Innovation systems in developing countries: A top-down and bottom-up approach to studying the Colombian National System of Innovation and the coffee, flower and sugarcane production chains

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Abstract

This thesis examines the evolution and development of science, technology and innovation (STI) policies in Colombia as a particular case study of a developing country within the Latin American and Caribbean (LAC) Region. The initial stage of the research analysed attempts by Colombian policy-makers from the 1960s onwards to build a National System of Innovation (NSI), following recommendations from transnational organisations such as the Organisation for Economic Co-Operation and Development and the Organisation of American States. This investigation found little evidence of systemic relationships between public, industrial and academic organisations to generate, exchange and apply knowledge. Central to these innovation strategies was a focus upon funding research with public resources to strengthen knowledge generation as the main mechanism for promoting innovation. This suggested that, although the STI policy was formally defined as following a 'systemic' approach, the policy mix reflected a linear reading of innovation (Tait & Williams, 1999) and generated an unhelpful (mis)perception of an uptake lag (Brown, Gregson, & Mason, 2015). The study was therefore refocused to develop a bottom-up understanding of innovation in selected industrial settings. A detailed analysis was undertaken of the innovation arrangements in three key Colombian agricultural industries - coffee, flower and sugarcane - within the national economy and global supply chains. This is an exploratory qualitative research based upon semi-structured interviews and specialised focus groups with key academic, public and private actors related with the evolution, design and application of innovation policies and strategies at the national and sectoral levels, supported by analysis of published and unpublished literature.

Moving beyond narrow Innovation Systems (IS) perspectives, this thesis brought together aspects of STI policy design with an analysis of formal and informal social, economic and political institutions. A detailed focus on specificities of the three ISs under study highlighted important differences in terms of the generation and exploitation of knowledge linked to differences in inter-organisational relationships within the sub-sectors and their governance and governability. This in turn pointed to

the importance of cultural factors shaping innovation dynamics and the co-evolution of sectoral actors with technical, organisational and market changes. These findings suggest a top-down and bottom-up approach to understanding how national innovation strategy can be embedded in firms and industries.

This thesis makes three contributions to knowledge. Firstly, it contributes to theories of sectoral innovation systems - showing that even at the sub-sectoral level, there are very different innovation pathways depending upon ownership, trading relations, scale, political insertion, longevity, sources and cumulativeness of knowledge. This reinforces the need for NSI to be grounded in broader historical and sociological understanding. Secondly, the operation of (de facto) innovation systems needs to be understood through a broad analysis of the embedded institutions and the power dynamics between the actors involved in the system. We suggest that the NSI approach might usefully be reconnected with earlier Latin American intellectual approaches that took into account the particularities of local/national industrial and knowledge institutions and the insertion of the LAC economies into global trading systems. Finally, it provides a critical appraisal of how the NSI approach can be read and understood by political actors to justify and shape particular policy mixes that encourage a narrow focus on the promotion and exploitation of public sector research based upon linear models of innovation.

Declaration of Originality of Submitted Work

In conformance to the regulations of the University of Edinburgh, I hereby declare that:

1. I am the sole author of this thesis;
2. This thesis is entirely my own work;
3. This thesis has not been submitted in part or whole for any other degree or professional qualification.

Signed: ___________________________________

Date: ___________________________________

For my sister Maria del Pilar

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Abbreviations

AC – Andean Community

APBS – Andean Price Band System

ASOCAÑA – Sugarcane Growers Association

ASOCOLFLORES – Colombian Association of Flower Exporters

CENI – Agricultural Research Centre

CENICAFÉ – Coffee National Research Centre

CENICAÑA – Sugarcane National Research Centre

CENIFLORES – Flower National Research Centre

COLCIENCIAS – National Administrative Department of Science and Technology

CIO – Coffee International Association

CONPES – National Council of Social and Economic Policy

CORPOICA - Colombian Agricultural Research Corporation

CPGA - Provincial Agribusiness Management Centres

DANE – National Administrative Department of Statistics

DNP – Colombian National Planning Department

ECLAC – Economic Commission for Latin America and the Caribbean

EDIT - Survey of Development and Technological Innovation in Manufacturing

EEA – Agricultural Experimentation Station of Palmira

ENI – National Strategy for Innovation

EPSAGROS – Technical Assistance Service Providers

FNC – National Federation of Coffee Growers

HEI – Higher Education Institutions

ICFES - Colombian Institute for the Promotion of Higher Education

IDB – Inter-American Development Bank

IDRC – International Development Research Centre

IMF – International Monetary Fund

INCOMEX - National Institute for Foreign Trade

ISA – International Sugar Association

ISI – Import Substitution Industrialization

K&T – Knowledge and Technology

LAC – Latin American and Caribbean Region

LACSA - Latin American Structuralism Approach

LAST – Latin American School of Thought

LDC – Less Developed Countries

MADR – Ministry of Agriculture and Rural Development

MNE – Multinational Enterprises

NSI – National System of Innovation

NSSTI – Colombian National System of Science, Technology and Innovation

NSTP – National Science and Technology Programs

OAS – Organization of American States

OCyT – National Observatory of Science and Technology

OECD – Organization for Economic Co-operation and Development

PTA – Program for Technical Assistance

R&D – Research and Development

S&T – Science and Technology

SENA - National Apprenticeship Service

SNCTA – National Agribusiness System of Science and Technology

SSATA - Subsystem of agricultural technical assistance

STA – Science and Technology Activities

STIA – Science, Technology, and Innovation Activities

STI – Science, Technology and Innovation

TFP – Total Factor Productivity

TDC – Technological Development Centres

TTG – Technology Transfer Groups

UBN – Unsatisfied Basic Needs

UMATA – Technical Assistance Municipal Units

UNESCO – United Nations Educational, Scientific, and Cultural Organization

WB – World Bank

Contents

List of Figures

List of Tables

1. INTRODUCTION

I started this doctoral journey considering the role that science and technology might play in developing economies. It was my intent to enquire about the nature of innovation, to understand the factors behind different innovation pathways and to analyse science, technology and innovation (STI) policy directed towards improving competitiveness in national strategic sectors. It seemed that ideas of progress and development were heavily based on a linear thinking of science as a main driver for innovation, but that there were some 'black boxes' in the process of developing basic research, its evolution to applied research, and the setting-up of spin-off companies and technology-based Small and Medium Enterprises (SMEs) with strong links between academia and industry (Tait & Williams, 1999).

I focused upon my own country, Colombia, as a case study of a Latin American emerging economy. The legal and formal establishment in Colombia of a National System of Science, Technology, and Innovation (NSSI) directed my attention to the NSI approach as the central political artefact used to build STI policies and to design policy mixes to fulfil the needs of actors involved in innovation processes. In order to analyse the development, implementation and outcomes of STI policies and the particular innovation dynamics in the Colombian economy, I realised the importance of having a broader understanding of the perspective of the main innovation players in the business setting as well as political and research settings. My aim was to analyse how innovation actually happens beyond the official and formal version of public documents. Thus, I found that only through conducting an empirical study at sectoral levels could I open up the understanding of the functional and structural dynamics of innovation systems. This is how this study moves beyond the narrow NSI perspectives, and through qualitative (historical and sociological research) brings together aspects of STI policy design, an analysis of formal and informal social, economic, and political institutions, and sectoral innovation.

The differing innovation dynamics of the particular (sub) sectors studied, drew my attention to the governance and governability of the sectoral innovation systems under study, and stressed the importance of cultural and historical factors in the shaping of innovation policies and in the coevolution of sectoral actors with technical, organisational and market changes. Hence, this study evolved from an initial top-down study of policy implementation, examining innovation promotion from the national level, to a bottom-up study centred on sectoral innovation dynamics.

This research is divided into two thematic pathways. The first one presents a policy study of the development, implementation and outcomes of STI policies at a national and sectoral level beyond their formal definition. The second part of the study illustrates how innovation processes take place in three particular agricultural sub-sectors. I found that in order to provide a wider and more complete picture for understanding innovation as a social phenomenon I needed to study different levels of aggregation. This is how, through an exploratory qualitative study, I attempted to present a comprehensive vision of a country and three sub-sectoral case studies going beyond the formal and narrow vision of innovation systems.

1.1. Background

Innovation and the way it is promoted in countries and industries has been a well-debated topic, particularly within the field of innovation studies, building upon Schumpeter's analysis of the relationships between market structure and the processes of competition and cooperation, and development studies examining the relationship between central and periphery countries. Various scholars during the 1980s and 1990s brought together historical insights on innovation processes; studied how national production systems relied on industrial dynamics affected by vertical and horizontal relationships between business, public, and academic actors; and analysed interactive learning relationships between users and producers as the main source of innovation. Several analytical perspectives emerged, the most successful of which was the National Systems of Innovation (Lundvall 1992b) followed by its variants (e.g. the Regional and Sectoral Systems). From this standpoint, I critically investigated the National and Sectoral Systems of Innovation Approach as part of the academic shift in innovation studies described above. I studied how the concept has been used and implemented in political and academic arenas – and noting a particular reading that appears to have been promoted by transnational organisations. Both approaches have been used as guidelines for designing policies in developed and emerging economies.

Given the focus of the study on Colombia, as part of the Latin American region, I analysed the historical background behind the evolution of science and technology policies and discovered that the analysis and implementation of strategies for encouraging innovation in the region has important roots in what is known as the Latin American Structuralism Approach (LACSA). LACSA is an attempt to focus on the particularities of the Science and Technology processes of the Latin American and Caribbean Countries (LAC).

LACSA contributed practical recommendations about the insertion of S&T in Latin America and informed priorities 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 policies, and the creation of S&T institutes to operationalize polices (Furtado, 1960; Munoz, 1981; Prebish, 1986). This was the first attempt to explain the different trajectory of development of the region from inside. This structuralist approach was based on completely different assumptions from ones of mainstream economics and classical international trade theories based on perfect competition and profit maximisation at the expense of weaker negotiation power. It had a focus on the systemic nature of the economic relationships between the centre and periphery, and the structural differences of the third world economy as explained by dependency theory (Kuntz Ficker, 2005; Munoz, 1981; Topik, 1987). Colombia was not exempted from the political and economic situation of LAC during the 1950 to 1990, and so Latin American movements determined its historical trajectory. Thus, the development stages of science, technology and innovation (STI) of the country are in accordance with the fluctuations and initiatives followed by LAC countries.

After the LAC regional stagnation as a consequence of the Industrial Substitutions of Imports (ISI) during the 1970s, in the 1980s there was a recessionary inertia characterised by a negative trade balance, an increase in external debt, and constant macroeconomic fluctuations that deepen social inequality and enlarged the gap with industrialised countries (Economic Commission for Latin America and the Caribbean ECLAC, 1990).

Subsequently the National Systems of Innovation Approach (NSI), promoted from the end of the 1980s, and based on Schumpeter's work, put institutions, knowledge, relationships between users and producers, and technical change at the centre of economic analysis and understanding of economic growth. It emerged as an alternative to the dominant neoclassical narrative that pursued enhanced competitiveness at the country level through the liberalization of markets, limited State intervention, and the presumption of a stable market where agents make rational choices among well-established options. In the neo-classical account, technical change and innovation were residual variables that were not central to explaining and encouraging economic growth (Sharif, 2006). The use and appropriation of the NSI approach among academics and policy-makers working on the definition and analysis of S&T policies in Latin America expanded rapidly. However, in most Latin American countries the approach was adopted with a normative agenda that downplayed the complexity of the local particularities and neglected that the base conditions under which the approach was formulated, for explaining the innovation dynamics of the industrialised countries of the Organisation for Economic Co-operation and Development (OECD), was completely different from the emergent economies of the south (Delvenne & Thoreau, 2012).

This is how in most of the political agendas of LAC countries, and certainly in Colombia, a narrow reading of the innovation system approach was taken that equated innovation with advances in science and technology knowledge generation and exploitation and sought to measuring innovation through solely economic performance indicators, and proxy research and development measures (Lundvall, 2007). These approaches were studied in the first stage of this doctoral research.

In order to understand how innovation processes were actually happening in the Colombian context, however, it became clear in the course of the research that I needed to go beyond this approach based upon whitepapers, official studies, and national indicators. I therefore pursued a broad approach for understanding social institutions, the supporting infrastructure, and broad macro-structural conditions (such as the financial environment, cultural setting, political situation, and international context) as crucial dimensions impacting learning and competence-building processes (Lundvall, Vang, Joseph, & Chaminade, 2009).

The second stage revolved around the turn to sub-sectoral innovation studies. In this I moved away from the NSI approach to the Sectoral Systems of Innovation (SSI) approach to understand the industrial setting, technological evolution, dynamic complementarities, market and non-market interactions and organisations, demand, networks and knowledge; and how these dimensions co-evolve in different ways in each of the cases, producing particular innovation pathways and dynamics. I found that the SSI had better tools to address actual innovation dynamics and was helpful to analyse crucial factors affecting competitiveness based on technical progress. Based on evolutionary theory and the innovation system approach, the SSI takes into account dynamic competition characterized by structural transformations caused by struggles between new and constituted firms. It explicitly explores the entrance of new technologies and products and the heterogeneity of knowledge, competences and learning processes governed by constant interactive processes of creative destruction and creative accumulation (Malerba, 2002, 2006; Malerba & Mani, 2009a). The same way that the concept and application of the NSI approach has evolved, the SSI approach has strengthened its theoretical and practical body of knowledge through the expansion of more case studies, so the framework has remained broad, open and flexible. However, it did not provide effective tools for engaging with the empirical complexity and the very differing outcomes observed in the study of the three sub-sectoral agriculture chains. I therefore supplemented the SSI approach with Global Value Chain (GVC) analysis to understand the connections and implications of international demand for building capacity and increasing competitiveness in sectors that are demand-driven and that base their economic activities in exports, as is the case of the coffee and flower production chains. Other perspectives were also important for understanding the differences in political governance as well as supply chain governance, rooted in the particular histories and social and economic structures of the three sectors.

The agriculture sector continues to have strategic importance for the Latin American region despite the negative perceptions of primary industries that reigned during the second half of the 20th century. The main objective was then seen as being to diversify the economic activities in the LAC countries to break the colonial dependence of peripheral countries specialized in the production of raw materials that were exported to central economies. This dependence, aggravated 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 (Gregson & Velasco, 2011). However, the importance of food production, the modernisation of agriculture practices, and insertion into GVC has transformed the sector and added value to the exports (Salles-Filho, Pedro, & V.Mendes, 2007). Although natural resources were not favoured by technological progress during the industrialisation period of the 20th century, and the little technological progress LAC countries experienced did not translate into larger demand or greater profits for the growers and agro-industrial firms, the shift in the specialized market demand and a progressive capability-building process in terms of infrastructure, technology and human resources during the 1990s and the 21st century, have changed the behaviour of the natural resources based business (Marin, Navas-Aleman, & Perez, 2009). The study of technological change in agriculture in developing countries remains crucial since it represents an important proportion of their national GDP and is a major source of employment for unskilled labour (N. Clark, 2002). With these considerations and the definition of agriculture as a strategic sector in every public document, I decided to base the innovation study in this particular sector.

At the beginning of the second research phase, I initially planned to compare two different sectors within the Colombian economy. However, once in the field I became aware of the complexity of the Agro-industrial sector, which integrates thirty-seven production chains, and the sets of activities that are linked technically and economically from the beginning of the production and processing of an agricultural product to its final marketing. Given the diversity of production chains and their different degrees of evolution and participation in the domestic and international market, there were obvious opportunities for comparative examination. I narrowed down my study to three specific chains that are significant and representative in the agricultural GDP and the overall Colombian economy. Colombia is well known internationally for the quality of its coffee and flowers and has been very innovative in the sugarcane sector diversifying the portfolio of products to offer non-traditional goods as biofuels coming from the sugarcane bagasse. My initial expectation had been that the three chains would have similar innovation patterns and that similar policies and practices would lead them to be successful at national and international levels. However, I found that even at the sub-sectoral level there is co-evolution of different dimensions of knowledge, type of demand, market size, type of networks and historical determinants. What remained important for these three chains was the presence of fairly strong producers' associations representing the growers and firms nationally and internationally to obtain better market conditions and to re-distribute profits between all the actors in the chain. Also, the existence of sectoral research centres funded by the producers themselves has made a difference in the existence and linkage between the knowledge creation and exploitation sub-systems. The knowledge sources, domains, applications, accessibility and cumulativeness in the sub-sectoral cases have shaped the innovation pathways and capabilities in the industries under study. It has also been crucial to keep the chains viable not only in an economic sense, but also in their social impact, since they are important sources of employment for the country.

The empirical findings of this study expand the understanding of innovation as a path-dependent process relying on social institutions for the diffusion and use of new products, services, and processes. The sectoral cases show how technology, demand and firms dynamics co-evolve with the type and structure of interactions between firms and other bodies, knowledge dynamics, and processes of variety creation, replication and selection. It also provides insights into the use of the NSI approach beyond being a currently-favoured political device to create synergies, stimulated from the government side, to promote flows of knowledge and learning networks among the heterogeneous actors that are part of the intended innovation systems. Finally, understanding of the cultural setting, governance and governability of the networks, cooperation and competition relationships between firms and power dynamics between actors in developing economies is crucial to explain and encourage upgrading and catching-up processes to narrow down global inequalities. It is for this reason that it was necessary to go beyond the traditional remit of the innovation systems research approach to include sociological and historical methods and perspectives.

1.2. Aim, research questions and scope

Being part of the Colombian National System of Innovation myself, I had an immediate concern to understand the nature of this so-called Colombian NSI, its origin and effectiveness for developing innovation in key sectors. This shaped how the first part of this research was initially conceived. In order to learn how a developing country such as Colombia managed to design an NSI and put it into operation, I needed to engage in a study of the policies supporting this evolution and investigate if the intended national purposes were being achieved. Therefore, the aim of this research was, in the first instance, to do a policy study on the evolution and implementation of science, technology and innovation policy in the context of the national systems of innovation approach.

Once I engaged in the study of innovation policies, I realised that, in order to understand the strengths and weaknesses of the designated Colombian NSI, a study of the operation of the sectors was essential. From an NSI perspective a number of acute weaknesses in the Colombian NSI were visible – particularly in terms of linking Public Sector Research to industry. However it was difficult to understand the reasons behind STI policy failures just by using the NSI lens. Thus, a new approach was required. This is how the second pathway of this research was defined: to do an innovation study of the dynamic complementarities of the Colombian innovation system through the study of specific sectoral dynamics.

The analytical power of the NSI approach and its utility in the policy sphere for less developed countries (or peripheral countries, developing economies, emerging economies or whatever the term used to describe countries that are not within the group of countries with better economic performance) has been central for this research. The systemic nature of innovation appeared to be an indisputable factor at the beginning of this study. As the study progressed however, the NSI approach, was revealed as a particular heuristic tool used by Colombian policy-makers. This is why the literature review of this thesis portrays an extensive analysis of the systems analysis approach in general and the systems of innovation approach in particular to fulfil the research aim. Colombia was chosen as a case study as it was my home country, where I was well placed to undertake the kind of detailed empirical study that could contribute to advance and strengthen the theoretical corpus of innovation studies in contexts where social, political and economic problems require a broader and deeper approach to promoting innovation, not only to encourage economic growth, but also (and more importantly) to improve the living conditions of the population. Consequently, it was clear for me that I needed to address not only economic variables when innovation processes through technical change are thriving, but to attempt to understand the social dynamics in which the innovation systems were rooted (Lundvall, Joseph, Chaminade, & Vang, 2009).

I also wanted to go beyond statistics and quantitative studies to find the reasons behind poor national and sectoral performance. This motivated me to perform a qualitative investigation. My aim was to have a closer understanding of the so-called national system of innovation and integrate the perceptions of those who are or were responsible for the national and sectoral STI strategy design. I wanted to see how sectoral actors interact and how actual learning processes were or were not taking place between public, private and academic actors. The role of intermediaries between the research and business systems is also taken into account, even when their presence in the Colombian NSI is limited. The necessity for having more qualitative studies is highlighted in the recent, and only, assessment of the Colombian National System of Science, Technology and Innovation made by the OECD (2013):

> The second category – evaluative studies – is less well developed in Colombia. There is a tradition of quantitative analysis of interventions that affect companies, normally based on surveys and econometric techniques. These are typically done by international funding bodies, especially the IDB, and are valuable in terms of accountability. However, they are not designed at present to generate the necessary

> insight into the mechanisms of intervention, alternative means to reach the desired goals, or identification of further needs for intervention. They need to be supplemented by more qualitative, "soft" approaches that enable learning. Evaluation needs to be better incorporated into national practice. (OECD, 2013, p. 36)

The above considerations were the standpoint to formulate the research questions that guided this study. The research questions emerged to some extent from the understanding of the systems of innovation analytical framework and the specificities of the Latin American innovation pathways, but they were importantly shaped by the empirical research and my experience as a practitioner. In this sense, as it is explained in chapter 3 (Methodology and Research Design), this study has an inductive nature. The first question is both descriptive and analytic, so it has implicit *what* and *why* questions.

1. *How has Colombia attempted to establish a national system of innovation?*

In order to contribute to the understanding of science, technology and innovation policies and instruments in Colombia, I studied the framework outlining what the national system of innovation is according to official public documents and the perception of key actors within the system. This question can be perceived at first glance as a descriptive inquiry about the object of study, and it certainly is, but once the investigation started, subsidiary questions about the divergence between the system described formally, and the system perceived by the actual actors, raised the questions: How has the process of development and implementation of STI policies unfolded? What has been achieved? The first part of this research deals with these questions. When reading policies, laws, decrees, and general normative frameworks, the explicit existence of a national system of science, technology and innovation was stated and taken for granted. My subsequent study of the evolution, implementation and outcomes of the STI policies both at the national and sectoral level revealed a whole spectrum of innovation practices beyond the normative and formal framework. I wanted to understand and analyse how innovation actually happens and to inquire about the existent challenges and opportunities to reach linkages between public agencies, research and educational organisations, firms and producers, and knowledge brokers. I analysed the Colombian STI policies from 1968, when the National Institute for Science and Technology was constituted, until 2011, two years after the current national law of science and technology was launched. I found that the actual innovation agents have developed networks which have led them to be competitive through a variety of mechanisms that go from formal models of knowledge and technology transfer, validation and appropriation, to informal techniques of communication, cooperation and competition that have encouraged substantial changes in their operation.

