al., 2010, p. 30), Bogota, which is the Capital District, has 42% and 53% of the national investment in STIA and R&D respectively, followed by Antioquia with 23.4% and 17.8% of participation and in third place, the department of Valle

\textsuperscript{21} Colombia is politically divided by departments.
with 8.1% and 7.8% of the national investment. These three regions account for more than three quarters of the total investment, which is profoundly unbalanced. Sectoral policies should encourage the development in the current places where opportunities are located. Sectors such as biodiversity and biofuels, which are strategic for Colombia, have their main resources to function in regions of low levels of development including Amazonas, Choco and Putumayo, where infrastructure, human and business capabilities are weak. Disarticulation between local governments, high levels of political corruption and historical paths of poverty must be broken in order to exploit the competitive advantage Colombia has in the international market. There are huge possibilities to innovate in these sectors, so political mechanisms to support this potential must be constructed.

Once it is understood how the system operates structurally speaking, it would be desirable to project desired scenarios for the future, and then to have specific strategies to achieve the presented goals. This means having balanced levels of alignment between stakeholders and the active intervention of all actors of the system. Although this can be difficult to achieve, given time constraints and the different agendas of the actors, consensus exercises must be achieved in order to produce effective policy instruments. If strategies, vision and future scenarios have been defined, a set of public programs and projects can be designed on all levels of the system, taking into account the articulation between the subsystems. These programs should be thought of as being transversal for the entire system and some others specific for particular sectors, regions or industries. In this phase, it is important as well, to have the active participation of all stakeholders; this could be done by reviewing the design of programs before they are executed. This will tune the scope and action of the programs. Finally, to implement the programs built within its different phases and during its implementation, it is necessary to have effective assessment mechanisms to take pertinent correctives during the execution. This is in some extension what is proposed by Teubal in his 2002 paper (Teubal, 2002), but here the proposal is to make prospective models for the design of public policy, given that the strategies must be systemic.

Colombia still guides its governance policy and production rationales (Bach 2006) by a prevalent neoclassical economic perspective. This implies that most economic policies have been designed to operate only when market failures occur. Nevertheless, in LDCs, given the immaturity of their NSI, more focussed policies are needed to encourage innovation in the production systems. The global perception of supply demand relationships and
international market fluctuations must be considered in the construction of effective policy frameworks. Then, it is important to use global dynamics to nurture local ones. In this sense, contextual policies should be carried out in all levels of a national system in order to have innovation. “...a government policy for glocalization of technology is necessary in order to achieve the objective of industrialization; and this must be done at sub-national, national and supranational levels” (Humbert, 2003, p. 186). Then, policy makers should further the compensation of market failures through subsidy or tax benefits toward specific industries and the private sector, creating a more active role in the understanding of the particular sectors and regional needs, considering and exploring their particular evolution. This implies having more than general policies directed at all sectors and industries, but also having a dynamic policy portfolio with specific strategies for the different subsystems of the NSI (Teubal, 1998).

Conclusions

In this paper, we explored the Colombian NSSTI using documentary analysis, described the system in its structure, delineated the strategies and objectives of it and exposed what we believe are its key constraints. We then performed an analytical study of the whole system through different theoretical approaches. Finally, we proposed some features and recommendations to academics and policy makers to improve the functioning of the system.

Approaches such as Systems of Innovation, Latin American Structuralism and the Latin American School of Thought are useful when trajectories in science and technology of developing countries are studied. Many Latin American countries during the second half of the twentieth century created their national systems of science and technology, following a more practical than theoretical perspective in their definition. This coincides with the stimulation of peripheral economies after World War II ended, the ideas promoted by the United Nations on development, and the strategies designed by the Economic Commission of Latin America and the Caribbean (ECLAC) to help Latin American countries to overcome the excessive reliance on the export of raw materials from natural resources, the import of technology and finished products and the unstable local markets totally dependent on international economic fluctuations. Colombia, as part of the region, went through all these
cycles. First of all, the central government promoted local capacities to generate innovation through science and technology; then after economic liberalization, the National System of Science, Technology and Innovation was designed, created, and put into action; and now the central government is improving policy instruments for ST&I according to national social, political and economic dynamics.

During the past 50 years Colombia has advanced in its performance and competitive productive capacities through strategies designed to promote learning processes to generate innovation cycles in the long term. However, the system has serious structural flaws that prevent the achievement of the national targets around the construction of S&T capabilities, and it is still far behind other countries in the region such as Brazil, Argentina and Mexico and even more, behind potential Asian tigers (China, Indonesia, Malaysia, and Thailand). Therefore, it requires a greater commitment from major stakeholders, to achieve the objectives that the country has set by 2019, starting with the structural reinforcement of the system components and a strong optimization of the learning flows and collaboration between subsystems.

Contextual policy frameworks must be raised to handle and improve the complex relationships and links inside the NSI. A flexible multi-scale approach for the construction of public policy can be useful to avoid rigid general policies, which could actually affect potential development paths. Policy makers can build, with the academic sector, improved policy instruments according with the specific technological trajectories of different sectors and industries. However, ST&I theoretical considerations must be translated into practical and feasible recommendations through the construction of a realistic conceptual framework contextualized within Colombian reality. In this sense, a SI approach coupled with LASA are useful for policy makers to understand the structure, relationships, links and ideal roles of actors within the NSI. From this understanding and looking for the definition of practical programs to operationalize the strategies of the system, the construction of future desired scenarios through prospective models can be useful.

Transformation of the economic, political and social systems through the introduction of S&T to produce innovation is the final aim of the NSI. This transformation has to be guided and oriented by the supportive structure of the system, generating virtuous learning cycles to have incremental innovation in the productive sector. Colciencias, as the national department of S&T in the country is in charge of orchestrating synergy between the different
blocks of the National System, to promote the effective use of the current political instruments, to maximize its action in the construction of the strategies, programs and models of assessment for the NSSTI, and to empower the three main actors of the system which compound the Sábato Triangle for innovation.

A strong systemic assessment of the whole system must be encouraged from the central government represented by Colciencias. The National Observatory of Science and Technology has been developing for the last seven years a report with the national indicators of ST&I, which is a kind of evaluation of the performance of the country in these areas. Some other studies about the development of national programs of S&T have been done, as well as sectoral and business studies have been developed where S&T has been measured to some extent. However, this is not enough. A comprehensive assessment differentiating results from each component of the system and from the horizontal action of the national goals, in a kind of inductive and cumulative evaluation of the inputs, outputs and impacts of the system is needed.
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