Once a national picture of the innovation landscape was achieved, I moved to investigate actual innovation dynamics between firms, research centres, sectoral actors and authorities. This took me to the second question.

2. *What are the main innovation dynamics differences in the Colombian coffee, flower, and sugarcane sub-sectors?*

As I began to address the dynamics of innovation in Colombian agriculture my attention was immediate drawn to the diversity of context and dynamics of the innovation between (sub)sectors. For responding to this question I mainly used the Sectoral Systems of Innovation (SSI) approach as the analytical base framework. The study started with the description and analysis of the agriculture sector in Latin America and in Colombia, and its importance in the economic activities of the region and the country (this also gives a sense of the social impact that the sector has in terms of jobs creation and absorption of unskilled labour). The purpose was to learn how the sectoral policies were created, the role of firm and non-firm organisations, and their internal interactions in the creation of learning cycles.

Given the complexity and variety in economic activities within the sector, I decided to restrict the study to three successful sub-sectors in which the country is recognised by its good performance both at the national and international levels. By investigating public documents, academic and market studies, and going to the field (so to speak) with the main actors in charge of the production of services and goods, I analysed the industrial setting, technological evolution, and dynamic complementarities; the type and structure among firm and non-firm organisations;

demand, network and knowledge types; and in general how the institutional setting, both formal and informal shaped particular innovation patterns.

Basically, with this question my intention was to explore these differences to determine and examine the factors that influence sectoral behaviour and innovation pathways. The subsidiary questions behind the main one are: How formal and informal institutions have affected the innovation pathways in the industries under study? What barriers and drivers to change have been crucial to generating alignment between actors and promoting effective knowledge generation and exploitation? What does the study of particular sub-sectors in addition to the Sectoral Innovation Approach tell us?

The final step was to analyse the way in which the national policies, and the policy mix designed and implemented, promoted innovation in the productive sector. My interest turned to examine the connection or disconnection between national and sectoral policies and more specifically to analyse innovation flows between the named innovation systems. This aspect took me to the third question:

3. *How are top-down and bottom-up innovation dynamics within sectoral levels developed and enhanced?*

This is an analytic question. Once a clear outlook of the national and sectoral policies was in place and the intention of having systemic relationships between actors and components was examined, the enquiry moved to focus on the relationship between the macro level, in terms of industrial, economic, educational and planning regulations and laws; the meso level, or the existence and operation of support infrastructure composed by standards, intellectual property rights, and non-firm support organisations; and the micro level, comprising producers and firms. It is important to note here, that even considering firms and producers in the agriculture sector, I did not delve into internal firm dynamics for carrying out their innovation processes. The purpose was to have a bottom-up approach to understand the relationship between firms and producers within the same sector and with their upward and backward vertical and horizontal integration, but this research did not attempt to produce an extensive account of innovation management at the firm level.

By looking at the national level in the first question, I intended to have a top-down approach towards innovation and its promotion through national and sectoral policies, and this question directed the analytical attention to innovation from the bottom.

The purpose was to examine the composition and relationships between enabling mechanisms expressed in policy mixes, and the actual dynamics and innovation pathways of public, research and business actors in the innovation space. I intended to explore the composition of the national, sectoral and sub-sectoral systems in the light of their purpose, the means or mechanisms available to execute innovation strategies and the financial and human resources devoted to achieve the expected goals.

By answering these questions, I expected to find common practices and aspects that could be identified as successful for having radical and incremental innovation and to understand if these processes and pathways have been influenced by sectoral and national dynamics or if on the contrary, the success of these sub-sectors have fed inter sectoral and national practices. Mostly, as Malerba clearly says (Malerba, 2002), it is important to determine what is co-evolving with what in the sectors, so more sectoral research studies can give a broader account of the importance of specific features and particularities to explain innovation in the heart of the backbone of any innovation system, the firms, and in the case of agriculture, the producers and growers themselves.

1.3. Structure of the thesis

Moving forward, the second chapter presents the analytical framework used in this thesis to answer the research questions and accomplished the research aim. I looked into the systems analysis approach as a mechanism to understand the world and provide a comprehensive view and solutions to problematic situations or to model intended realities. Then the national system of innovation approach (NSI) and sectoral system of innovation approach (SSI) were analysed as heuristic analytical devices to understand innovation and intervene in national and sectoral patterns to maximise social and economic benefits. A deep study of institutions, knowledge transactions, networks and co-dependence of social, technical and economic factors to lead innovation in the business sector were included in this chapter. Given that the case study is a Latin American country considered as a developing economy, I provided an explanation of the economic, political and academic particularities of the LAC region in order to understand the historical and cultural setting that makes the region particular and explains the social and economic shifts which occurred during the 20th century. Since the innovation systems cannot be studied in isolation from the political framework (Foray, 2009; Galli & Teubal, 1997), in this chapter I analyse different approaches to design, implement and asses science, technology and innovation policies and highlight the importance of specific governability and governance types to manage innovation systems. Finally, a flexible approach to understand social systems and enhance innovation policies in uncertain and complex conditions –every human system is complex, and has different levels of ambiguity and uncertainty- is explored as a complementary analytical framework.

In the third chapter, I present the methodology followed to develop this research. First I outline the research strategies, epistemological and ontological assumptions, and the research paradigms behind the options chosen. In this section I explain the main research choices made in the research along with an explanation of the reasons behind the methodological decisions. A second section explores the data collection performed, a description of the methods used and the distribution of research participants according to their action field. The third section provides a detailed account of the methods and tools used to analyse the data and finally the chapter explores the methodological and practical limitations of the present research.

Chapter four includes discussion and findings about the first theoretical strand of the thesis: the policy study of the national and sectoral systems of innovation. The chapter is divided into six sub-sections, two of them being introduction and conclusions, and the four remaining bring together findings and analysis of the processes of science, technology and innovation policy development, implementation and outcomes at the national level and a fifth section about the evolution and results of the Agro-industrial system of innovation. This chapter presents the top-down view intended in this thesis as an analytical strategy to understand the explicit and implicit mechanisms that affect and guide specific innovation patterns.

Chapter five presents the second thematic branch, the innovation study performed in this thesis. In this chapter I present the sub-sectoral case studies using the same analytical lenses to understand the sub-sectoral dynamics towards knowledge generation and knowledge exploitation to keep the production chains viable both at the economic, social and environmental levels. I found that the historical context of the case studies is a crucial factor to understand their innovation pathways and the cooperation and competition relationships between actors. I also found that the institutional setting for building technological capabilities and learning capacity is central and goes beyond the offer of certain incentives coming from the central government. Each sector - and in the cases studied, each production chain- has its own dynamics, shaping the pathways which determines how actors learn and consequently the behaviour of the different blocks within the subsystems when new sources of knowledge are part of the production activities. It is a matter of *learning how*, more than *learning what*, irrespective if the access to knowledge is direct or indirect. In this sense, applying the same rationale to support different institutional settings is not always effective.

The sixth chapter brings together the analysis of the three chosen sub-sectoral cases. This chapter carries forward the second thematic strand and explores, in a comparative way, the main factors that have impacted the evolution of sectoral practices to be more competitive through the adaptation of their practices to market fluctuations and the particular composition of the actors of the sector. I analyse which factors are co-evolving with which and what practices and strategies can be recalled as successful to provide social welfare to the growers themselves, to have sustainable environmental practices, and to maximise the economic profit of the growers and firms involved in the sub-sectoral chains. Particularly I wanted to study the principal determinants that have shaped the capability building strategies, technological evolution, knowledge networks, and the institutional setting of the coffee, sugarcane and flower sub-sectors. Therefore, this chapter outlines the main challenges, opportunities and strengths to innovate in a comparative analytical framework.

Finally, chapter seven brings together the findings of this thesis. I summarise the main aspects found to answer the research questions, present the theoretical contributions developed through this particular research, and specify practical findings and advice to practitioners and policy makers about the understanding of innovation inter-firms. Also, important aspects to take into account when designing national innovation strategies are highlighted. The chapter closes with some suggestions for further research that can enhance the current research.

2. LITERATURE REVIEW

2.1. Introduction

This chapter reviews the theoretical bases upon which we built our empirical, practical, and theoretical contributions. We start the chapter with an exploration of what it is and what it implies to follow a system analysis approach and locate the systems of innovation approach within the broad soft tendency of systems analysis. The third section focuses on the systems of innovation approach, its different branches, and gives special emphasis to the National Systems of Innovation approach and the Sectoral Systems of Innovation approach, since both of them are used in the formal and informal institutional setting of our case studies. The fourth section presents a comprehensive account of the evolution of science and technology and innovation studies in Latin America, and the way that the region evolved in terms of political choices across the 20^{th} century. Finally, we explore the importance and significance of institutions in evolutionary theory and the SI approach and examine different approaches towards STI policy design and implementation.

2.2. System Analysis Approach

Before talking about systems of innovation, it is worthwhile to think about the main idea of what a system is. In the systems analysis approaches, be they hard or soft, the idea of system itself is not always problematized. In biology, the idea of system is widely use to explain how living organisms have intrinsic structure, properties and internal functions allowing them to be alive. However, even in biology or in astronomy, this whole notion of "system" is a conceptual device to describe something we can "see" in operation. Then, the whole notion of "system" is inscribed within a conceptual framework humanly created to make sense of a reality that is outside and inside us. This particular conceptual and theoretical way for seeing the world or *Weltanschauung*[1] is just one of the possible ones to understand reality. Of course, no particular *Weltanschauung* is infallible.

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[1] Literally 'world view'. An individual (or collective) viewpoint, which is conditioned by environment, background, beliefs, upbringing, etc. It is not itself a set of beliefs, but a framework which underlies one's beliefs. (Open Systems Group, 1981)

> One of the more dangerous consequences of the scientific approach is a tendency to encourage people to think that their perceptions of reality are real and that there is indeed an objective reality 'out there'. (Open Systems Group, 1981, p. 14)

Now, considering that the systems approach is a way among many others to perceive, interpret and analyse reality, it is good to return to the basics, to the meaning of 'system'. The most simple definition of system is found in the Oxford English Dictionary as "a set of things working together as parts of a mechanism or an interconnecting network; a complex whole" (Oxford University Press, 1989). This simple definition gives a sense of the existence of different units interconnected to perform a specific purpose according to the existence of certain attributes. However, in this definition there is no explicit mention of the role of the system analyst. Perhaps, a richer and more comprehensive definition of what constitutes and involves understanding reality as a system is given by the open group (Open Systems Group, 1981, p. 14):

A system is an assembly of parts where:

1. The parts or components are connected together in an organized way.
2. The parts or components are affected by being in the system (and are changed by leaving it).
3. The assembly does something.
4. The assembly has been identified by a person as being of special interest.

In this definition the observer participation is explicitly mentioned. Also, it outlines the system's structure (components related to each other), behaviour (elements are changed by being in the system, there are inputs and transformed outputs), and interconnectivity between the structure and the behaviour (attributes and dimensions of action). In order to preserve a systemic dynamic, inner and external links of the system components need to be maintained.

Defining a system presupposes that there is an external environment. The system has a boundary that defines it as a separate unit. Subsequently, the system analysis implies an inner analysis of the structure, behaviour, functions, and interconnections, and an analysis of the feedback process between the system and the outer space or the environment. In this sense, defining a system is defining its boundaries. In natural sciences it is perhaps easier than in social sciences. Defining a system in social sciences presupposes the acceptance of subjectivity, because the system definition and its boundary are constrained by the analyst's interests and *Weltanschauung*. Depending on the unit and purpose of analysis several systems can be defined and can be part of different bigger systems.

> But this interface between inner and outer is elusive. Sub-systems may be parts of more than one whole and so may fall within more than one *system boundary*. The boundary itself may be differently perceived and defined by different elements in the system. (Vickers, 1983, p. 20)

This makes us conclude that systems are abstract conceptualisations to understand reality according to specific interests, social, economic and political contexts. The acceptance of the existence of a system depends then on the negotiation of different actors to fulfil a particular purpose.

2.2.1. Systems Thinking

The systems' thinking comes from biology. Biologists were among the pioneers in thinking of natural phenomena as a whole, a whole with components, and functional and structural relationships. In fact, the biologist Ludwig von Bertalanffy was the first to suggest the use of systems thinking to understand all sort of problems. "Biology is now established as an autonomous science which is not reducible to chemistry and physics. Establishing this has established systems thinking." (Checkland, 1983, p. 32). The second strand using systems thinking are electrical, communication and control engineers. In their case, to explain how waves, electric impulses, and bits can be modelled.

About the systems thinking definition, Checkland gives a useful insight:

> It is the concept of organized complexity which became the subject matter of the new discipline 'systems'; and the general model of organized complexity is that there exists a

> hierarchy of levels of organizations, each more complex than the one bellow, a level being characterized by emerging properties which do not exist at the lower level. (Checkland, 1983, p. 32)

There are open and closed systems. Living organisms are open when they exchange energy, information, and materials with an environment. That exchange makes them resilient to the changing environment. In biological systems, the living systems themselves create and re-create. This is something that wants to be emulated in the innovation systems but that is difficult to achieve. Self-monitoring and control are desired stages of a mature system. Moreover, living systems in the long term may adapt and evolve to different kind of organisms or living entities enclosing different systemic inner and outer relationships with the environment. For the case of social systems, this means that purpose and scope of a system are under constant negotiation by the actors. System thinking implies having flexibility to understand how boundaries are constantly under negotiation and the ability to capture information exchange between the components of the system. The systems are constantly evolving and therefore are always dynamic.

2.3. The Systems of Innovation Approach

The concept of Systems of Innovation (SI) emerged in the late 1980s and early 1990s, and different authors coming from different disciplines and traditions have developed it since then. It is first mentioned at the national level as a reaction to mainstream neoclassical economics urging for perfect market conditions, less state intervention and conceiving technological progress as another external variable affecting market conditions. As Sharif explains:

> Garnering their inspiration from Schumpeter, and holding up List as one intellectual forebear, Freeman and Lundvall represented the reawakening of an institutionalist 'school of thought' within innovation studies under the NIS banner. (Sharif, 2006, p. 753)

It is on this perspective and background that the systems of innovation approach evolved from an evolutionary and institutionalist economic dimension (Edquist, 1997b; Freeman, 1987; Lundvall, 1988, 1992b; Nelson, 1993). The approach has extended and broadened through a range of studies addressing variously: the central role of institutions, the importance of social and historical dimensions to study innovation dynamics, the role of knowledge and learning cycles among central innovation players, and the importance of science, technology and innovation (STI) policy design to operationalize systemic strategies (Chaminade, Lundvall, Vang, & Joseph, 2009; Galli & Teubal, 1997; Metcalfe & Ramlogan, 2008; Nelson & Nelson, 2002; Niosi, 2010).

Coming from another tradition, but preserving a systems thinking, the socio-technical systems of innovation framework presents a different perspective towards sectoral innovation systems. It includes an explicit analysis of the role of users in technological change; a distinction between the actors, the systems which they are embedded in, and the institutions that guide the system functions; use of institutional theory to examine the dynamic interplay between actors and structures; and the explicit study of change in fluctuations between systems. This perspective, rooted in the Constructive Technology Assessment (CTA) (Schot & Rip, 1997), includes sociological and historical notions to understand long-term dynamics and socio-technical shifts between systems. (Geels, 2001, 2004, 2010; Geels & Schot, 2007).

The National System of Innovation (NSI) was the first approach of the systems of innovation movement. The concept was both coined for academic and policy-making processes as a device for studying innovation and to give a common ground for international and national policy agents. During the 1990s the NSI approach gained high scientific prestige mostly because of the academic support it had and its diffusion by transnational organisation like the OECD (Sharif, 2006). From the emergence of the NSI concept, the systemic lens for studying innovation started to spread in academic circles. The boundaries and scope of analysis determined the type of system under study and the analytical tools needed to study innovation processes.

> Systems of innovation can be viewed in several dimensions. One important dimension is the physical or geographical dimension. Sometimes the focus is on a particular country or region which then determines the geographic boundaries of the system. In other cases the main dimension of interest is a sector or technology. In such cases, the determination of the relevant geographic boundaries is itself a theoretical or at

> least methodological issue. (Carlsson, Jacobsson, Holmén, & Rickne, 2002, p. 233)

Given the wide variety of existing definitions of innovation systems, differences in the use of the approach, and the divergences found when applied to different case studies, Edquist argues that it would not be correct to say that the systems of innovation approach is a formal theory, nor even an appreciative theory. He prefers to label it as a conceptual framework or as an approach useful for the analysis of innovation. In his own words: “It is a kind of ‘wide trawl’ intended to capture processes of innovation, their determinants, and some of their consequences (e.g., productivity growth and employment) in a useful way.” (Edquist, 1997b, p. 28) However, in the latest development of the approach, the epistemic communities[2] working with the concept have divided into two postures. One group wants to keep the approach open and flexible in its interpretation and use, and the other group holds that the concept should have a rigorous theoretical base in order to be broadly applicable. The first group is mostly led by Lundvall and the emphasis is put on strengthening learning, innovation, and competence building systems in developing economies around the world (Sharif, 2006). This effort is materialised in The Global Network for Economics of Learning, Innovation, and Competence Building Systems (Globelics[3]), with its corresponding branches in Latin America (Lalics); Africa (Aficalics); and Asia (Asialics). Globelics brings together scholars focusing on interactive learning for the creation and strengthening of competences and capabilities towards generation of innovation. On the other hand, looking for an academic formal theorisation, Edquist has been leading, first as director and lately as chair in Innovation Research, the Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE[4]) based at Lund University. The Centre has

[2] We agree with Sharif on calling the group of practitioners and academics building the concept and using it, as an epistemic community. The NSI concept was co-constructed in political and scientific circles by an informal network of researchers and decision-makers working in an interdisciplinary manner within the innovation studies field (Sharif, 2006).

[3] The first formal meeting to constitute the network took place in 2002 and has academic conferences every year to bring together scholars all around the world. The website is: http://www.globelics.org

[4] CIRCLE was established in 2004 with initial funding from the Swedish government, Lund University, and the Ruben Rausing Foundation. It is based at Lund University and has had a broad impact within and outside Europe. The website is: http://www2.circle.lu.se/about/

researchers from all around the world and has extended its influence to academic and policy actors in different countries.

Lundvall argues that the NSI is a focusing device that helps to analyse, foresee and explain courses of rational action and that in that sense, it can be called a theory since it serves the same purposes of a formal theory (Lundvall, 2007). On the other hand, Edquist keeps arguing the need for a theoretical base to straighten up the approach and make it more like a theory. That is why he led a project to compare ten small economy countries using the same parameters to study innovation using the SI lens. The main objectives of the project were: to further refine, elaborate and operationalize the SI approach to make it more theory-like; to use the SI approach by carrying out empirical and comparative studies of NSIs; and to draw policy conclusions (Edquist & Hommen, 2008).

Notwithstanding the discrepancies and depth in the use and understanding of the SI approach, the analytical emphasis remains on the economic dimension of technological innovation. It is true that knowledge, networks and social institutions are taken into account as part of the approach, but these are only seen as a means to promote or hinder innovation. The goal for having innovation at the national level is to generate higher levels of economic growth. Ideally, a higher economic growth can be redistributed in the population and can help to continue building capabilities to fight against poverty, but the approach does not go that far and does not provide any guideline to foster social innovation. Hence, the SI approach and specifically the National System of Innovation approach are far from being unproblematic for both political and academic circles in its understanding and application.

2.3.1. Differentiation of Systems of Innovation

One of the reasons why systems of innovation analysis remains as an approach and not as a theory is the diverse ways in which scholars understand and use it for academic and political purposes. There are different definitions of what an innovation system is and what it comprises and that is exactly the reason why (Edquist, 1997b) argues that the approach lacks of stringency to be even an appreciative theory. For instance, Nelson gives the following definition of an innovation system: “a set of institutional actors that, together, plays the major role in influencing innovative performance.”(Nelson, 1993, p. 4). Carlsson et al., on the other hand develop the concept of technological system of innovation, but give a previous account of the state of the art of innovation systems. They suggest that for analytical purposes, it is “possible, at least in principle, to view a national system of innovation as the aggregate of a set of technological, sectoral or regional systems” (Carlsson et al., 2002, p. 236). Niosi et. al. present what they call a ‘workable concept’ of a national system of innovation and define it as: “the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interactions among these units may be technical, commercial, legal social, and financial, inasmuch as the goal of the interaction is development, protection, financing, or regulation of new science and technology” (Niosi, Saviotti, Bellon, & Crow, 1993, p. 212). What remains certain in the idea of the SI approach is the systemic nature of innovation where private, public and academic actors forge complex relationships to trigger technical change to enhance business competitiveness at the national level.

It is important to outline what we understand by innovation, since it is the cornerstone in the innovation systems approach and is central to this thesis. The SI approach focuses its attention on technical innovation in products and processes and builds upon Schumpeter’s classical concept. Schumpeter defines innovation “…as the setting up of a new production function. This covers the case of a new commodity as well as those of a new form of organization such as a merger, of the opening up of new markets, and so on.” (Schumpeter, 1939, p. 87). This is an economic definition that explains changes in the production function as the main aspect required to have innovation. Nelson and Rosenberg specify clearly that the scope of their book is restricted to technical innovation. They propose a broad definition of innovation, within the main concept of National System of Innovation. For them, innovation “…encompasses the processes by which firms master and get into practice product designs and manufacturing processes that are new to them, if not to the universe or even to the nation” (Nelson & Rosenberg, 1993, p. 4). Lundvall focuses on technical innovation as a cumulative path-dependence process.

From that standpoint he defines innovation "as a process encompassing diffusion and use as well as the first market introduction" (Lundvall, 2007, p. 101). For Edquist, "innovations are creations of economic significance. They may be brand new but are more often new combinations of existing elements." (Edquist, 1997a, p. 1). Niosi et. al. define innovations as "new and improved products and processes, new organisational forms, the application of existing technology to new fields, the discovery of new resources, and the opening of new markets." (Niosi et al., 1993, p. 209)

Although most scholars who are part of the epistemic community using the SI approach limit their understanding of innovation within the economic dimension of technical progress, we include social innovations produced by the interaction of actors that result in better or newer practices that improve the welfare of a determined social group. We take into account product, process, organisational and market innovations either incremental or radical. Incremental innovations are those that generate improvements on products, processes or services that are already in use, but that can be adapted to fulfil other needs or to increase productivity through the use of the improved tools. This kind of innovation usually generates short wave disruptions in the production function of the markets. On the other hand, radical innovations are those that introduce a 'new to the world' product, process or service and that represent a long wave structural change in economies (J. Clark, Freeman, & Soete, 1981).

There are also different types of systems of innovation, depending on the boundary the analyst uses to determine the object of study. Although all of the typologies have developed their own theoretical corpus, they shared the systems thinking perception and recognise the non-linearity of innovation processes. There are definitions for National SI (Freeman, 1987; Lundvall, 1992b; Nelson, 1993), Regional SI (Braczyk, Cooke, & Heidenreich, 1998; Cooke, 1992, 2001; Cooke, Gomez Uranga, & Etxebarria, 1997), Sectoral SI (Malerba, 1999, 2002; Malerba & Orsenigo, 1996; Montobbio, 2004), Technological SI (Carlsson & Jacobsson, 1997; Carlsson et al., 2002), and Continental SI (Freeman, 2002). Yet, the boundaries between them are not always clear and it is easy to find overlaps between the definitions of different systems. This is one of the shortcomings of the SI approach. However, the systemic nature of the approach makes explicit that there are always connections with different layers at the micro, meso and macro levels. It is also clear that the core of any innovation system is inter-firms interactions operating within institutions set by education, labour, financial, welfare and intellectual property systems.

Regional Innovation Systems (RIS) can be specified inside a country or even inside a continent. A great number of publications about RIS have used Silicon Valley as a case study (Kenney, 2000; Lécuyer, 2006; Rogers & Larsen, 1985; Saxenian, 1996). The Silicon Valley case is a *de facto* system, which has been taken as a successful example to replicate in other countries, regions, and even country clusters. However, as it is shown by (Brown et al., 2015) trying to replicate regional systems is full of shortcomings. Their study of a regional innovation policy in Scotland: *The Scotland's Intermediate Technology Initiative* (ITI), which was supposed to promote high-tech regional innovation following the example of Silicon Valley, showed how RIS are context dependent. The program ended up being a linear model of innovation in practice and could not connect the knowledge production side with the knowledge exploitation elements. The program failed to grasp the nature of the local entrepreneurial ecosystem. (Brown et al., 2015)

We will have a deeper analysis of the definition, application and analytical power of the Sectoral Systems of Innovation (SSI) later in this section; however, we provide a short reference to its definition. Malerba defines the SSI as "…a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and existing, emergent and potential demand. The agents composing the sectoral system are organizations and individuals."(Malerba, 2002, p. 250) Nevertheless, the concept of SSI can be, in a sense, problematic in its boundaries, as it happens with the NSI, because a sectoral system can integrate even different NSIs, as it is mentioned by Edquist "Systems of innovation may be supranational, or subnational (regional, local) – and at the same time they may be sectoral within any of these geographical demarcations. There are many potential permutations. Whether a system of innovation should be spatially or sectorally delimited depends on the object of study." (Edquist, 1997a, p. 12). Again issues regarding the definition of the research object in a practical case study arise.

Finally, there are Technological Systems of Innovation (TSI). Here, the unit of analysis is a particular technology represented by products and the way these products are related to the economic and political dynamics within the system. It is defined by Carlsson and Stankiewicz as "a network of agents interacting in a specific technology under a particular institutional infrastructure and involved in the generation, diffusion and utilization of technology" (Carlsson & Stankiewicz, 1995, p. 49). According to Carlsson's definition, the analytical approach to this class of systems could be done in three levels of analysis: "to a technology in the sense of a knowledge field, to a product or an artefact, or finally to a set of related products and artefacts aimed at satisfying a particular function, such as health care or transport" (Carlsson et al., 2002, p. 237). According to this definition, boundaries in TSI are drawn depending on the spectrum of expansion a technology can have without geographical constraints. Again, although an explicit methodology is proposed by Carlson et al. according to the different levels of analysis, the concept is broad and it could be problematic to define where the technological system ends and where a sectoral, regional or continental system begins.

The different variants of the SI model all share a common conception of innovation as a (systemic) consequence of the operation of a system comprised of a set of components (conceived in broadly similar ways). Looking at the different definitions reviewed above, it is feasible to say that all of them follow the NSI model. This was the first concept in the SI approach developed for the Japanese case (Freeman, 1987) and broadly discussed by authors like Lundvall (Lundvall, 1992a). The differences between all these subsystems are found in the level of study (i.e.: the zoom in or zoom out made according to the analytical goals). Although some SI such as the Technological ones focus more on the expansion, operation and effects of a particular technology, the system is analysed with the same principles: The interaction between main actors, main sectors included in the TSI, processes and links between sub-units and knowledge transfer throughout the system.

2.3.2. National System of Innovation Approach

The most widely used definition of systems of innovation is the National Systems of Innovation (NSI). The concept started to be used within the construction of industrial policy in Europe in the latter 1980s and was adopted afterwards by the OECD as a recommended analytic and political approach to be applied to national contexts. It emerged to challenge the Washington Consensus[5] and mainstream neoclassical macroeconomics to bring a different perspective on economic policy by recognising the role that innovation and knowledge generation and exploitation had in the economic growth of nations (Lundvall, 2007). The approach was born and used simultaneously in academic and political circles, given the overlap of academics who for the first time mentioned it (Freemand and Lundvall) with positions within the OECD. As Sharif states: "[T]he NIS concept had the advantage of proponents who inhabited the academic and policy realms, thereby easing the concept's movement between the two worlds."(Sharif, 2006, p. 752)

There are many definitions of National Systems of Innovation. These definition were conceived first as a description of national frameworks supporting and promoting innovation in industrialised countries, so we could say that represents an *ex-post* account of a perceived reality identified through empirical cases. Later on, the NSI approach was promoted by transnational organisations like the OECD, Economic Commission for Latin America and the Caribbean (ECLAC), and the Organisation of American States (OAS), so it was disseminated to developing countries as an *ex-ante* framework to build STI policy (Arocena & Sutz, 2000).

The innovation system research and mostly the NSI approach have been understood and applied in two different perspectives: a narrow and a broad one. The narrow perspective has an emphasis on the science and technology side of innovation (STI) and its measure through national performance in research and development activities

[5] The Washington Consensus refers to a set of free market, floating exchange rates, and macroeconomic measures defined in 1989 to encourage economic development in Latin America, South East Asia and other developing economies. It develops ten policy recommendations that were supported by the US government and the international financial institutions based in Washington, hence its name. The aim of the consensus was to maintain macroeconomic stability and integration of developing economies into the international economy through major policy reforms (Williamson, 1990).

and academic production. The broader one also encompasses learning and competence building at different levels of aggregation and focuses on learning through structures and relationships mediated by *Doing, Using and Interacting* (DUI). The former is the one that has been widely disseminated in policy circles since with this perspective it is easier to measure policy results, neglecting what seems more difficult to assess. This perspective also provides formal measures that can be used to compare countries' performance and so can *easier* guide resources allocation. The latter, requires a deeper and contextualised analysis of tacit and formal knowledge, learning interactions between and within firms, and analysis of cooperation and competition relationships between innovation players. This perspective requires the analyst to examine social institutions between customers and suppliers and formal and informal links between research and production sub-subsystems (Lundvall, Vang, et al., 2009). Interaction between formal and informal dimensions of the narrow and broad perspectives of innovation systems can be seen in Figure 2.1:

	Narrow	Broad*
Formal	Science & technology organisations, institutions and formal networks	Organisations supporting innovation in general + institutions & formal networks
Informal	S&T informal institutions and informal networks	Informal institutions influencing innovation and informal networks (like cultural and historical values)

*Includes the organizations and networks included in the narrow concept of IS as well.

Figure 2.1. Interactions between formal and informal elements of the innovation system

Source. (Lundvall, Vang, et al., 2009, p. 11)

Given its multiple uses, understanding and action frameworks, we agree with Sharif that the NSI is a boundary object diffused by epistemic communities part of the academic and the political worlds (Sharif, 2006). Given its flexible nature, the approach has been used and even abused, using it as a label for all sort of policy initiatives or even academic discussions related with the study of innovation within geographical, sectoral or technological boundaries. In this respect Lundvall states that:

> [T]he wider implications of an innovation and learning perspective on general economic policy have not been seriously considered and worked out. Innovation policy has been added to an economic policy based upon static economic theory. Policy implications have been worked out on the basis of a narrow definition of innovation system where the focus is on science based innovation. The wider setting that has a major impact on interactive learning and on the performance of the innovation system has not been given sufficient attention. (Lundvall, 2007, p. 98)

Although the NSI is an approach in the sense that it does not represent a right way to understand innovation and to apply economic policies based on technological change, in most developing countries where the concept has been embraced, policy-makers and even local academics have understood and followed an ideal model following the pioneer studies made in industrialised countries. It is true that the precursors of the NSI approach avoid such a thing as an *ideal system,* but it does not mean that there are not expectations of how a good NSI should operate and what results should achieve. It is in that sense that Arocena and Sutz express that "the NSI concept carries a normative weight." (Arocena & Sutz, 2000, p. 58)

Several scholars working with the SI approach have also problematized the national dimension of the NSI. Nelson and Rosemberg problematize the concept of *national* because it is difficult to demarcate a system as national, given the broader connections it has with the international context: "Indeed, for many of the participants in this study, one of the key interests was in exploring whether, and if so in what ways, the concept of 'national' system made any sense today. National governments act as if it did. However, that presumption, and the reality, may not be aligned." (Nelson, 1993, p. 5) Still, they stress that the concept is valid when the sub-systems inside the system are defined clearly.

When a sectoral view of the whole system is performed, boundaries are visibly stated and consequently the concept of national can be better demarcated. That is why Lundvall (Lundvall, 1992b) argues that the concept of National System must remain flexible and open according to the subject studied. The emphasis on the national level has an explanation. Since the approach emerges as a reaction to the national macroeconomic policies promoted by the Washington consensus, the national dimension was crucial to bring another analytic dimension where learning, interaction between innovation players and technical change were the centre of the national economic measures (Sharif, 2006). Nevertheless, the concept remains diffuse and short in analytical tools when existing networks between the NSI and other broader and more specialized systems of innovation are part of the picture. The NSI keeps being developed to connect different levels of analysis with the national level, but given the steady growth of global links between users and producers, it is more difficult to keep the analysis at the national level. “The concept of national system had a well-defined meaning in the past when basic decisions concerning the science, technology, and innovation policies of a given country were taken essentially at a national level.”(Galli & Teubal, 1997, p. 345)

In terms of its suitability for developing economies, less developed countries (LDC) or countries from the South, there have been extensive debates about the appropriateness of the NSI approach. (Delvenne & Thoreau, 2012) present three main deficiencies of the NSI approach, particularly for developing economies: 1. NSI approaches do no pay sufficient attention to the regimes of science and technology and fail to integrate effectively broader socio-political landscapes and global contexts; 2. The approach reproduces the balance of power between richer and poorer countries, with many of its studies centred on OECD countries; 3. It is highly focus on GDP generation and economic growth as the main outputs of catching-up and progress.

On the other hand, Arocena and Sutz develop a *southern perception* of what the NSI implies for Latin American countries that they formulate in four statements. The first two were already mentioned: the *ex-ante* nature of the concept for LAC countries given the lack of systemic socio-economic patterns towards the creation, and encouragement of technical change and innovation; and the normative weight that the concept brings when applied to LDCs. The third aspect is related to the relational character of the approach where connections between innovation players are crucial to generate virtuous innovation cycles. However, although bridge institutions or intermediaries between the research and industrial systems have been created in the Latin American countries, most of the intended NSIs of the region lack of systemic connections between actors. Fourthly, they state that the NSI is a *policy subject* intended to design policy mixes that can contribute to the promotion of innovation through science and technology capabilities. However, S&T have never occupied a high position on the political agenda of Latin America, which has made failed many initiatives when it comes to their implementation (Arocena & Sutz, 2000).

Even though (Alcorta & Peres, 1998) base their analysis of LAC countries from the origins of the strengthening of S&T capabilities from the 1940s until the 1990s using the NSI approach as analytical device, their findings clearly contradicts the existence of NSIs in the region. They analyse the Latin American countries in terms of technological infrastructure, interactions between organisations, public and enterprise investment in innovation, human capital formation, and public policies. Among the most notable deficiencies they found in the region are: limitations in physical infrastructure (roads, energy and water supply, ports, telecommunications, among others); mismatch between demand and supply of research services; highly hierarchical functional lines of management and activities in firms; low and ineffective support organisations to link the research and productive systems; lack of cooperation among domestic firms and among national and international firms; no interaction between blocks of the innovation systems; little interest of cooperation between universities and firms; low levels of investment in R&D and innovation activities from the public sector and mostly from the private sector; low quality and variety of human resources required for technological upgrading; and overall lack of clarity about the objectives of the so-called systems of innovation. In other words, all the structural components and functional setting that constitutes a National System of Innovation, were missed in the countries of the region.

> This creates a paradoxical situation, where scholars stress the pressing need to develop an innovation agenda for Southern countries with a 'Southern mindset', while at the same time they continue to heavily rely on a reductionist version of the NIS-approach. (Delvenne & Thoreau, 2012, p. 212)

In words of Sagasti: "Building science and technology capabilities in developing countries appears to be a Sisyphean task. Time and investments are made, people are trained, institutions are built, and policies are designed and implemented – often with considerable effort – only to see them fall apart and disappear without trace." (Sagasti, 2004, p. xvii). Perhaps a different approach needs to be taken both to cope with complexity and uncertainty in policy-making processes and to understand and analyse innovation in developing economies that have very particular historical and cultural pathways that shape their current realities.

The response to scholars working with the broad definition of NSI about these shortcomings is that the SIs in developing countries are emerging rather than mature and so on should be analysed in a different way. "If we consider that an IS exists only when all its systemic aspects are in place, *it would be impossible to trace and identify any IS in developing countries*." [original italics] (Chaminade et al., 2009, p. 365). This suggests that for emerging systems the general principles still apply but some of the blocks are still being developed or are non-existent, and the connection and interactions between components are weak.

2.3.3. Sectoral Systems of Innovation

The focus of the SSI is the study of the factors that affect innovation and production in a sector, not necessarily within national borders; sectors can be global or local. The main scholar that has developed the approach is Franco Malerba. Sectoral studies have been central in innovation studies. Sectoral innovation studies have built upon two traditions: the industrial economics literature, which examines the sectors' structure and dynamics in terms of concentration, vertical and horizontal integration, firms' growth and the interaction between firms according to their strategic behaviour; and others focused on case studies looking at particular dimensions of sectors such as firms' competencies and structure of production. There is an intermediate level of study developed and widely used by the OECD that presents empirical taxonomies concerning sectoral R&D intensity and *Shumpeterian Mark I and Mark II* dividing sectors characterised by *creative destruction* with a central role of entrepreneurs and new firms introducing new technological solutions, and *creative accumulation* dominated by few large firms that rise boundaries for new competitors and new innovation. Taking these roots, Malerba develops the SSI approach integrating a further dynamic view of innovation. He brings together other intellectual traditions and contributions about change and transformation in sectors, links and interdependencies within sectoral boundaries, the innovation system approach, and evolutionary theory (Malerba, 2004).

> The starting point will be the empirical recognition, as it has emerged from the rich literature of empirical case studies, that (i) sectors are characterized by specific knowledge bases, technologies, production processes, complementarities, demand and a population of heterogeneous firms and non-firm organizations and institutions, and that (ii) sectors differ greatly in several of these dimensions. (Malerba, 2004, p. 15)

Since the SSI approach pays central attention to the type of knowledge, knowledge dimensions and learning processes within and among firms, the characteristics of demand and institutions, and the relationships and networks between firms and non-firm organisations, we will examine these factors in detail.

2.3.3.1. Knowledge

For the purpose of this thesis we differentiate knowledge from data and information. The former includes the cognitive context in which agents exchange information that contains meaning and a purpose from both those who build it, and those who use it and transform it. In that sense, information is more than codified knowledge and knowledge is more than the junction of information and tacit knowledge (Cowan, David, & Foray, 2000).

Since organisations are mainly composed of individuals and the learning processes take place among the human resources the firms have, and from there evolve to higher units of aggregation (as sectors, technological fields, research areas), it is important to recall the importance of individuals and the skills they bring or develop in the execution of their activities. (Nelson & Winter, 1982, p. 73) highlight the importance of the skilled behaviour of individuals. Their definition of skill is: "a capability for a smooth sequence of coordinated behaviour that is ordinarily effective relative to its objectives, given the context in which it normally occurs."

There are three aspects closely interrelated that characterise a skilled behaviour: skills are programmatic; they mostly rely on tacit knowledge; and they imply the selection of choices between multiple options. The first characteristic relates to the separation of the skill in small units that follow a particular order, or steps, to complete the final desired result. However, this sequence of steps is performed unconsciously and automatically by the individual, which makes it programmatic and executed without conscious volition. This brings us to the second characteristic, that of tacit knowledge as one that cannot be articulated. As it is explained by Polanyi in his 1962 book and cited by Winter and Nelson:

> I shall take as my clue for this investigation the well-known fact that the aim of a skilful performance is achieved by the observance of a set of rules which are not known as such to the person following them. (Polanyi, 1962 in Nelson & Winter, 1982, p. 77)

The degree of tacitness depends on the ability of the individual to articulate their knowledge into words. A skill can be taught so it can be absorbed and appropriated through a learning process. However, to learn, the individual has to go through imitation and practice. That implies repetition and unconscious selection of choices so the desired result can be achieved. Thus, tacitness of knowledge depends on the recipient and not on the nature of the knowledge itself. “In short, much operational knowledge remains tacit because it cannot be articulated fast enough, because it is impossible to articulate all that is necessary to a successful performance, and because language cannot simultaneously serve to describe relationships and characterize the things related”. (Nelson & Winter, 1982, p. 81). The third aspect, skills and choices reflects upon the performance of a skill through the application of an automatic program where a particular set of options is chosen out the whole set of possibilities so the desired final result can be accomplished. This is not a deliberate process since the performance of a skill is a smooth flow of behaviour and is executed in an opportune moment (Nelson & Winter, 1982).

Loasby explains how the concept of capabilities was introduced to economists by Richardson and its view of firms as “a collection of physical and human resources which may be deployed in a variety of ways to provide a variety of productive services.” (Loasby, 1999, p. 49). In Richardson words, organisational capabilities are:

> [K]nowledge, experience and skills. The capability of an organisation may depend upon command of some particular material technology, such as cellulose chemistry, electronics or civil engineering, or may derive from skills in marketing or knowledge of and reputation in a particular market…What concerns us here is the fact that organisations will tend to specialise in activities for which their capabilities offer some comparative advantage (Richardson, 1972, p. 888)

The creation and evolution of knowledge, experience and skills is context-dependent and is developed within the firms, which make it an endogenous process of trial and error. Capabilities are not detached from the internal setting of industries and firms. Therefore, training programs are always constrained by the internal formal and informal institutional framework. Knowledge is also built following the internal divisions of labour creating specialisation according to the expertise area of actors within firm's units, and shaping generic knowledge brought by the staff to the particular needs of the company. In this sense, there are different knowledge subsystems within firms, sectors and clusters. (Loasby, 1999).

Kinds of knowledge

According to Loasby, we can distinguish four kinds of knowledge (see Table 2.1.). 'Knowing that' does not imply that individuals or firms 'know how', or that one is an effect of the other. The relationship between both is bidirectional and do not follow a particular pathway of events. Sometimes the application of knowledge results in unforeseeable results, which means that the application of knowledge is also context-dependent. Moreover, knowledge in its codified form may be public, but know-how is a private asset acquired by firms' maturity and experience. It is harder to codify 'knowing how' and it requires a different coding system.

Kind	Direct Knowledge	Indirect Knowledge
Knowing that	Formal knowledge about what a phenomenon is and why it exists. This knowledge is embedded in the individual.	The individual knows where to find relevant knowledge to explain what a phenomenon or problem is and why it exists or happens.
Knowing how	The individual has the skills to perform the appropriate actions in order to achieve a desired result.	The individual knows where to find someone that has the skills to perform the appropriate actions in order to achieve a desired result, or knows where

		to find the relevant knowledge to achieve a desired result himself/herself.

Table 2.1. Kinds of Knowledge

Source. Made by the author based on (Loasby, 1999, p. 51)

It cannot be inferred that *knowing that* directly gives the capacity of *knowing how*. There may be – and it is desirable – a progression from having the formal knowledge to its eventual application to solve specific problems, but that is not always the case. Not because there is knowledge available about the optimal production factors, rather, it means that firms necessarily know how to apply this knowledge or convert it to their specific needs and strategies. Hence, the only obstacle to support the process of building capabilities in the industrial sector is not the lack of appropriate incentives. Processes of knowledge appropriation and validation become fundamental for the exploitation of technical knowledge and capacity.

> The development of knowledge is a path-dependent process, in which the acquisition of certain kinds of 'knowledge how' facilitates the acquisition of further knowledge of the same kind, and impedes the acquisition of knowledge of incompatible kinds; and this principle applies both to the performance of productive operations and to the procedures by which we seek to develop new 'knowledge that'. (Loasby, 1999, p. 58)

There cannot be complete knowledge or knowledge free from ambiguities. Humans are constrained by a bounded rationality given their cognitive limitations. This implies that there are no perfect choices amongst a finite and restricted set of options, as we studied before, when most of the choices are taken by the rational actors using irrational choice processes. So building *knowledge that* and *knowledge how* is an iterative and interactive process (Loasby, 1999). Learning is a natural and continuous process of doing, using and interacting. Firms innovate using existing knowledge and transforming it into novel creations or adapting novel knowledge to traditional routines. It is an evolutionary process that determines the degree of success and failure of companies, or a set of companies within an industry, sector or technological system.

> “[A] good deal of knowledge is required in order to use markets effectively, and much of this…, is ‘knowledge how’. Using markets to obtain what one wants, like using inputs to create the outputs that one wants, require the appropriate capabilities” (Loasby, 1999, p. 57)

In this sense, knowledge is not created and appropriated within firms in an automatic way. Each firm has particular capabilities that allow them to absorb knowledge and technologies in different ways and at different paces. The sectoral knowledge base and network dynamics among the actors of the system enable different learning processes related to innovation (Malerba, 2002).

Moreover, the state as an active actor promoting the production of S&T as public goods, has failed to understand that codified knowledge, or knowledge that, does not imply that the appropriation process will happen automatically and be straightforward. The tacit knowledge, or knowledge how, is what gives competitive advantage to industries and leads to a process of innovation. The application of the old scheme of linear S&T policy is still applied in many countries, even when the official discourse denies it.

> Knowledge does not travel freely, a condition that rests largely on the importance of tacit knowledge residing only in the heads of the scientists and engineers engaged in its production. Codified knowledge may have low marginal costs of transmission and is thus slippery and hard to contain, but that is largely irrelevant if what one needs is its ‘sticky’, tacit counterpart. (Cowan et al., 2000, p. 222)

The ‘sticky’ knowledge is a term use by von Hippel (1993) to underscore the cost of transferring information relevant for innovation activities that is not codified. Thus, the most valuable asset firms have is their repositories of *know how* that gives then a competitive advantage.

Knowledge Dimensions

Malerba has outlined different dimensions that impact the way knowledge is created, transferred and appropriated within sectors (Malerba, 1999, 2002, 2006, 2007; Malerba & Mani, 2009b). These dimensions are:

- *Knowledge sources*: Sources where the knowledge is built or where it has come from. It can be in universities, public or private laboratories, advancements in R&D, equipment and instrumentation, suppliers or users within the value chain, among others. If the knowledge comes from the sector it favours imitation, if it comes from external sources its appropriation depends on the integration capabilities the firms have to transform the knowledge in innovation.
- *Knowledge domains*: Specific scientific and technological fields at the base of innovative activities in a sector.
- *Knowledge applications*: Novel applications of new knowledge or recombinant of existent knowledge into new knowledge or technological applications. This includes the application of tacit and codified knowledge.
- *Knowledge accessibility*: Opportunities of gaining knowledge that are external to the firm but that may be internal or external to the sector that the firm belongs. External sectoral or industrial accessibility of knowledge is related to scientific and technological opportunities that can be brought by human capital with a certain level and type of knowledge or knowledge that is developed elsewhere by firms or non-firm organisations. Greater accessibility of knowledge decreases industrial concentration.
- *Knowledge Cumulativeness*: Degree by which the generation of new knowledge builds upon current knowledge. There are three different sources of cumulativeness: learning processes that build upon past knowledge and generate increasing returns at the technological level; firm-specific organisational capabilities that provide the base to absorb, use and create new knowledge; feedback from the market that guides new R&D and learning processes to keep innovating. These sources can be examined at the technological, sectoral, or firm level.

Learning processes

A central and crucial factor recognised by most scholars within the innovation studies tradition in general, and the innovation systems in particular, is the capacity of firms to learn so there can be effective links between knowledge generation and knowledge exploitation. The most important resource of the modern economy is knowledge and, therefore, the most important process is learning (Lundvall, 1992b). The complexity in innovation processes in the global economy requires a rapid rate of change and adaptation of innovation players, be they individuals, firms or non-firm organisations. In order to cope with the demands of the learning economy, a new mixture of cooperation and competition between firms, as well as new forms of governance are central factors for the production and diffusion of knowledge towards better economic performance (Lundvall, Johnson, Andersen, & Dalum, 2002). Interactive learning supposes informal cognitive and behavioural patterns that constitute the base for innovation. It is often based on *Learning by Doing*; and *Doing, Using and Interacting* processes (DUI), rather than through formal and codified forms of knowledge transfer (Lundvall, Joseph, et al., 2009).

> [B]ehavioural adaptation and cognitive evolution need to be closely coupled for 'learning', in the sense of improved practice, to occur. In most instances of 'learning by doing', the 'feedback' from 'experience' to inferred 'understanding' is severely constrained. The 'doers' have limited facilities for accurately observing and recording process outcomes, or for hypothesizing about the structure of the process they are trying to control. (David, 2000, p. 130)

Agents within firms, and firms as a whole are permanently involved in evolutionary learning processes where the interpretation of data, the application of concepts or procedures and results from these actions shape the learning curve in a dynamic way. Actors consciously or unconsciously envisage a recurrent assessment of the outcomes of past behaviours and accordingly bound their cognition to repetitive successful selection mechanisms. "They introduce – into a system that already operates a process of 'adaptation by selection' – further elements of 'adaptation by coding' and 'adaptation by revision'." (David, 2000, p. 132)

The concept of learning can have different connotations for late industrialising countries, as is sustained by (Viotti, 2002). For him, learning is directly related to the capabilities acquired by sectors and economies to absorb incremental innovations. He argues that developing economies are technological learners rather than innovators *stricto sensu*. Although this posture can be debated, it highlights the differences of learning processes according to the economic and social setting of countries. Learning is even more strategic for LDCs as the most effective instrument for catching up with market leaders. This can be achieved through an evolutionary process of adaptation, validation and transformation of knowledge according to specific contexts.

> Historical evidence strongly supports the view that self-sustained technological dynamism in catching-up countries is hardly possible without a progressive construction of widening manufacturing sector also involving indigenous skills in a set of 'core' technologies. (Cimoli, Dosi, Nelson, & Stiglitz, 2009, p. 344)

2.3.3.2. Networks

Networks are the base constituting the structure and operation of systems of innovation. It is through cooperative and competitive relationships between firms and production units within a sector that knowledge and technological capabilities are shared and enforce.

> [The] competitive capabilities of a firm rest not only on its own knowledge or on its knowledge of the network. The capabilities of the firm, rather, are dependent upon the principles by which cooperation among firms is coordinated and supported in the network. (Kogut, 2000, p. 406)

Since networks usually emerge to meet the needs, institutional setting and technological capabilities of a sector or a business area, they self-regulate and govern in accordance with the particularities of the industry. Hence, there are not generic rules followed by specific settings. Networks' structure depends on the interaction of social, technological and economic factors. Furthermore, a business network latest purpose is capturing rents. The firm as a unit of accrual build cooperation and coordination features within the collaborative space, so there can be a sharing of capabilities that can result in higher profits (Kogut, 2000). In this sense, two kinds of network structures can be differentiated for the purpose of this study: A Burt network or a Coleman network. The former is characterised by the notion of "non-redundant" ties.

> A tie is non-redundant if it represents the only path between two nodes as constituted by individuals, firms, or even industries. Entities that have multiple unique (i.e., non-redundant) ties with other nodes who are not connected occupy powerful brokerage positions called "structural holes." (Kogut, 2000, p. 414)

The latter are those where redundant ties are predominant, which result in a flatter structure and a tendency to solve problems and share capabilities collectively. "A Coleman rent is associated with the benefits of trust supporting *coordination* in long-term relationships" (Kogut, 2000, p. 414, original Italics). (See Figure 2.2.)

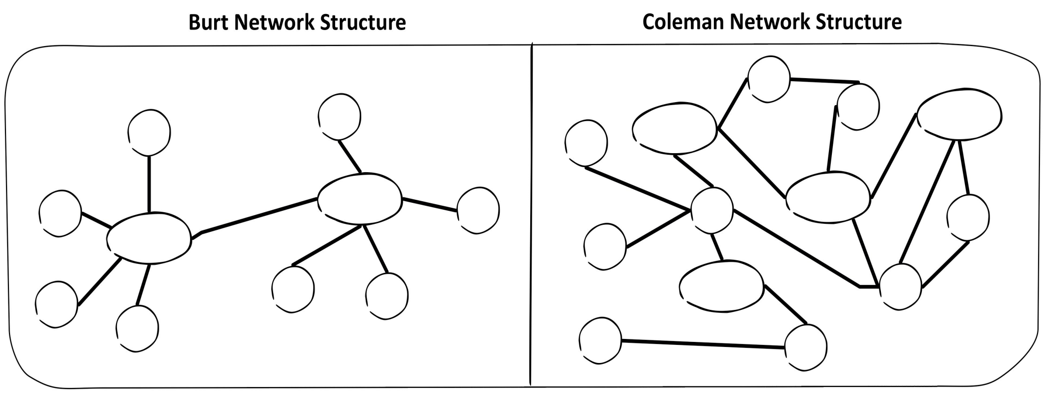

Figure 2.2. Burt and Coleman network structures

Source. Made by the author based on (Kogut, 2000)

The way in which a network is organised is highly influenced by the way firms and individuals approach problems and build knowledge. Therefore is not surprising to find totally different network structures within sectoral and sub-sectoral systems. As it is explain by Loasby:

> Differently organised networks, within each organisation and within each individual's brain, generate different operating procedures and refer differently defined problems for explicit consideration; each person's and each firm's reflective level will have its own way of working and so may reach a distinctive conclusion even if problems are similarly defined. (Loasby, 1999, p. 141)

The division of labour is another important factor that determines and guides the way knowledge is produced and divided within firms. It is through the specialization of labour that relevant knowledge emerges and thereby creates a particular set of relationships among the actors involved in the network, production chain or system (Loasby, 1999). It is also true that networks emerge based on complementarities in knowledge, capabilities and specialization, rather than on similarities between actors. Firms and non-firms are connected in sectors so they can maximise the benefits of cooperation with producers, suppliers and competitors, and vertical integration so processes of exchange, competition and command can be enhanced. The degree of integration between firms and non-firms and governance in the network is highly determined by the power and trust relationships that determine the operation and effectiveness of the SSIs (Malerba & Mani, 2009b).

2.3.3.3. Demand

The size, growth, structure, composition and source of demand are crucial for understanding market composition, segmentation and innovation processes between firms. The role of demand during the evolution of industries determines innovation dynamics that force firms to be more competitive in global and domestic markets. Demand is also heterogeneous in terms of segments, imports and exports compositions, entrance of public and private players and national and international economic fluctuations. Customer-driven sectors are very sensitive to demand patterns, so sectoral innovation dynamics evolve according to customers' taste, requirements and consumption changes. For these sectors, more than others, customer behaviour plays a major role affecting innovation (Malerba, 2006). Hence, study of demand taxonomies related to consumers and users and their involvement in research and development of products and services and their knowledge and mental frameworks is highly relevant to determine factors affecting innovation.

> [A] good deal of knowledge is required in order to use markets effectively, and much of this…, is 'knowledge how'. Using markets to obtain what one wants, like using inputs to create the outputs that one wants, require the appropriate capabilities. (Loasby, 1999, p. 57)

Therefore, to be an effective source of accrual with growing profits, it is important that firms develop capabilities to understand their customers' needs and preferences and to have good managerial resources to generate synergy with the providers to make the supply chain as effective and productive as possible. In order to do that, firms need to 'know how' so they can enhance their technological capabilities. Moreover, technological evolution and technical change are not only, or even mostly, determined by the supply side of markets. Understanding that demand heterogeneity is an active part of the products and services creation and evolution, as well as the innovation processes, suggests a rationale to include demand as a link, trigger, and selection force within the technology production and absorption cycle (Adner & Levinthal, 2001).

2.3.3.4. Coevolution

In an SSI, innovation dynamics are subject to systemic relationships between firms and non-firms organisations, knowledge types, dimensions and learning processes, types of networks between actors, particular institutional settings and demand heterogeneity. That is why the process of interaction of all these factors, or their *coevolution*, is at the very heart of the interaction, cooperation and competition processes and are sector-specific (Malerba, 2006).

Firms' innovative capabilities and size appear to be an important factor that determines the survival in the market. Although (Klepper, 1996) recognises in his model the importance of firms capabilities, sectoral characteristics and innovation patterns, his study is overly focused on the capacity of firms to innovate over the product life cycle through investment and performance in R&D. It illustrates, however, how dominant industrial concentration is coerced by random differences in firm capabilities. A wider study on firm capabilities and transaction cost coevolution to understand firm's vertical scope and industry evolution, is performed by (Jacobides & Winter, 2005). They introduce the concept of *productive capabilities*, as follows:

> [T]he term 'productive capabilities' embraces the underlying determinants of the efficiency with which firms manage to carry out their productive activities. Productive capabilities rest on the firm's general and specific knowledge of how to do things (Richardson, 1972; Teece *et al*., 1997), and also involve specific investments in equipment, training, and retention of key personnel, etc., required to put that knowledge to work. (Jacobides & Winter, 2005, p. 397)

Selection and development of sectoral productive capabilities affect the vertical scope of firms and the whole industry. This is mediated by endogenous and external transaction costs, that in turn affects the nature of development of new capabilities brought by new entrants to the sector (Jacobides & Winter, 2005).

Learning processes are conditioned and driven by the degree of integration and specialization of a particular industry. The knowledge cumulativeness of firms and actors within a sectoral setting depends on the capabilities built to respond to market demand and supply cycles and the further development of productive capabilities. As it is explained by (David, 2000), learning opportunities are developed and shaped by the production systems where firms are embedded:

> The creation of learning opportunities through field implementation of production systems, and the sequential incremental modification of such systems, has been found to constitute an important, and for some industries the dominant, source of cumulative productivity improvements. (David, 2000, p. 124)

Following this line of reasoning, we agree with (Malerba, 2006) to pursue a finer degree of analysis fed mostly by empirical studies to determine what is coevolving with what in each sectoral case. Coevolution of the aforementioned factors is path-dependent on sectoral structure, historical context and particular firms' compositions and capabilities. Although the SSI approach grasps better than the NSI approach the specificity of innovation contexts, it still lacks a deeper study of the role of innovation in innovation dynamics, how power and trust are an essential part to understand the structural and functional setting of the dynamics of the innovation players and how different forms of governance impact upon the sectoral innovation goals.

2.4. Technological Change in Latin America

The Latin American and Caribbean (LAC) region has gone through several institutional stages that have been characterised by an unequal distribution of wealth, high economic dependence on natural resources, unstable political structures, and a slow development of scientific and technological capabilities that inhibits the region from catching up with the world's top tier countries. From the late 19th century until the Great Depression in 1929, LAC countries focused their economic growth on an export-led pattern. This path dependence was identified as the key cause of underdevelopment; therefore, to counteract this problem, the region followed a structuralist economic approach. This analysis identified three specific intervention strategies:

> [F]irst, Latin American countries should promote industrialization, producing what had been previously imported from abroad; second, they should rely basically on the internal market to find demand for their new industrial production; and third, as the structural changes that were necessary to achieve these aims could not take place spontaneously, the state should play a central role in shaping this pattern of growth. (Kuntz Ficker, 2005, p. 148)

The Latin American Structuralism Approach (LACSA) was an 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 historically dependent process attached to cultural, political, social and economic variables (Furtado, 1960). It implies the need to go beyond the application of ideal models derived from developed countries to solve the structural failures in Less Developed Countries (LDC).

LACSA was thought of and applied by what is known as The Latin American School of Thought (LAST). This was a group of academics, technicians and politicians formed during the late 1950s focused on LAC development. LAST contributed practical recommendations for building technological capacity in the region in order to have innovative productive sectors. The ideological corpus followed was mainly Schumpeterian economics (Schumpeter, 1939). The intention was to generate "development from within" using a strategy of temporary protection of national and regional industries to build internal capabilities and have a competitive advantage in international markets, but what prevailed "was an inward-oriented model of industrialization based entirely on the internal market and with a strong anti-export bias." (Kuntz Ficker, 2005, p. 149) Although it can be said that the political thought was democratic and academic - private and public actors were building consensus about the economic path that the region should take -, the result was that LAC economies lost dynamism; the intended "destructive creation"[6] was not achieved because S&T capabilities were not built, or a modern industrial system based on innovation; and there was a strong deterioration of equity levels in the population.

The principal achievements of the school were practical impacts on the definition of public policy, and stronger relationships with transnational organizations such as Economic Commission for Latin American Countries (ECLAC), United Nations Educational, Scientific and Cultural Organization UNESCO, International Monetary Fund (IMF), International Development Research Center (IDRC) and the World Bank (WB). Through the action of its members, most of the national entities in charge of S&T were created in each country. The central aim was to promote innovation to change the productive patterns based on S&T; however the result was "late industrialised region" status. As described by the ECLAC in 1990 about the results of Imports Substitution Industrialization (ISI):

> There are at least five main interrelated characteristics that should be pointed out, albeit briefly. The first is the slowdown in economic growth; the second, the persistent macroeconomic imbalances; the third, the regressive nature of the adjustment; the fourth, the marked weakening of the public sector; and, finally, the decline in capital formation. (Economic Commission for Latin America and the Caribbean ECLAC, 1990, p. 21)

Consistent with the structural economic changes in Latin America, Colombia followed a trade liberalisation at the beginning of the 1990s and a growing tendency to privatise what were state-owned enterprises. An evolving structural change in the economic relationships between domestic enterprises and state-led investment programs in promising sectors, built-up a fitting momentum for attracting foreign direct investment, which energised the entrance and construction of new technological capabilities within traditional industries and the creation of emerging new sectors. At the firm and industrial levels, a higher dynamism was created downstream and upstream between users, producers and chain providers.

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6 Schumpeter's gale for describing the processes in which the capitalist structure based on economic innovation goes through cycles of destruction and creation of new economic orders or regimes.

This dynamic setting in which the region has evolved after the so-called 'lost decade' in the 1980s product of the Import Substitution Industrialisation (ISI) taking place from the 1940s to the 1980s, is better analysed and explain using an evolutionary approach towards firms capabilities, cultural, political and economic institutions, learning cycles and the 'creative destruction and accumulation' of technological capabilities in industries. This approach leads us away from the concept of a 'representative firm' usually portrayed in the neoclassical theory. We are dealing with imperfect relationships between firms and the construction of capabilities to succeed in the marketplace. Firms react to an incomplete understanding of the market and competitors, and respond to profit signals, not always maximising their performance and competitiveness (Katz, 2001).

> In Latin America, since the 1970s, it has been recognized that malignant macroeconomic contexts jeopardize long run investments in real and intellectual capital and have larger implications to industrial development than specific industrial and innovation policies. That is why traditional macro-economic policies have been called 'implicit' industrial and technology policies (Herrera, 1971). As a number of authors in the region have stressed, following Herrera's insight, hyperinflation, high external debt and high interest rates are significant constraints to technological (and productive) development in these countries. The risk of ignoring this perspective can lead to the design of completely inoperative policies. (Lastres & Cassiolato, 2005)

Technological change in Latin America can be seen at the firm level, within the competitive and technological regime that firms are immersed, and from the macro regulatory system and S&T policies that evolve from the ISI process. At the firm level, three different types of firms had a major role in the construction of knowledge and learning capabilities: domestic subsidiaries of TNCs, large local conglomerates, and SMEs. In the case of TNCs branches, during the mid-1950s until the 1980s, they needed to customise their based products according to the available raw material found in the local countries and to the local formal and informal institutions. As a result, many of them had to create engineering departments according to the needs of local production. There was a local creation and adaptation of knowledge that generated a downstream effect on the industrial supply chains. Most of the large domestic companies based their activities in the NRs exploitation such as coal, oil, steal and cooper. In this case, the technical progress was embedded in the machinery and equipment used for the local production. However, these companies did not invest much in adding value to the final products, focusing their strategy on the extraction volume of the trading resources. The last type, SMEs, most of them family-owned, focused their business on manufacturing industries as textiles, shoes or furniture. These firms were benefited by high state tariff protection, which kept them alive even when they were not very efficient in their production and their business portfolio was based on copies of out-dated international tendencies. During the 1990s, when the region opened to trade liberalisation, the business sector went onto a deep structural reform in their competence and innovation patterns (Katz, 2001).

Higher competition pushed the domestic market to be more efficient and to modernise the technological infrastructure in order to catch up with the imported products and services. Thus, transnational companies' branches based in the region closed down their R&D and engineering departments since the new setting they were a part of was global and had different parts of their supply chain in different markets in order to reduce costs and rise productivity. The production of goods and services in the local environments was minimised and with them, the construction of local capabilities. In the case of public companies, the region went through a privatisation scheme, which gave more participation to the private sector in the S&T investment, but also cut off resources or disappeared the great centres of basic knowledge production formerly funded by the state. In the case of large national conglomerates, a machinery modernisation process came through which produced a growth in the productivity levels but foreign technologies were imported with a 'black box' scheme. SME's that could not restructure left the market, leaving room only to the most dynamic ones that could structure a new product portfolio able to meet higher quality and price standards. In terms of innovation systems, the LAC countries increased their private investment in R&D and went through a process of modernisation. However, domestic technological capabilities were not built. On the contrary, countries of the region relied more on imported knowledge and foreign 'black box' technological solutions (Katz, 2001).

> [T]rade liberalization and the deregulation and privatization of economic activities are significantly affecting the structure and behavior of the national innovation systems of the various countries in the region. To a large extent, the change in the global incentive regime has blurred the limits and national identity of the various local innovation systems, enhancing the role played by external firms, institutions and sources of know-how (Katz, 2001, p. 18).

The region went through a transformation led by international patterns, going from the establishment of strong S&T institutes after the Second World War until the 1980s when international economics started to move towards neoliberal policies favouring open markets and less state intervention. During this period many of the public research centres were dismantled and in some countries the budget for S&T was trimmed (Sagasti, 2010).

> In the 1990s, most of LAC countries' NSI changed in similar directions…S&T institutions have also been streamlined or eliminated, and previous attempts to develop indigenous technologies through public enterprises in telecommunications or informatics have ceased and firms privatized. (Alcorta & Peres, 1998, p. 862)

Although the ISI strategy failed, STI policy building capabilities and a school of thought emerged and were the base for the first regional attempts towards formation and strengthening of a technological base for traditional and new business sectors. It is remarkable that the dependency theory and the Sabato's triangle, the precursor of the triple helix model, were born within the LAST movement. It was clearer during the 1960s than during the 2000s the structural dimension of science, technology and innovation in the economic and social development of LAC countries. We are struck by the fact that a school of thought developed those measures, based on the particular historical, political and social context, and that gave higher importance to the firms as the innovation engine. The intended results were not achieved, but that does not mean that there cannot be opportunities to learn from the failures and experiment with other policy mixes following a similar structural view of development and progress.

2.5. Institutions and the Governance of Innovation

> [*I*]*nstitutions and policies always matter* in all processes of technological learning and economic coordination and change. (Cimoli et al., 2009, p. 338)

For evolutionary economics and the innovation systems approach, institutions are a key factor for moulding technologies and explaining the (differing) dynamism of technological change in different contexts (Nelson & Nelson, 2002). There has however been some debate about how to conceptualise institutions. The definition of institutions as explained by North and used within the SI approach is:

> Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction. In consequence they structure incentives in human exchange, whether political, social, or economic. Institutional change shapes the way societies evolve through time and hence is the key to understanding historical change. (North, 1990, p. 3)

Hence, institutions shape and are shaped by human behaviour and interaction and create a set of formal and informal options and social boundaries for individuals to act. Formal institutions are those created explicitly by humans to regulate social behaviour such as laws, codes of behaviour and conduct. Informal institutions emerge as part of the daily life of human systems as trust and power relationships, implicit codes of behaviour and specific rules set by social groups. In this sense, the concept of institutions is different from that of organisations as formal bodies that have a particular purpose (firms, political parties, churches, universities, etc.) (North, 1990). Institutions provide the framework within which economy operates and together with technology they determine specific innovation pathways. Both formal and informal institutions vary according to geographical settings (global, national, regional, local), industries and sectors, and specific cultural settings. The interrelation between these set of institutions determine the incentives and constraints to innovation processes and the operation of particular SIs (Dosi & Malerba, 1996).

In the same vein, (Nelson & Nelson, 2002) integrate the concept of institutions with technological change and innovation systems. For them, institutions are *social* *technologies* as they shape social rules of game and determine particular modes of governance. As such, effective social technologies promote low transaction costs across organisational borders.

> Indeed, institutions can be seen as the *social technologies* (Nelson and Sampat, 2001) mastering externalities and matching/mismatching patterns between innovative activities, labour training, and socially distributed skills. In turn, the institutions governing such externalities and complementarities do so also governing interaction rules among agents, shaping their beliefs and the information they may access, their 'ethos' and behavioural rules. (Cimoli et al., 2009, p. 343)

It is recognised by most contemporary scholars working on effective operation of market economies that innovation is a fundamental driver to bring economic growth and, therefore, wealth to countries. However, more attention needs to be paid to the role of institutions to support market and knowledge transactions. These institutions evolve with the interaction of market and non-market organisations and the development of technological. (Cimoli et al., 2009)

From this perspective, the process of policy construction needs to take into account existing formal institutions and the actual dynamics of innovation players within domestic and global markets. If a systemic approach is thought to promote and strengthen innovation, STI policies need to be designed and implemented accordingly, taking into account the systemic or lack of systemic nature of the relationship between components of the SIs.

With this purpose, (Morris Teubal, 2002) proposes a strategic perspective to build STI policies which includes the definition of a vision of what is intended with a particular innovation system; a set of strategies to achieve the purpose or purposes; and mechanisms to operationalize the strategies given a predefined priority to the expected results of the policies (i.e. programs portfolio). These strategies should be directed to the backbone of SIs, firms, and the supportive infrastructure to promote innovation (IP systems, financial systems, norms and standards, etc.). "Thus a major theme within an *evolutionary* system of innovation perspective is coevolution between changes in the business enterprise sector and changes in the 'facilitating structure' of institutions and non-business organizations." (M. Teubal & Andersen, 2000, p. 88). However, we argue that this policy cycle, although logical, it is not always feasible, mostly in developing economies with highly hierarchical policy institutions and exploitative economic institutions. Teubal analyses the cases of top-tier countries such as Israel and Korea, with particular institutional settings that made possible the application of such policy cycle. We are inclined to take a different approach towards the construction of inclusive STI policies in developing contexts and in sectors such as agriculture, that are composed by vulnerable populations under poverty conditions. We agree with (Hall & Clark, 2010) on embracing complex adaptive system theory for policy analysis and development.

Innovation systems are composed by humans performing all sort of activities and acting under different narratives and dominant discourses coming from actor's cultural backgrounds and broad social technologies. Under new configurations of innovation processes shaped by formal and informal institutions and guided by embedded routines that innovation actors bring to the system, policy processes should embrace complexity and be resilient in order to cope with unforeseen change (Hall & Clark, 2010).

> Although formal rules may change overnight as the result of political or judicial decisions, informal constraints embodied in customs, traditions, and codes of conduct are much more impervious to deliberate policies. These cultural constraints not only connect the past with the present and future, but provide us with a key to explaining the path of historical change. (North, 1990, p. 6)

The CTA is one of the perspectives that advocates for the active participation of publics in the design and evaluation of hard and soft technologies and therefore in the articulation of political mixes with social problems. With this premise, the aim is to minimise mismatches, wrong investments, and possible social conflict with the introduction of technological change. CTA then acts as a mediation framework for technology policies and technology assessment. (Schot & Rip, 1997)

> CTA is not simply a management tool. CTA can be seen as a new design practice (which includes tools) in which impacts are anticipated, users and other impacted communities are

> involved from the start and in an interactive way, and which contains and element of societal learning. (Schot & Rip, 1997, p. 255)

As it was said in section 2.3, the CTA was a precursor and a base for developing the multi-level socio-technical SI framework and includes dynamics of technological developments with socio-technical mappings of interaction between different actors. Hence, when designing policy, we are analysing complex systems where narratives of different actors embodying differing systems-framings, goals and interests are part of a process traversed by risk, uncertainty, ambiguity and ignorance. What policy decisions and mixes are eventually designed depends on which narratives become dominant, marginal or hidden, and what groups' interests prevail. "[N]arratives are at least partly (and often deeply) about social relationships and political institutional power; about who is responsible for a problem and who has the power to deal with it." (Leach, Scoones, & Stirling, 2010, p. 65). Since innovation implies the mobilisation of different actors, knowledge and imperfect information, it requires the interaction of multiple actors where firms and producers are at the centre and shape the direction of innovation through informal, adaptive and transient arrangements. Most innovations are incremental and happen outside big research centres, the policy-making model have to look at these 'under the radar' innovation processes in order to be adaptive, deliberative and reflexive accounting social construction and inclusive participation. (N. Clark & Chataway, 2009)

Lastly, the evolutionary process of policy construction depends largely on the interaction between governability and governance arrangements. Governability is focused on the governmental organisations, their role and influence on the decision-making processes and guideline development to organise and control the relationships among actors of a determined system. On the other hand, governance privileges the organisation capacity of the system players and their capacity to auto regulate the rules of the game following a cooperative model for decision-making (Lucio-Arias, Salazar, & Durán-Sánchez, 2013). We believe that a balance between governability and governance is necessary to bring together top-down and bottom-up approaches where actors themselves have power of coordination, but enough support from central governments at formal institutional levels to carry on with their practices.

> Governance is a descriptive label that is used to highlight the changing nature of policy process in recent decades. In particular, it sensitizes us to the ever-increasing variety of terrains and actors involved in the making of public policy. Thus, governance demands that we consider all actors and locations beyond the 'core executive' involve in the policymaking process. (Richards and Smith, 2002 in Leach et al., 2010, p. 68)

Therefore, governance in a complex adaptive system determines the innovation pathways followed by innovation players and focalise policies according to particular necessities that are not noticed by traditional processes of policy-making and governability. We agree with (Morris Teubal, 2002) that having a vision, scope, strategies and prioritised programs for policy mixes is ideal, but we highlight that the policy making processes are surrounded by uncertainty, complexity and ignorance. Then, a neat and rational process involving a well-defined portfolio of innovation programs is difficult to achieve.

2.6. Conclusion

In the first chapter of this thesis, we presented the research aim and research questions guiding this thesis. This chapter explored in detail the systemic nature of innovation, the policy processes behind national and sectoral performance based on technological and scientific capabilities and the high relevance of institutions and different governance approaches towards innovation networks. We built the bases for the understanding and analysis of our two main thematic pathways: science, technology and innovation policies development, implementation and outcomes; and understanding of innovation at national and sectoral levels. Since our case studies are centred in Colombia and in the agro-industrial sector, we dedicated one section to analyse the evolution of technological change in Latin America and found an early school of thought formed by Latin American scholars and policy-makers that developed intellectual and practical tools to understand development, structural elements affecting innovation processes, and strategies to generate economic growth and social welfare different from the neoclassical approach.

We identified a research gap in the understanding of the NSI approach in developing and emerging economies. The NSI concept seemed to emerge as a 'boundary object' utilised in different (and often incompatible) ways by a wide spectrum of policy-makers, consultants, and academics. We discovered deep failures coming from a narrow and simplistic understanding of innovation that encouraged the traditional linear thinking of knowledge construction and exploitation disguised as a systemic approach. In order to close this knowledge gap this study applied multiple methods to inquire about the nature of innovation dynamics at national and sectoral levels. Our first question focused upon the implementation of NSI policies; our second research question addressed the innovation support emerging at a sectoral level through comparative sub-sectoral cases; and the third research question brought together the national and sectoral studies from a top-down and bottom-up approach.

This literature review sought to provide a theoretical foundation to answer this questions by building bridges between the national and sectoral innovation systems approaches and complementing these generic frameworks with a complementary tradition rooted in earlier Latin American theories geared towards the promotion of competitiveness at industrial levels using a mixture of macro economic and political measures from the 1960s onwards. We enriched the former approaches by including sociological and historical analytical lenses to capture the essence of innovation dynamics in socio-technical systems surrounded by uncertainty, complexity and ambiguity. The role of institutions and governance of innovation systems is crucial to explain particular pathways and to shape future intended trajectories in order to prevent undesirable lock-in. This literature review provided us with the necessary theoretical and analytical tools to propose a top-down and bottom-up framework to study developing economies.

In light of these theoretical blocks, we analysed our data and presented a discussion of our major findings. We also found that the generic NSI model and the SSI approach can be enhanced by giving particular attention to socio-economic and political institutions that are context-dependent, so they might be strengthened by integrating explicitly historical and sociological studies.

3. METHODOLOGY AND RESEARCH DESIGN

"No study conforms exactly to a standard methodology; each one calls for the researcher to bend the methodology to the peculiarities of the setting." (Miles & Huberman, 1994, p. 5)

3.1. Introduction

This is a qualitative study that seeks to develop a particular understanding of the factors influencing innovation processes in selected case studies within the Colombian context. We follow a 'systems thinking' approach to formulate and give answer to the research questions. Since the research aim and questions oriented our sight to the study of innovation systems, as explained in Chapter 1, our analysis is focused on the so-called systems structure, functions and purpose.

The qualitative nature of the study is demonstrated by the following: it is conducted through an examination of the 'field' where the research object lays; it presents a systemic account of the context under study; it captures data through a process of empathetic understanding of key actors; attempts to give an explanation of the way a particular issue is understood by different groups of action; and the main results are presented in the form of statements assembled, sub-clustered, and broken into semiotic segments (Miles & Huberman, 1994). We conducted 50 interviews, 30 in the first data collection phase and 20 more in the second phase. We also conducted two specialised focus groups, one in each phase, and a deep documentary analysis of selective public documents.

Adopting a qualitative view of the innovation processes in particular case studies allows us a richer and deeper look at what the systems of innovation are in 'real life', beyond the traditional statistics and assessments based on quantitative studies. Given the complexity of human systems, we needed a qualitative approach to capture the richness of the phenomenon under study, so we could provide thick descriptions and analyses of socio-technical innovations according to people's lived experiences.

The methodology adopted emerged over two research phases to understand innovation using a top-down and a bottom-up approach. The existence of two phases was not intended from the beginning of the project, but emerged after review of initial findings about the operation of the Colombian NSI that highlighted a schism between the national policy framework and the circumstances of industrial players. Addressing the latter necessitated a second phase of data collection focusing on industrial sectors. Accordingly, we selected one macro case study (Colombia) and three meso case studies (coffee, flower, sugarcane sectors). We firstly conducted an exploratory study of the Colombian STI policies through documentary analysis, followed by focus groups and interviews as main research methods.

The research questions also evolved over the research. Once we went to field and found an intricate set of relationships that showed the complexity and uncertainty in innovation processes, our understanding of the phenomenon under study was enhanced and key features emerged that gave us feedback and reshaped our research questions. In that sense, our research design remained flexible during the whole process.

> Your aim is to come up with a final set of research questions, which are relevant to the purposes of the study (which may, or may not, have been renegotiated along the way), which show clear linkage to theory (from whatever source it has obtained) and for which the sampling has been such that the data collected and analysed provide answers to those questions. (Robson, 2002, p. 83)

In the following sections, we will explain the research design process, how we collected and analysed data and how we finally built a solid understanding to answer the research questions posed, in order to fulfil the research aim.

3.2. Research Strategies and Epistemological Assumptions

3.2.1. Research Questions

The process of defining the nature and scope of a research project is done through the specification of research questions. Following (Blaikie, 2010, p. 60), there are three kinds of questions: *What* questions are concerned with descriptions to discover the characteristics and patterns of a social phenomenon; *Why* questions are directed towards finding causes, reasons, existence of characteristics and regularities for the explanation of a particular phenomenon; and *How* questions are concerned with strategies and mechanisms to produce change, practical outcomes and intervention (Blaikie, 2010).

Even though our main research questions do not start with 'what' or 'why', they are within these two groups of questions described above. The research aim is divided into two main enquiries: to understand the nature of innovation promoted from a national institutional setting, and to understand and analyse innovation dynamic complementarities through the study of specific sectoral dynamics.

We decided to focus our study on Colombia, given our personal interest to expand the current research on innovation studies and science and technology studies in countries still in an emergent phase, and our interest to strengthen the knowledge base related to innovation dynamics of the Latin American region. Besides our personal interest, the study responds to a call from academic scholars to enhance evolutionary innovation studies with more case studies, particularly in emerging and developing economies (Kaplinsky et al., 2009; Lundvall, Joseph, et al., 2009; Metcalfe & Ramlogan, 2008).

The final questions that guided us through the first research phase and emerged as part of our research analysis and shaped the second phase are presented below. Recommendations for policy-makers and practitioners are also expected to emerge in attempting to answer internal and subsidiary forms of *how* questions:

1. *How has Colombia attempted to establish a national system of innovation?*

This question involves a descriptive account of the Colombian National System of Innovation, since it is within this formal framework that the STI policies have been developed. This question has two subsidiary questions:

- How has the process of development and implementation of STI policies unfolded?
- What has been achieved?

Our initial questions were focused on the promotion and institutional setting of innovation at the national level. After performing an exploratory study of the Colombian innovation public and official documents, we found that there was an explicit acknowledgement of the existence of a National System of Innovation. This focused our attention on examining the so-called national system. With the main and subsidiary questions, we established the bases to explore our object of study, the Colombian NSI, and the political institutions supporting its implementation, and outcomes. We also explored diverse accounts of the strengths and weaknesses of the STI policies and attempted to present a richer perspective of the relationships between social, political and economic institutions interacting in the social construction of the complex intended national system of innovation. This question was answered in Chapter 4.

2. *What are the main innovation dynamics differences in the Colombian coffee, flower, and sugarcane sub-sectors?*

As we began to analyse findings from the study of the implementation of innovation policies, we identified a gulf between those actors closely associated with NSI policy, who were broadly concerned with promoting the conduct and exploitation of public sector research, and the perceptions of industrial players who perceived these activities as far removed from their world. Therefore, we engaged in a study of sectoral innovation dynamics to understand and identify critical factors triggering competitiveness and technical change, according to the perception of the sectoral players.

An important question arose regarding which industrial sector(s) to examine. After a deep documentary analysis of Colombian strategic public documents, we found a broad diversity of sectors identified as 'strategic' by different national departments, ministries, public missions for science and technology and long-term planning exercises. Each document presented a different list of sectors in which Colombia, as a country, should be a regional leader first and then, a world leader. Initially we selected agriculture, biotechnology and biodiversity as our possible case studies, but upon further exploration of the sectors, found that there was rather little biotechnology R&D and commercialisation and no identifiable exploitation model for biodiversity – which lead to further consideration of agriculture as a sector to study.

Colombia has been traditionally recognised as an agrarian country, with vast wealth in natural resources. Between 2000 and 2009, the Agro-industrial sector accounted for approximately 30% of Colombia's GDP growth. Agriculture is also a critical sector in social terms; representing 67% of formal rural employment in the country[7]. The sector is not only strategically important for Colombia, but for other developing countries as well, as is explained by Clark: he describes agriculture as "a context that has tended to be sidelined in the standard literature dealing with innovation and technological change…and yet for poor developing countries it is precisely the agriculture sector that is so crucial" (N. Clark, 2002, p. 353). For these reasons, we chose to undertake an in-depth study of the innovation dynamics of the agricultural sector in Colombia.

Once we defined the agriculture sector as our case study, we encountered a wide diversity within the agricultural (sub) sectors. There are 37 sub-sectors or production chains; each of them with completely different dynamics and economic activities (i.e. livestock, staple, seafood, flowers, aromatic plants, etc.). After an extensive research of public documents, statistics and interviews, we discovered that the three most successful production chains - in terms of productivity and exports representation - were coffee, cut-flowers and sugarcane. We also found that these three production chains also had a strong research element, each possessing their own research centre and strong producers association. We identified the oldest research centre (coffee), the newest research centre (flower), and one successful research centre just in the middle time of the creation of these other two (sugarcane).

The subsidiary questions were:

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[7] According to the European Union in its report for the European Regional Development Fund about the agriculture sector in Colombia.
http://observatoriointernacionalizacion.igape.es/index.php?option=com_k2&view=item&task=download&id=18_ff284a1d1024d8d89bd4eedeac445742&lang=gl

- How formal and informal institutions have affected the innovation pathways in the industries under study?
- What barriers and drivers to change have been crucial to generating alignment between actors and promoting effective knowledge generation and exploitation?
- What does the study of particular sub-sectors in addition to the Sectoral Innovation Approach tell us?

These further questions directed our study towards the specific innovation pathways of each of the sub-sectors, the role of formal and informal institutions in the innovation dynamics and the transit between knowledge generation and exploitation. With our case studies we finally assessed the analytical power of the SSI approach for analysing complex sub-sectoral systems.

3. *How are top-down and bottom-up innovation dynamics within sectoral levels developed and enhanced?*

This is an analytical question that brings together our two thematic pathways, the policy study and the innovation study. With the first question, we captured the national landscape with its specific and general enabling policies to promote science, technology and innovation in order to make Colombia more competitive in regional and international markets. We studied the nature, weaknesses, strengths, opportunities and challenges of the Colombian NSI and provided a critical glance of the construction of national strategies to boost innovation at the sectoral level.

With our second question, we examined the actual dynamics of three particular sub-sectors, analysed their knowledge creation and exploitation dynamics, the relationship between firms and non-firms organisations, and different institutional arrangements related to innovation practices. Finally, with this question we examined the existence of synergetic relationships between macro, meso and micro levels.

We sought to have a broader picture of innovation by adopting a top-down and bottom-up approach to understanding how national innovation strategies can be embedded in firms and industries. By exploring the composition of the national, sectoral and sub-sectoral systems in the light of their purpose, the means or mechanisms available to execute innovation strategies and the financial and human resources devoted to achieve the expected goals, we aimed to go beyond a superficial understanding of innovation guided only by macro policies or the sub-sectoral perception separated from the sectoral and national realities.

3.2.2. Research strategies and approach

In this section, we specify the research strategies and approach adopted, since research strategies differ in their ontological assumptions, starting-points, execution, use of concepts and theories, styles of explanation and understanding, and the status of their products.

In order to acquire an understanding of our object of study, the so-called systems of innovation, and the social phenomena of the relationships between main actors and drivers of innovation, we used an inductive[8] strategy to generate the descriptive base of our study. Once we engaged in a deep examination of the characteristics, dynamics, pathways and the macro, meso and micro mechanisms operating to keep the functional structure of the systems, we employed a retroductive[9] research strategy.

We adopted a critical realism epistemological perspective, which suggests that social practices, rules and realties can only be understood according to their specific context and within different layers of social reality. We explained before that we use the systems thinking approach in the study, which recognises that we are dealing with open systems that are constantly evolving and changing their structural and functional configurations. Our focus was to identify the factors that are coevolving for our particular case studies as part of a broader body of realities (Robson, 2002). This posture does not mean that we do not have a social account of the construction of reality. On the contrary, our study is rooted on the STS tradition, and we commenced our research acknowledging that science and technology are socially

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[8] “The aim of the inductive research strategy is to establish limited generalizations about the distribution of, and patterns of association amongst, observed or measured characteristics of individuals and social phenomena.” (Blaikie, 2010, p. 83)

[9] “The aim of the retroductive research strategy is to discover underlying mechanisms that, in particular contexts, explain observed regularities.” (Blaikie, 2010, p. 87)

constructed; they are active so they produce results that are socially interpreted and used; and therefore the products of science and technology are not themselves natural (Sismondo, 2011).

> At best, our outcomes will be suggestive rather than conclusive. They will be plausible, perhaps even convincing, ways of seeing things –and, to be sure, helpful ways of seeing things- but certainly not any 'one true way' of seeing things. (Crotty, 1998, p. 13)

We mainly use case studies understood as:

> [A]n empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident. The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, as an another result benefits from the prior development of theoretical propositions to guide data collection and analysis. (Yin, 2003, p. 13)

The macro case we selected is Colombia as the social unit where we study innovation processes and evolutionary dynamics. Once we started to explore the Colombian NSI, we engaged in the study of embedded cases at the sectoral level in order to have an understanding of the 'real world' dynamics between innovation players in action. As (Miles & Huberman, 1994, p. 26) express, "multiple cases offer the researcher an even deeper understanding of processes and outcomes of cases, the chance to test (not just develop) hypotheses, and a good picture of locally grounded causality." The multiple case studies were selected and built upon the findings of the original case study (National setting), which made us seek to complement the first study by focusing on sectoral cases not originally covered (Robson, 2002).

The selection of the three cases and undertaking of a comparative analysis to capture innovation dynamics in the agriculture sector followed specific criteria: (1) strategic sub-sectors that have had a strong pattern of growth; (2) sectors that have been strongly integrated into global markets and that represent an important participation in the national GDP; (3) traditional sectors that have evolved to include technological change to further up their competitiveness both in the domestic and international market and that highlight industrialisation processes in the Agro-industrial sector; and (4) labour intense sectors that represent large employment opportunities for the poor.

In the next section, we explain the research phases, methods and reflexivity that we employed in order to keep our study valid and reliable.

3.3. Data Collection and Data Analysis

This section contains the data collection methods and analysis strategies we used in our research. We decided to present both data collection and data analysis in the same section, since we developed an iterative, interactive and continuous process of data collection and analysis, so both processes informed and feedback the next stage of the other.

> "As data collection proceeds, further episodes of data reduction occur (writing summaries, coding, teasing out themes, making clusters, making partitions, writing memos). The data reduction/transforming process continues after fieldwork, until a final report is completed." (Miles & Huberman, 1994, p. 10)

Therefore, our analytic practices were informed by the data gathering and vice versa, which took us to divide our study into two thematic branches that were developed in two research phases. With both of them we followed the same analytical approach. We followed what (Miles & Huberman, 1994, p. 9) call "a fairly classic set of analytic moves" for analysing the data, which includes the following simple but powerful steps, proficiently summarised by (Robson, 2002, p. 459):

- Giving codes to the initial set of materials obtained from observation, interviews, documentary analysis, etc.;
- Adding comments, reflections, etc. (commonly referred to as 'memos');
- Going through the materials trying to identify similar phrases, patterns, themes, relationships, sequences, differences between sub-groups, etc.;

- Taking these patterns, themes, etc. out to the field to help focus the next wave of data collection;
- Gradually elaborating a small set of generalizations that cover the consistencies you discern in the data;
- Linking these generalizations to a formalised body of knowledge in the form of constructs or theories.

NVivo was used for analysing the data and organising all the information collected through our different research methods, which included documents, audio files of the interviews, memos, notes, and minutes from the specialised focus groups. We conducted the coding process using the software utility for coding. In that way we could keep all our sources in the same project and codified according to our analytical process. From the beginning of the project, we kept a journal with all the steps we followed, to include sources and codes, and also to keep our research memos within the project.

Our research methods included documentary analysis, specialised focus groups and interviews. In the first research stage, we used documentary analysis, a focus group and semi-structure interviews. In the second stage, we conducted another focus group and more semi-structure interviews. All of the information gathered during the data collection was in Spanish. We recognise the problems translation can bring, but since data was collected in Colombia, and the national language is Spanish, we conducted the interviews and focus groups in the local language.

Most of the interviews were recorded. Only two interviews were not recorded because we did not have permission from the interviewees. At the beginning of every interview, we asked for consent to record and we asked if we could use the names of interviewees for the research project, always providing context for their comments. We did not get permission to use the names in three cases.

For transcribing the interviews we used Express Scribe, a specialised software that allowed us to use a transcription pedal and transcribe the text in a more comfortable and quick way. We kept the original audio interview files, a copy in the transcription software and another copy in the NVivo project. When we moved the files to NVivo, we synchronised the audio with the transcription, so we could go to specific extracts of the interviews not only in text but also in audio. Although this process required more time, we decided to transcribe all the interviews, and include them in NVivo with audio and text synchronised in order to add reliability and validity to our research (Robson, 2002). However, we did not translate the interviews from Spanish to English, given the low analytical advance this would have given to the research. Instead, we translated the extracts of the interviews we used along the chapters. For every source that was in Spanish and we used in quotations, we translated it into English.

We used memos to analytically interpret data, and to explore, explicate and find emergent patterns in our data as we were codifying our sources (Bex Lempert, 2007). We also wrote our own reflections about the on-going data collection process including: what we considered the data was telling us; how we felt during the data collection process, according to the person or persons that were part of the interview or focus groups; and subjectivity and judgements we had while conducting the data collection. We used a free narrative style, in first person, for keeping record of the whole process and to be aware of our own bias and limitations.

The advantages of using NVivo were: to have an organised and single location storage system; quick and easy way to access all the sources and the ability to codify them directly from the sources without generating many copies. We could also use quick search, reports and graphs to visualise our data and finally it helped us to develop consistent coding schemes. In terms of disadvantages, NVivo required training to use the software and therefore we had to invest time and financial resources to get the training and buy the software license. There was also some level of confusion at different times in using different tools of the software; loss of focus at times with the data analysis; and loss of computer power and performance from using the NVivo software, which interfered with our research analysis process (Robson, 2002).

Finally, given the scope of the research - which focuses upon highly aggregated processes rather than individual respondents - there were no particular ethical issues; insofar as the data collected did not impinge upon the concerns of individual participants or researchers. We accessed public documents and all interviews, and focus groups were carried with consent of participants. We asked for permission to record and use the interviews and focus groups. We also asked for clarification of information when necessary, before using quotations in the thesis.

3.3.1. First Phase

Our data collection was divided in two stages. The first stage was oriented by our first research question to understand and analyse the way in which Colombia has attempted to build a National System of Innovation. This question also represents, in what would be our first thematic pathway, a policy study on innovation at a national and sectoral level.

Throughout the study, but especially during the first phase, we triangulated our data in order to preserve the validity and reliability of our research results. We used data triangulation through the comparison of data found in public reports and government documents, and information gathered through interviews and specialised focus groups. We also triangulated our findings with the theoretical frameworks we used. In this sense, triangulation was used as an epistemological claim to help us find structural and functional settings of the innovation systems under study and their institutional settings (Denzin, 1988).

3.3.1.1. Documentary Analysis

The first method that we used in the data collection was documentary analysis. We selected relevant public documents related with the promotion of innovation at national and sectoral levels and where strategies and assessment of the Colombian STI policies were outlined. In the selection of documents, we followed (Scott, 1990) criteria for assessing the quality of documents: authenticity (the document is genuine and has a known origin); credibility (the document has not been distorted); representativeness (the document gives an extensive account of the object of study); and meaning (the document is clear and comprehensible).

For analysing the documents, we adopted a ‘critical stand’ to examine the content and postulates of the official and report documents (Jupp & Norris, 1993). We read the documents in the light of their social function and their structural position within the political institutions and innovation systems. We were aware of their role as normative documents and the power and control they exert, giving prevalence to certain groups over others and as part of a social negotiation. They reflect a particular ideology constructed through an evolutionary process and are relevant according to different stages in the social evolution. In that sense, we recognised that they act as a legitimation instrument of intended initiatives rather than on-going realities. Therefore, we did not take for granted what is said and exposed in them; that is why we planned to triangulate the analytical categories that we built in their analysis, with information gathered from interviews and specialised focus groups. Finally, we presented in our research alternatives, definitions, explanations and solutions to the existent documents, not only challenging their statements, but also offering a grounded account of the reality perceived by key actors.

We examined in-depth fourteen documents with the following characteristics:

Type of Document	Purpose of the document	Number of documents
Science, Technology and Innovation Laws	Promote, orientate and regulate the development of national initiatives and programs for science, technology and innovation. Provide a legal framework for the creation and operation of a NSI	2
National Council of Social and Economic Policy (CONPES)	Highest body of coordination for economic policy in Colombia. It provides the guidelines for the macro policies of the country.	6
Special missions and planning exercises promoted by successive governments	Provide council, guidelines and action lines to promote science, technology and innovation integrated to other national systems as the industrial and education ones.	3
Decrees	Legislative decrees to provide instruments to materialise law dispositions and sometimes change dispositions of the general laws.	3

Table 3.1. Documents analysed in the first stage of the research

Source. Made by the author

We included the documents in NVivo and codified them guided by the principles of the SI approach, institutional theory and the principles of the Latin American Structuralism. We produced a total of 33 nodes codified according to the parameters explained earlier in this section. The nodes were codified according to three main analytical categories: Institutions, policy processes, and systems structure and functions. We also generated two complementary nodes: one with all the references we found of the Agroindustrial sector in the documents analysed; and other with information that helped us to have analytical bases to understand the political institutions, definitions of central concepts as innovation, competitiveness, entrepreneurship, science and technology, and with diagnosis about different stages of the NSI. A summary of the coding process in the NVivo project is presented in Appendix I. We divided the nodes for documentary analysis; and interviews and focus groups in different folders.

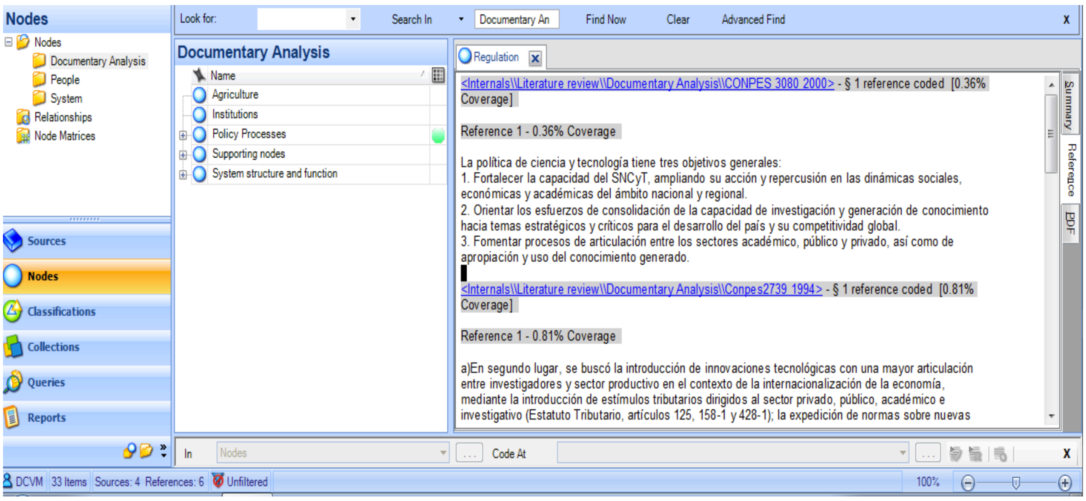

Figure 3.1. Documentary Analysis Categories in NVivo

Source. Made by the author.

3.3.1.2. Interviews

The documentary analysis was part of an exploratory phase in our research design, so we could choose other research methods to triangulate the information and have a broader account of the phenomenon under study. Given the political nature of the innovation processes and the importance of formal political institutions in the definition of national strategies, we opted for doing semi-structure interviews (see figure 3.2.) with elite actors[10] in academic, public, industrial and mixed-nature institutions that are or were part of the Colombian NSI and that could provide us with a context and evolution of the STI policies in Colombia, so we could have perceptions not explicitly mentioned in the official documents. In order to preserve validity and reliability in our interviews, we were aware of the constraints the interviewee could have as being part of a particular organisation; we were aware that our interviewees did not have the obligation to be objective and tell us the truth; and sometimes they could exaggerate in order to highlight their own role in a determined situation. Before conducting the interviews we investigated the role of the interviewee in the Colombian NSI, we probed and followed-up answers that we felt could be expanded or were unclear; and we remained impartial during the interviews, so the interviewees would feel safe in their answers (Berry, 2002). Again, we found that the best type of interview was semi-structure with open-ended questions.

> For projects where depth, context, or the historical record is at the heart of data collection, elite interviewing using broad, open-ended questioning might be the best choice. (Berry, 2002, p. 682)

Jointly with the literature review, we used the inputs of the documentary analysis and the first specialised focus group to design the thematic branches to follow in our semi-structured interviews. With the interviews, our aim was to have a reconstruction of events that we could not find in secondary sources. As suggested by Mason, "Qualitative interviewing therefore tends to be seen as involving the construction or reconstruction of knowledge more than the excavation of it". (Mason, 2002, p. 63)

[10] We define elite interviews as such conducted with bureaucrats, politicians, and people in high administrative positions that have an overall view of the landscape and participate or have participated in the definition of public policies and instruments. (Aberbach & Rockman, 2002)

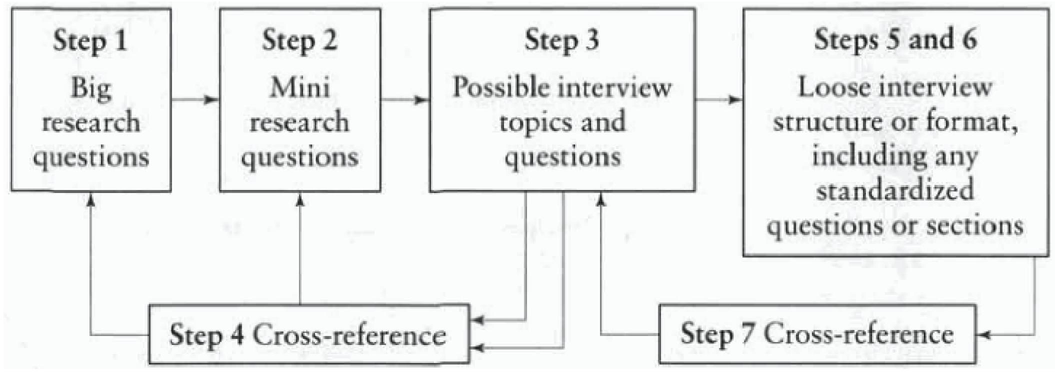

Figure 3.2. Structure for preparing semi-structure interviews

Source. (Mason, 2002, p. 72)

The thematic branches included in a base questionnaire were:

- Structure and functioning of the national system of innovation
- Institutions
- Organisations as key actors
- Learning cycles and knowledge transfer, adoption and validation
- Policy framework

We started with thirty initial questions distributed over these themes and, according to the expertise of the interviewee and the course of the interview we emphasised some of the themes, skipped some questions, or added questions that were not initially foreseen. Since "elites specially –but other highly educated people as well- do not like being put in straightjacket of close-ended questions" (Aberbach & Rockman, 2002, p. 674), we had protocols to probe and followed-up questions. According to our previous knowledge about the topics discussed in the interview and the experience of the interviewee, we sometimes chose to have a deeper account of a specific theme, rather than cover all the thematic branches we had in our base questionnaire.

We selected actors in public organisations that have a direct relationship with the design, implementation and assessment of STI policies; organisations in the private sector either representing industrials, or part of firms; academics doing research on topics related to innovation studies and science and technology studies in Colombia;

and people working in mixed public-private organisations in charge of promotion of innovation both at regional and national levels. The reason behind choosing actors in high positions within STI organisations was to have a holistic view of how STI institutions have evolved and prevent the partial and fragmented glance that actors working in specific departments could have about innovation programs. Once we found that Colombia was following the NSI model, we selected actors in the aforementioned categories, in search of having perspectives from key actors in the main blocks of the NSI.

The first stage of this research was focused on the national level, resulting in interviews with those actors representing national organisations or doing research at a macro level. The interviews were conducted between December 2011 and May 2012 for the first phase of the research. We made initial contacts with influential people in different sectors, and from these contacts we generated more contacts that were insightful for the purposes of our research. In this sense, we used the snowball sampling strategy, which "identifies cases of interest from people who know people who know what cases are information-rich." (Miles & Huberman, 1994, p. 28)

Table 3.2 details the number of interviews conducted by class of interviewees:

Group	Number of Interviews
Public Sector	13
Private Sector	4
Research and Academic Sector	8
Mixed public/private organisations	5
Total	30

Table 3.2. Distributions of interviews conducted in first stage of research

Source. Made by the author

As we explained before, most of the interviews were recorded and analysed using NVivo. The interviews that were not recorded because the interviewee did not authorised us, had notes taken during and after the interview, capturing the most important information for our research questions. We did not dismiss any of the interviews we conducted and all of them were transcribed and included in NVivo for the codification process.

The codification process included nodes in six analytical themes: policy processes, actors, agriculture, institutions, supporting nodes and systems of innovation, as can be seen in figure 3.4. Agriculture emerged as an important category since the interviewees made explicit references about the sector, mainly relating innovation systems to it, since there is account of the National Agriculture Research System as the first innovation system in the country. These findings helped us also to define the Agroindustrial sector as our case study for the second phase of the research.

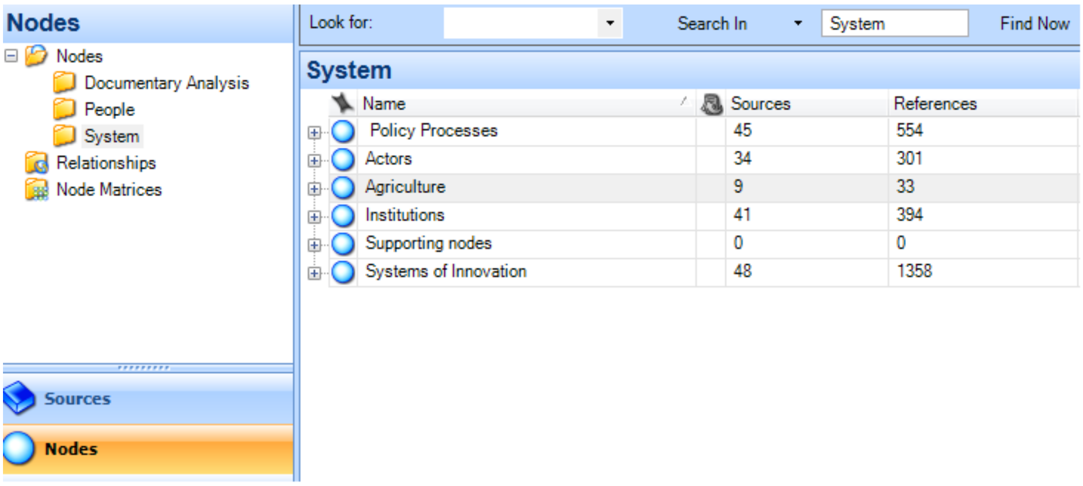

Figure 3.3. Analytical information categories interviews and focus groups

Source. Made by the author

3.3.1.3. Specialised focus groups

We use the term, *specialised focus groups*, to denominate a guided small-group discussion between specific and strategic actors that could inform particular parts of our research and that by interacting, can produce very different results than having a one-to-one conversation with each one separately. Although we did not follow an *Integrated Assessment* strategy in our research, we used the focus group as a collection data method in the sense (Dürrenberger, Kastenholz, & Behringer, 1999, p. 342) use it for bridging science, technology and innovation with policy: “In the context of IA, focus groups may receive expert information about complex policy problems and associated policy options."

The first data collection method that we used after documentary analysis was a specialised focus group with key innovation actors in the public, private and academic sectors of the so-called Colombian NSI. Through the results of this focus group, we refined and nurture our semi-structure interview guidelines.

The focus group was conducted in Universidad del Rosario in Bogotá in December 2011. Since we kept the academic filiation with the university, we received institutional support (university facilities). Although we had problems with the workshop date (e.g. that day there was a national protest and all people arrived to the central downtown square, very near Universidad del Rosario were the workshop was, so arriving and leaving was very difficult that day), there was a good assistance. There were eleven participants in total: 4 from the academic sector, 4 from the public sector, and 3 from the private sector.

The topics we covered in our focus group were: identification of the major barriers that diminish the effectiveness of policies for STI; Colombian NSI future visions through the construction of ideal scenarios; linkages and connections between innovation players in the NSI; and knowledge flow between firms, universities and government.

This was an extraordinary opportunity to have the input of key players of the three sectors to have a collective construction of strengths, weaknesses and future ideal scenarios that participants had in their minds for the Colombian NSI. The focus group took place between 8:00 a.m. and 12:00 a.m. so in order to make the most of the time and presence of the assistants and to avoid that certain participants centered the discussion, excluding the inputs of others, we designed activities were everyone could have a representation of their own voice and thoughts. An extended account of the activities and results of the focus group can be found in Appendix II.

3.3.2. Second Phase

As explained in the introduction of the chapter, the second stage of data collection of this research took place after the collection and on-going analysis of the first phase, described in the previous section. Once we defined that we would examine in-depth the agriculture sector, we found that the sector is composed by 37 sub-sectors, each one very different from each other. Thus, we defined that we would focus on three case studies: coffee, flower and sugarcane production chains.

3.3.2.1. Specialised Focus Groups

We followed up with contacts from the first stage who had a close relationship with the agriculture sector to define our sources for the sub-sectoral cases. In the second phase, we followed the same logic that in the first phase. We conducted a specialised focus group, but this time with sectoral actors, academic, and policy actors. There were eight participants, out of eleven that confirmed their assistance.

There were five presentations followed by a discussion that we directed according to a specific set of questions we had for the participants. For this second focus group, we invited some of the participants that were in the first focus group and new participants representing the sectoral case studies. In this opportunity we deliberately planned to allow the participants to show freely their results towards innovation strategies to the assistants and based on the concrete initiatives they presented, we planned a guided discussion towards our research topics. This focus group followed the same logic than the first one, and lasted four hours, from 8:00 a.m. to 12:00 p.m. and was conducted in May 2013. For designing and preparing it, we used results of the analysis of the first stage of data collection.

3.3.2.2. Interviews

We conducted semi-structure interviews as well for the second research stage. Our interest in this second phase was to have a deep knowledge of the innovation dynamics of our selected case studies. Guided by a previous research of general characteristics of the production chains, we conducted 20 semi-structured interviews to producers associations, firms, academics, and public servants related with the activities of the coffee, flower and sugarcane chains.

We detail the distribution of the interviews in table 3.3:

Production Chain	Number of Interviews	Type of actors
Coffee	6	Firm, producers association, research centre
Flowers	5	Firm, producers association, research centre
Sugarcane	9	Firm, producer association, research centre

Table 3.3. Interviews second phase data collection

Source. Made by the author

We needed to travel to the locations of the research centres and main firms; for sugarcane, Valle del Cauca; for coffee, Antioquia; and for Flowers, Cundinamarca. We followed the same structure and logic in the first phase for collecting and analysing the data, and included our interviews and codes in NVivo. We built three main information categories for the agriculture sector: production chains, SNIA (National Agroindustrial System of Innovation), and supporting nodes (figure 3.5).

Agriculture	9	33	10/09/2012 01:56	DCVM	18/01/2015 21:13	DCVM
Production Chains	0	0	18/04/2015 17:51	DCVM	18/04/2015 17:51	DCVM
Added Value	2	6	10/06/2013 00:25	DCVM	06/05/2014 22:59	DCVM
Coffee	8	133	07/03/2013 16:57	DCVM	17/06/2013 23:16	DCVM
Comparison between sectors	5	7	14/06/2014 11:21	DCVM	23/01/2015 16:59	DCVM
Flower	9	149	07/03/2013 16:55	DCVM	18/04/2015 17:51	DCVM
Sugar Cane	11	245	07/03/2013 16:58	DCVM	22/07/2014 15:31	DCVM
SNIA	5	15	11/03/2013 14:38	DCVM	04/07/2014 13:16	DCVM
Corpoica	7	22	08/05/2013 19:31	DCVM	18/01/2015 20:03	DCVM
Cultural setting	5	11	12/06/2014 18:17	DCVM	18/01/2015 19:43	DCVM
Formal vs Real System	7	33	12/06/2014 00:33	DCVM	30/01/2015 17:15	DCVM
Functional dynamics	7	27	08/05/2013 18:53	DCVM	18/01/2015 14:20	DCVM
Funding for Agriculture	12	32	08/05/2013 14:26	DCVM	18/01/2015 23:41	DCVM
Human Resources	2	4	14/07/2014 17:40	DCVM	21/07/2014 21:25	DCVM
Intellectual Property	7	12	03/06/2014 17:27	DCVM	08/07/2014 12:07	DCVM
Knowledge transfer, technical assita	12	55	14/06/2013 18:25	DCVM	30/01/2015 17:16	DCVM
Political setting and special program	7	19	14/06/2013 18:19	DCVM	22/07/2014 01:09	DCVM
Relationship between actor SNIA	13	49	08/05/2013 18:12	DCVM	18/01/2015 23:41	DCVM
Research	7	31	10/06/2013 00:46	DCVM	18/01/2015 23:45	DCVM
Strategy	5	46	11/03/2013 17:06	DCVM	16/07/2014 19:11	DCVM
Strenghts	3	4	08/05/2013 18:33	DCVM	22/12/2013 21:48	DCVM
Structural elements	17	42	08/05/2013 19:34	DCVM	18/01/2015 23:53	DCVM
Successful cases	5	12	10/06/2013 18:15	DCVM	18/01/2015 23:34	DCVM
Unions and associations	4	6	14/06/2013 18:20	DCVM	16/07/2014 14:52	DCVM
Weaknesses	8	32	08/05/2013 18:37	DCVM	18/01/2015 23:50	DCVM
Supporting nodes	0	0	18/04/2015 17:49	DCVM	18/04/2015 17:49	DCVM

Figure 3.4. Agriculture analytical information categories

Source. Made by the author

3.4. Methodological Limitations

In conducting the study we were aware of the need to make a number of practical choices. For example the selection of Universidad del Rosario as the locus for conducting both of the focus groups did have implications for the research. The participants identified the study as partly supported by Universidad del Rosario, and although this gave us support at an academic level and facilitated participation, the research could be seen as not being independent from organisational interests.

We also acknowledge that we did not have direct contact with producers and farmers. This left a part of the story out of the results presented in this study. However, time and resource constraints forced us to determine realistic boundaries about the research that could be undertaken, and we decided that our research would have a limited scope that would not go down to the individual level. The micro level for this study, in studying the dynamics of innovation was therefore firms and producer associations.

The distribution of interviews and participants in the focus groups depended on the contacts that we could find and that finally agreed to participate in the research. It would have been desirable to conduct more interviews with actors in the private sector and we are aware of this limitation. However, to lessen the impact of this constrain, we selected key actors part of industrial and producer associations.

One limitation in the flower production chain data collection was the high secrecy the sector has to give any kind of information. It was very difficult to have access to the interviewees and we had to turn to personal contacts and wait for a long time to get the first interview that subsequently would give us more contacts to talk to. This affected the number of interviews we could conduct in this specific case study.

3.5. Conclusion

In the introduction of this chapter, we explained the nature of this research as qualitative and our research strategies and epistemological assumptions related to data collection and analysis. Through multiple case studies, we shifted from a vision centred on a top-down level, as emphasised in the NSI approach, towards a bottom-up approach to understanding the nature of innovation processes at sectoral levels. With our multi-case sampling, we added confidence to our research results and conclusions; initially thinking that we were analysing similar cases, but after performing our data collection we found that they were more contrasting than similar in several respects. In qualitative research samples are purposive rather than random, that is why we set specific criteria to select our cases and developing our comparative analysis.

Also, we worked with a relatively small sample of people, since we were interested in having an in-depth investigation of the path-dependence and coevolution of innovation dynamics and therefore we selected specific groups of relevant actors (Miles & Huberman, 1994). Finally, we showed how the research was carried out systematically, following a specific research strategy and going through dedicated and complementary research phases of exploration, analysis and triangulation. We critically verified our observations and conclusions with other experts in the field and with codified knowledge about the Colombian systems of innovation. Through recurrent validation with our informants, we could be sure that we were portraying their visions and statements in context and without manipulation of the information. Finally, we preserved ethics, ensuring that the interests and concerns of those taking part in the research were safeguarded (Robson, 2002).

4. FIRST THEMATIC STRAND: SCIENCE, TECHNOLOGY AND INNOVATION POLICY STUDY

4.1. Introduction

Consistent with the regional development, the application of the NSI approach in Colombia was preceded by the pioneer input of Latin American scholars, who spotted early, the crucial impact of S&T in the economic and social development of the region. Therefore, this chapter builds upon the regional context and evolution of the Latin American Structuralism, and provides a detailed account of how the Colombian STI policies have been developed and implemented from 1968 to 2011.

The third section of this chapter is focused on the development of a national framework to build STI policies. Since all strategies, programs, projects, and mechanisms for promoting STI are embedded within the Colombian National System of Innovation[11], we investigate the evolution of the so-called system. In section 4.4. we study the results obtained through the various explicit and implicit STI policy guidelines. This does not imply that there is a linear and single process from design to implementation and from implementation to expected outcomes. As we showed in section 2.5. (Institutions and the Governance of Innovation), policy construction is a complex practice that is always under constant negotiation between different stakeholders.

Finally, in section 4.5. we present the structure and development of the S&T agriculture system, and how the coffee, sugar cane, and fresh flower sub-sectors have

[11] In this thesis the terms National System of Innovation (NSI) and National System of Science, Technology, and Innovation (NSSTI) are used indistinctively. Decree 585 of 1991 declares the existence of a National Council of Science and Technology (NCST), it mentions explicitly the existence of a National System of Science and Technology, and creates National Program councils for every strategic sector. But it is until CONPES 2739 of 1994 that innovation is mentioned as a key element having a whole chapter about innovation, competitiveness, and technological development. In 1995 the NCST decreed the existence of a NSI as a as a collective and interactive learning model with accumulation and appropriation of knowledge, that involves various actors associated with technological development, production and marketing of goods and services within a process of continuous pursuit of sustainable competitiveness and improvement in the quality of life of the population. After that, in CONPES 2875 of 1996, a National System of Innovation is recognised as part of the National System of Science and Technology. Then again, a NSI is presented in CONPES 3080 of 2000. Finally in "Vision Colombia II Centenario" in 2006 a National System of Science, Technology and Innovation is described throughout the document. The latest law 1286 of 2009 inserts officially the concept of having a NSSTI. In practical terms, the NSI was always embedded in the NSST.

evolved within the so-called agriculture sectoral system of innovation. We start by describing the evolution and dynamic complementarities of the agriculture sector in the Latin American region before immersing in the particularities of the Colombian Agroindustrial sector.

4.2. Policy Development at the National Level

4.2.1. Macroeconomic environment

The regional framework within which Colombia was situated during the first half of the 20th Century was discussed in section 2.4, and while Colombia has never been within the most critical LAC group of countries in terms of social, political and economic development, it has not been hugely successful either. Enhancing science, technology and innovation capabilities is not independent from structural conditions of the countries (economic structures, political institutions, population education level, access to health conditions) (Dutrénit, 2011). Colombian economic development has been characterised by deep fluctuations. During the 1980s the LAC region experienced a recessionary inertia, growing external debts, and a negative trade balance. In Colombia there was a recovery period from 1986 to 1995 that was followed by the deep recession that occurred in the 1990s because of a mortgage and financial crisis that accounted for a negative GDP growth of 5.2%. Again, the international economic crisis in 2008 and 2009 slowed down the economic performance (Figure 4.1). The economic evolution from 2010 onwards has shown a recovery attributed to an energy and mining exploitation boom. Needless to say that an economy based on the exploitation of fossil fuels is contrary to any sort of sustainable development.[12]

[12] "Colombia's strong economic growth in recent years has been driven in part by extraction of oil, metals, minerals and coal for export. The downside of this is that these extractive industries are polluting soil and water, harming sensitive ecosystems and damaging human health. The review urges Colombia to improve its management of the environmental impacts of mining." (OECD, 2014b)

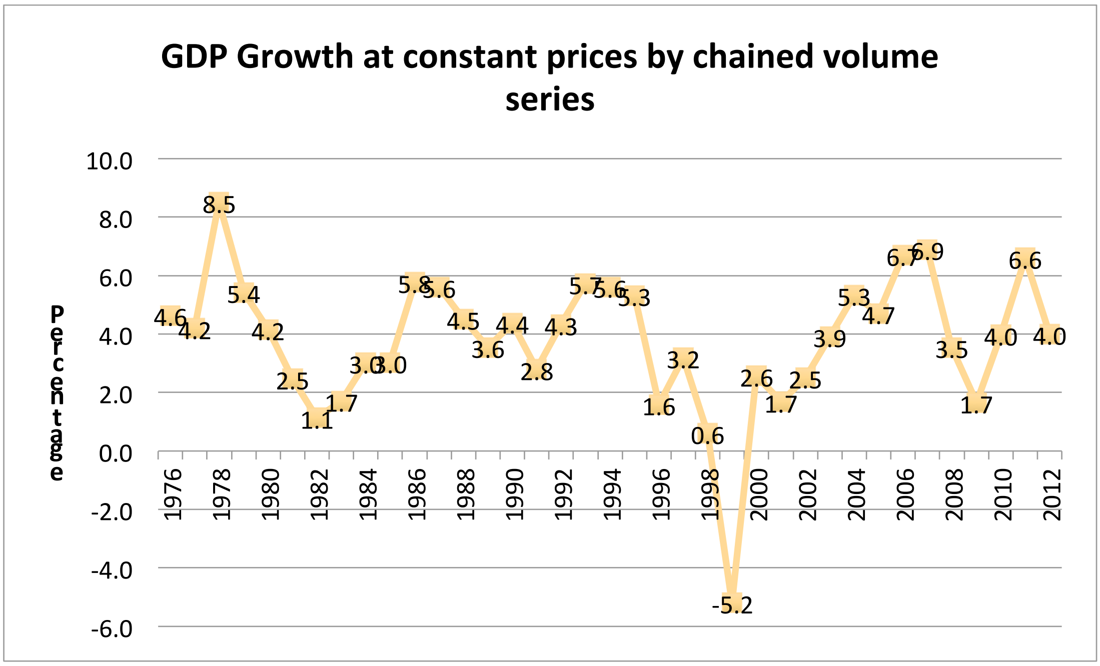

Figure 4.1. Colombian GDP growth 1976 - 2012

Source. DANE. Updated series of National Accounts for the period 2000-2011. Base 2005

Using Total Factor Productivity (TFP) average growth as a measure for long-term technological change and technological dynamism illustrates that the performance of the country has been moderate in terms of capital, labour and knowledge inputs (Figure 4.2). Again, the lost decade (1980 - 1990) of the LAC countries and the 2008 international finance crisis can be seen in the evolution of this indicator. Low levels of trade openness, of human capital accumulation, and of infrastructure deficits are explanatory factors for the TFP low performance.

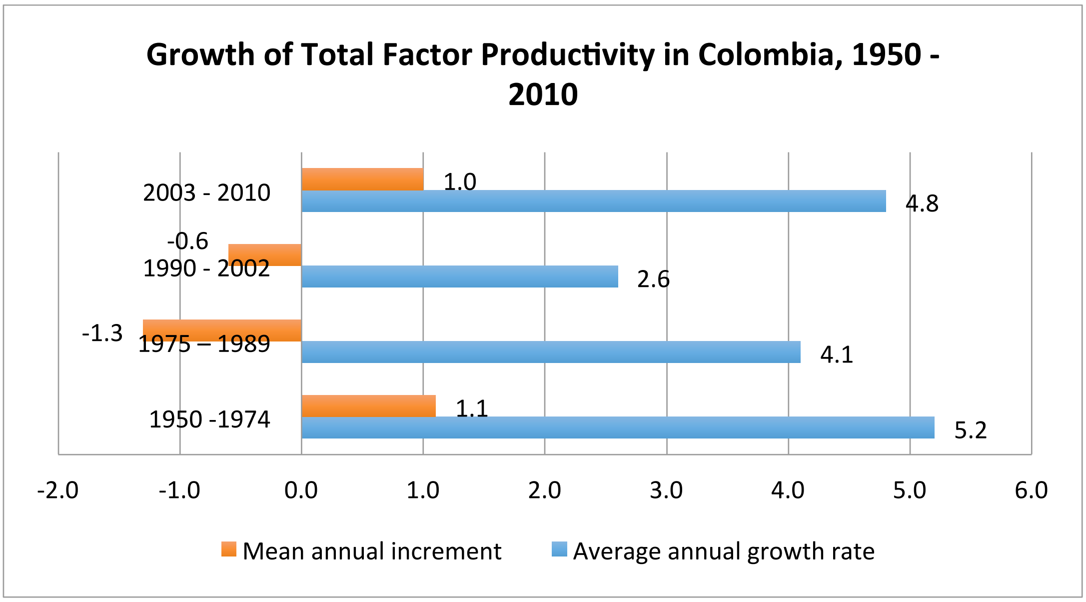

Figure 4.2. Total Factor Productivity in Colombia 1950 - 2010

Source. Based on DNP information

In considering the relationship with international markets, Colombia has had permanent fluctuations characterized for deficits in the trade balance, with some trade balance surplus, specifically notorious during the 1980s with the imports substitution strategy of the LAC region. This can be seen in Figure 4.3:

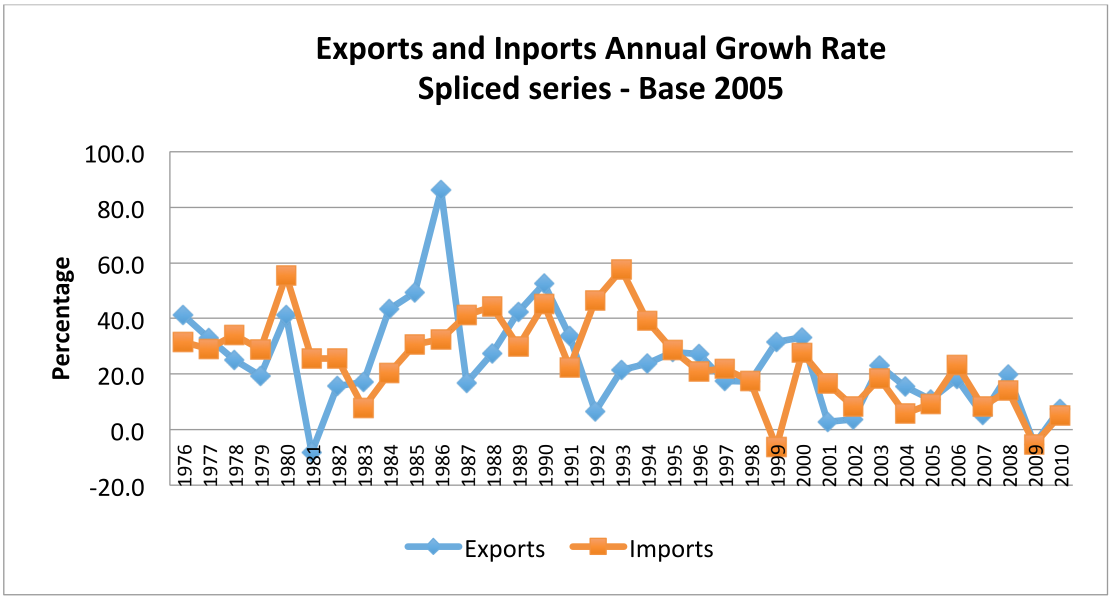

Figure 4.3. Colombian Exports and Imports 1976 - 2010

Source. Based on DANE information

The macroeconomic environment impacts the way that science, technology and innovation policies are conceived of, designed, applied and assessed. In crises times there are budget cuts that commonly affect STI national investment. During the second half of the 20th century the LAC region experienced several economic changes and followed a structuralist approach to overcome the inequality between North and South. After the Great Depression in 1929 analysts of the economic and political trajectory of the region noticed that having a high reliance on primary exports would increase the vulnerability of the region (Furtado, 1960). This is how the strategy became focussed upon having greater technology capabilities for substituting imports and producing higher value-added products for the domestic and international markets. However, although imports were substituted, it was not with competitive low cost services and products, but with low quality and highly subsidised products, while in the meantime the rest of the world was experiencing a fast process of industrialization. Although during the 1970s the LAC region had a deep intellectual and political development on studies, projects and programs for promoting S&T to overcome the region’s lag, the “lost decade” of the 1980s focussed all efforts on dealing with the macroeconomic crisis of all LAC countries. By 1990 the economic and technology gap between LAC region and the rest of the world was bigger.

4.2.2. Evolution and Development of ST&I Policies in Colombia

Before 1968 Colombia did not have public institutes or departments focus on developing Science and Technology. However, there were important milestones like:

1. The foundation of decentralized institutes like The Colombian Institute of Educational Credit and Technical Studies Abroad (ICETEX), The Institute for Technological Research, The Research Coffee Centre CENICAFE, The Colombian Institute for Agriculture (ICA), and the National Apprenticeship Service (SENA), among others.
2. The increased influence of international organizations like the Organization of American States (OAS); the Inter-American Development Bank (IDB); and the United Nations Educational, Scientific and Cultural Organization (UNESCO); on the design and implementation of state policies.
3. The foundation of some of the most important universities in the country.

Since 1968, the process of institutional development of Science and Technology in Colombia has gone through four major stages. The first, between 1968 and 1989, focused on the formation of human resources and research groups. This was the strongest stage in terms of the thought and conceptualization of S&T policies. During this stage, systemic relationships between actors of the private, public and academic sectors were built and strengthened. Although there was not a formal law formulated, this was the main stage to build the bases of the national system of innovation. In the second stage, between 1990 and 1999, the Science and Technology Policy was formally promulgated. As part of this policy, the National System of Science, Technology and Innovation was instituted, following general guidelines from the Systems of Innovation approach (SI), and practical recommendations produced by the Latin American School of Thought (LAST). During this decade, the country built capabilities in Science, Technology and Innovation (STI) through enabling policies from the central government. This coincided with the Latin American and Caribbean (LAC) region impulse of S&T to generate economic development during the 90's. This process of formalisation of an on-going inertia started by the end of the 1960s is outlined by Dr. Fernando Chaparro, former head of Colciencias and Corpoica (Colombian Corporation for the Agricultural Research):

> The formal system of science and technology is created by the law, the law of 1989, the science and technology law. I'm

> not talking of the recent law, but the one of the end of the 80s, the first law of science and technology. What this law really did was to give juridical existence to something that started from the 70s…this is a formal discourse. If we had not built systemic relations between diverse actors, the law from the late 80s would have not been a reality. (Fernando Chaparro, personal communication, May 22nd, 2012).

A third stage is identified from 2000 to 2008. During these years efforts were directed on developing key economic and productive sectors, according to the objectives and strategies included in the definition of the NSSTI. Accordingly, programs were launched for encouraging regional competitiveness, funding for the creation of more national Ph.Ds, and strengthening the S&T system through formal institutions. Finally from 2009 to date, government policies have focused on strengthening the National System of Science, Technology and Innovation. With this purpose in 2009 The National Fund for Science, Technology and Innovation Francisco José de Caldas was created. The fund allows Colciencias to integrate public, private and international resources to fund programs, projects, activities and organizations to promote STI. Innovation remains at the centre, including it within the government plan of the current Colombian President[13] (2010 – 2018) as part of the five development "locomotoras" [locomotives]. This means that more financial resources have been invested in ST&I projects and that innovation and R&D are vital – at least that is what is stated in the government plan[14] - for all economic and social sectors.

Throughout these phases the system has acquired a stronger legal and political framework, at least formally. When talking to diverse major actors in the public, private and academic sectors, we encountered recurrent complaints about the lack of coherence of the public instruments, the dispersion and scarcity of funding, and a deep problem of linkages between actors. It seems that the so-called innovation system is composed by isolated islands that work together as an exception more than as a rule. These are not totally novel findings. Similar observations can be found as

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[13] Juan Manuel Santos is the President of Colombia. He was elected by popular vote in 2010 and re-elected in 2014.

[14] "Prosperidad para todos". Governement Presidential Plan Period 2010 – 2014. Chapter 3: "Crecimiento Sostenible y competitividad"

early as the 1994 recommendations by an expert commission convened by the presidency (*Colombia al Filo de la Oportunidad*) (Consejería presidencial para el desarrollo institucional, 1995) and a report made by the UNCTAD and published in 1999 about the Colombian Agriculture Sector (UNCTAD, 1999). In these reports there was clarity about the dysfunctional nature of the national innovation system and its lack of linkages with the sectors. Moreover, as it is clearly outlined by the latter report, agriculture sectors such as coffee, flower and sugarcane were becoming successful by their own means and initiatives more than because of a national infrastructure supporting their development. It seems that national organisations such as Colciencias should learn more from the successful sectoral cases so it can replicate good practices in other industrial sectors.

Currently, the law that regulates scientific and technological activities is Law 1286 of 2009.[15] This law modifies Law 29 of 1990[16], transforming the national entity that regulates science and technology (Colciencias) into an administrative department[17], and strengthens the National System of Science, Technology and Innovation. Further considerations about the application of this reform will be done in the next section.

A summary table with the main events of S&T in Colombia is presented according to the stages described:

Institutional Development of Science and Technology in Colombia	
Stage	**Events**
From 1968 to 1989	Creation of the Institute for Science and Technology – Colciencias.
	Creation of the Colombian Institute for the Promotion of Higher Education.
	Creation of the National Council of S&T.
	First Ph.D programs.
	International Forum of S&T Policy (1987).

[15] Law 1286 of 2009, Congress of the Republic of Colombia. http://www.secretariasenado.gov.co/senado/basedoc/ley/2009/ley_1286_2009.html
[16] Law 29 of 1990, Congress of the Republic of Colombia. http://www.cnsc.gov.co/docs/arc_619.pdf
[17] Before Law 1286 Colciencias was a National Institute that depended of the National Planning Department (DNP). Now Colciencias has the same legal status as the DNP and depends directly of presidency. It has the status of a Ministry, at least legally speaking.

	S&T Mission (1988).
	Consolidation of the institutional system of agriculture and its network of Research Centres (CENIS) associated with the guilds.
	Creation of The Colombian Association for the Advancement of Science - ACAC.
From 1990 to 1999	Promulgation of the National Policy for Science and Technology. Law 29 of 1990.
	Ascription of Colciencias to the National Planning Department (DNP). Decree 585.
	Tax incentives for Activities of S&T. Law 6a of 1992.
	Mission of Science, Education and Development (1993).
	Approval of the first S&T National Council of Social and Economic Policy (CONPES 2739 of 1994).
	Creation of the National Commission for Masters and Ph.Ds.
	Creation of the National System of Innovation and Regional Systems (1995).
	Allocation of SENA resources to Programs for Competitiveness and Technological Development. Law 344 of 1996.
	Creation of Maloka Corporation (1998).
	Creation of the Colombian Observatory of S&T (1999).
From 2000 to 2008	Connectivity Agenda. Focus on competitiveness. (CONPES 3072 of 2000).
	Policy of Science and Technology 2000 – 2002. (CONPES 3080 of 2000).
	Creation of the National Program of Technological and Industrial Foresight (2002).
	Establishment of regional agendas of S&T.
	Support to National PhD programs. BIRF Loan (2002-2003).
	Incorporation of direct resources for S&T in the National Development Plan of 2003.
	Access Program (Access to Quality Higher Education) 2003 – 2006.
	Approval of National policies for Social Appropriation of S&T and Internationalization of S&T.
	Direct participation of Colciencias in the S&T CONPES.
	Creation of six Excellence Centres (2004 - 2006).

	National Policy for the promotion of research and innovation (2008).
From 2009 to date	Promulgation of the National Policy of ST&I (CONPES 3582 of 2009).
	National Fund for STI Francisco Jose de Caldas to send national researchers to get Postgraduate formation in first class universities around the world and in the country (First generation in 2009).
	WB loan to Colciencias for the strengthening the National System of Science, Technology and Innovation (2010).
	National Development Plan 2010 – 2014. Emphasis on Knowledge and Innovation; Entrepreneurship; Intellectual Property; Development strategy (Locomotora): new sectors based on innovation.
	National Innovation Strategy (ENI). Developed by Presidential mandate in 2011.
	Legislative Act 05 of 2011, for the constitution of the General System of Royalties (natural resources). 10% of the total royalties fund goes for a Science, Technology and Innovation (STI) Fund. Promotion of regional STI regional development.

Table 4.1. Institutional development of science and technology in Colombia

Source. DNP and information compiled by the author (National Planning Department & Colciencias, 2006).

In terms of formal institutions represented by official regulations, the key public documents can be seen in the following table. These documents have oriented the development and application of policies related with science, technology and innovation:

Legal documents	Purpose
Law 29 of 1990	1. Gives responsibility to the State for the promotion of S&T; 2. States mechanisms for funding S&T projects; 3. Confers on the State the responsibility of establishing linkages between universities, the scientific community, and the private sector.
Decrees 383, 585, 591 of 1991	Decree 383 authorizes decentralized national entities to partner with private organizations to do Since and Technology Activities. Decree 585 formalizes the decision-making structure for S&T (Innovation is not mentioned by this time explicitly). This decree defines national programs that represent S&T priorities to develop. It mixes productive sectors (agriculture, education, health) and science areas (social sciences, basic sciences, environment). Decree 591 regulated the different types of contracts for the promotion of STAs.

Science, Education and Development Mission - Colombia al filo de la oportunidad (1993)	Diagnosis and analysis of the evolution, development and results of education, science and technology policies until 1994. Proposal for the development and implementation of the "Program for the endogenisation of science". This is a short, mid and long term plan for developing S&T capabilities and improving the educational system.
CONPES 2739 of 1994	Policy for S&T during the period 1994 - 1998. First CONPES for S&T. This policy was mainly focussed on bringing competitiveness to the productive sector developing and strengthening S&T capabilities. First official document including innovation explicitly. It has a chapter about Innovation, Competitiveness and Technological Development.
CONPES 2875 of 1996	This CONPES is highly relevant because it is the first time that in official documents the National System of Innovation is mentioned. The purpose of this CONPES is to approve an external loan for the improvement of technological capabilities in the productive sector.
CONPES 3080 of 2000	Is the National Policy for Science and Technology 2000 - 2002. It mentions again explicitly the National System of Innovation as part of the National System of Science and Technology.
Vision Colombia II Centenario of 2006 - Focusing growth and social development on science, technology and innovation	It gives an action horizon for Colombia until 2019. The focus is on building an economy and society based on knowledge. A diagnosis of the institutions and application of S&T policies is presented and new strategic sectors and goals are proposed.
National Policy for promoting science and innovation - Colombia construye y siembra futuro (2008)	This is the preliminary document for Law 1286 of 2009. The main goals proposed in the policy are: increasing knowledge generation; promoting innovation for competitiveness; promoting the public appropriation of science and technology; strengthening the institutionality of the NSI; strengthening the infrastructure for supporting information systems for S&T information; promoting the regional integration; and strengthening the international links for transversal projects of S&T. Definition of five strategic areas: biodiversity, water, health, peace, and social cohesion.
Law 1286 of 2009	The main change in comparison with Law 29 of 1990, it is that gives to Colciencias the status of an Administrative Department, at the same level of the National Department of Planning (DNP), and the same status as a Ministry.
CONPES 3582 of 2009	It outlines instruments and strategies to implement the new dispositions of Law 1286 of 2009. It contains also one of the most comprehensive assessments of the system up to 2009.

Table 4.2. Main official documents related to science, technology and innovation policies in Colombia.

Source. Information compiled by the author

4.3. Policy Implementation at the National Level

4.3.1. Definition, Structure, Functions and Principal Actors of the Colombian National System of Science, Technology and Innovation

A Colombian National System of Science, Technology and Innovation (NSSTI) is defined in public documents and policies, reflecting an attempt from policy-makers to follow a systemic approach towards the construction of STI policies. The National System of Science, Technology and Innovation of Colombia is defined in Law 1286 of 2009 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 technological innovation, as well as public, private or mixed organizations that perform or promote the development of scientific, technological and innovation activities. (Congress, 2009 Art. 20)

The system operates through Research and Development (R&D) inputs, and through Scientific, Technological and Innovation Activities (STIA), following the Frascati Manual definitions. The former definition is:

> 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. 30).

The latter 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.[18]

According to Law 1286 of 2009, the functions of the system are:

1. Promote the exploration and development of strategies to insert Colombia in the international science, technology and innovation context.
2. Promote the improvement of the national productivity and competitiveness.
3. Develop strategies for developing, transferring and adapting scientific knowledge, technological development, and innovation in the production of goods and services for regional, national and international markets.
4. Do research and have innovation based on science and technology.
5. Promote the social appropriation of science, technology and innovation.
6. Develop STI capabilities in organizations, sectors and regions.
7. Link supply and demand of knowledge at the national level.

A careful look of the definition, units of operation and functional setting of the Colombian NSI shows the important role that the NSI approach has had in the vision and action of policy-makers in charge of STI policy and the prominent role that the OECD orientations have had in the way science and technology is measured at the national level.

In terms of governability, Colciencias[19] is the head of the coordinating system of the NSSTI. However, it has support and advice from the councils for the national programs of S&T and from departmental councils for science, technology and innovation. This system of coordination is illustrated in figure 4.4:

[18] A complete definition of these categories can be found in (OECD, 2002, pp. 30 - 35)
[19] Colciencias was first created in 1968 as a special department within the Ministry of Education. Then, after the first law for S&T in 1990, Colciencias was upgraded to be a national institute ruled by the National Planning Department. With the latest 2009 S&T, Colciencias was recognised as an Administrative National Department depending directly from the President.

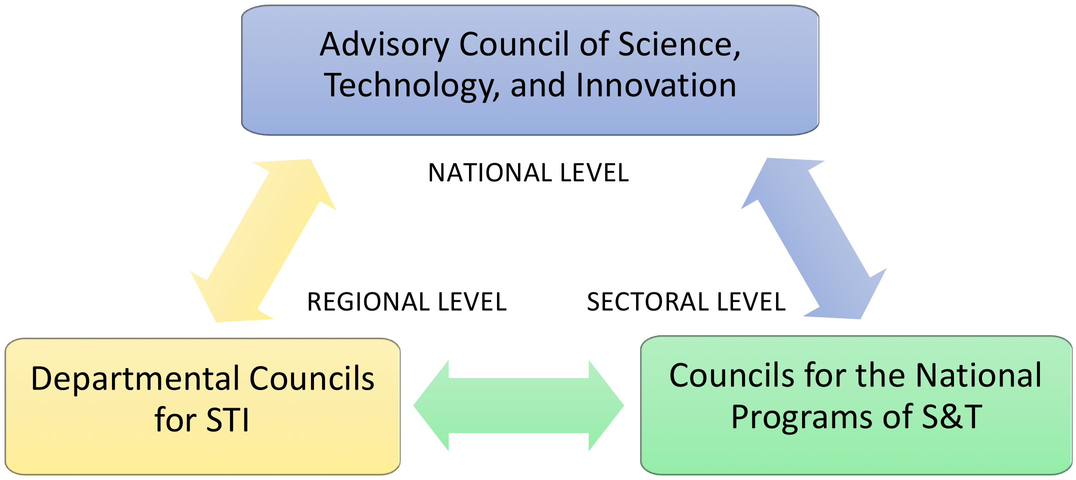

Figure 4.4. Coordination Sub-system for the Colombian NSSTI

Source. Elaborated by the author according to different public documents.

The *Advisory Council of STI*[20] is the highest decision-making body within the system and is chaired by the director of Colciencias. Its principal aim is to advise the design, monitoring, and evaluation of the national policies of STI. It is composed of:

- Director of Colciencias
- The ministers of education; commerce, industry and tourism; health and social protection; and the director of the national planning department
- General Director of SENA
- Four outstanding persons from the academic and scientific sector (Appointed by the President)
- Four outstanding persons from the productive sector (Appointed by the President)
- Two outstanding persons from the regional scientific sector (Appointed by the President).

[20] Law 1286 of 2009 modifies Decree 585 of 1991. Before 2009, the name of the council was *National Council of Science and Technology*. The composition of the council was different and the director of Colciencias had voice but no vote in the decision-making process.

Although the composition of the council is mixed in order to have input from the main actors involved in innovation processes, the election of the participants of the academic and productive sectors and the regional representation is not democratic and the delegates are not always the most suitable. Also, the council do not meet regularly and many times ministers and the SENA director are not present, instead they send delegates to represent them.

The *Departmental Councils of STI* are the regional entities in charge of proposing, organising, promoting and approving local STI programs. Colombia is politically divided into departments, so each department has its own council for STI. Through the departmental councils the system links the national interests with the regional ones and vice versa.

The *Councils for the National Programs of S&T* represent the particular areas and sectors of interest for the country. These programs are structured with objectives and tangible goals organized into projects executed by private or public organizations, community organizations or persons. Each national program has its own council that is in charge of the promotion of knowledge creation, operation, and management of the national programs. The current national programs are: Biotechnology; Science and Health Technology; Basic Sciences; Ocean S&T; Agricultural S&T; Energy and Mining Research; Industrial Technology Development and Quality; Social and Human Sciences; Scientific Studies for Education; and Promotion of Research Training. The Advisory Council of STI can modify these programs according to the national strategic interests, either changing the scope and goals of the existing programs or creating new national programs for developing different strategic knowledge areas.

However, as happens with the national advisory council, the departmental and programs councils do not meet regularly and it is usual that the expected participants send delegates that many times do not have decision power, so the intended purpose of the councils is not achieved.

In terms of the explicit model followed, Colciencias, being head of the sector, has used the system structure proposed by Kuhlmann and Arnold (Kuhlmann & Arnold, 2001, p. 2). This is a conceptual model to understand the dynamics between actors and subsystems in a National Innovation System.

Exhibit 1: **A National Innovation System Model** (source: E. Arnold and S. Kuhlmann)

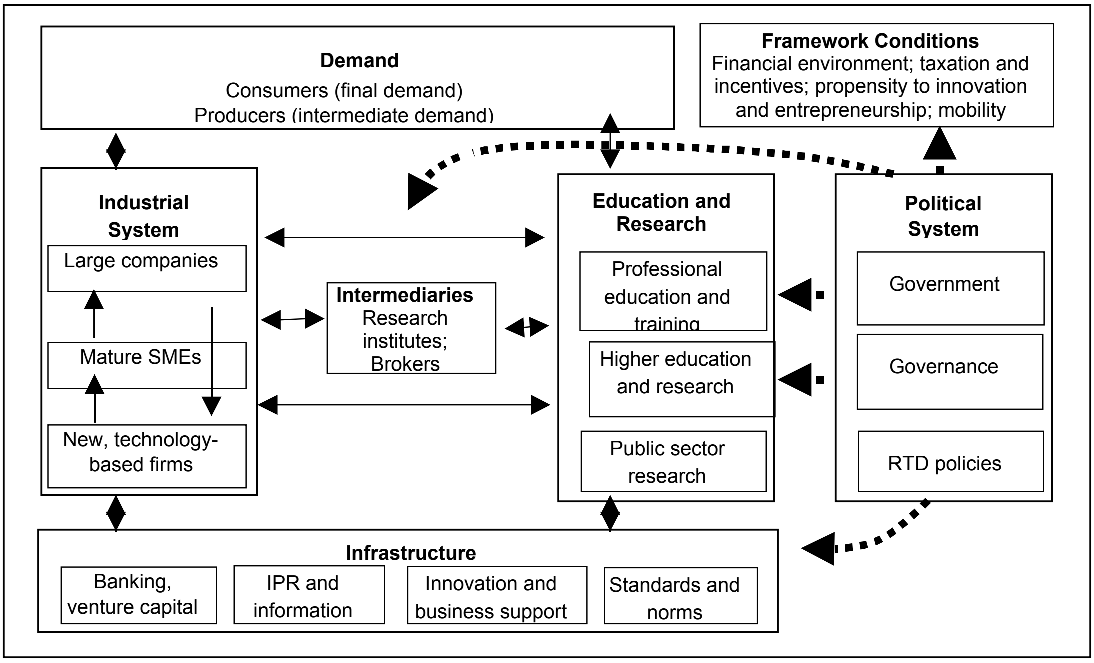

Figure 4.5. Model followed by Colciencias as head of the Colombian NSI

Source. (Kuhlmann & Arnold, 2001, p. 2)

The main actors in each subsystem are detailed in the following table:

Actors	Functions within the NSSTI
Political System	
Colciencias	Head of the system.
National Council of Social and Economic Policy (CONPES)	Institutional definition of policies for STI.
National Planning Department (DNP)	Technical secretary of CONPES.
Ministries	Formulation and coordination of sectoral policies.
SENA	Promotion of technological development and innovation in enterprises. Technical and technological higher education.
Education and Research System	

Public Research Centres	Knowledge generation.
Private Research Centres	Research in specific areas of knowledge.
Research Groups	Formal Knowledge generation in specific niches.
Public and Private Universities	Formal education. Technological and Scientific research.
Technical and Technological Institutions	Formation of technical human resources.
Intermediaries	
Technological Development Centres (CDT)	Knowledge transfer and technological services.
Regional intermediaries (Ruta N, Connect Bogota, Tecnova, CTA)	Articulation of public-academic-private networks to promote innovation for regional transformation.
Trade Union Research Centres (ICIPC, Biotec, Cenicaña, Cenicafe, Ceniflores)	Research based on sectoral needs.
Incubators of technology – based companies	Support to entrepreneurs of technology-based companies.
Technological Parks	Integration of research and technological services capabilities.
Sena's Formation Centres	Strengthening of enterprise technological capabilities.
Industrial System	
Goods and Services Companies	Private enterprises for the production of economic goods and services.
Production Guilds and Business Associations	Producers' guild organizations.
Chambers of Commerce	Promotion, services and registration for productive and commercial companies.
Infrastructure	
First-tier banking	Banks with direct operations with clients.
Second-tier banking BANCOLDEX	Private or public financial organizations with commercial operations through first-tier banks.
Venture Capital Funds	Capital from private investors to support viable companies or

	projects with proportional return to risk taken.
Fomipyme	Promotion and co-financing of technological projects developed by SMEs.
International Funds	External resources for development of ST&I.

Table 4.3. Actors in the Colombian National System of Science, Technology and Innovation.

Source. Based on (Monroy, 2006)

Although there is a general classification of the domains where actors belong, their functions are not always clear and boundaries are blurred most of the times. This has caused that actors of different subgroups end up doing all sorts of activities within the system to justify their existence. There is a fierce competition for scarce resources, so actors tend to adapt themselves to current conditions; basically they shape their activities according to the available funding sources. This can be positive in terms of encouraging resilience to adapt to changing knowledge demands, but also can cause their extinction since they lose expertise and focus on their core activities. In this sense, the functional structure of the system is messy, especially in the delineation of the expected roles of the actors. Actors that are in the middle of different domains, the intermediaries or bridge institutions, hardly recognise themselves with that identity and do not always fulfil the requirements of the business sector. Related to this situation, Luz Elena Castrillón, head of the Colombian Pharmaceutical Research Centre (CECIF) says:

> We need a better institutionality of the system, to define what role universities must play, what role has to play the productive sector, what is the role of technology development centres, what role plays a regional productivity centre as the CTA. All of us play different roles, so it is crucial to define the parameters or variables to classify us. It is not fair that those that do nothing capture more resources than those that do a lot. Such things are problems in the policy definition. (Luz Elena Castrillón, personal communication, March 17, 2012)

The system lacks systemic relationships between public, private, academic and intermediary agents, and also within actors in each subgroup. The coordinating subsystem composed by the national, departmental, and program councils has not been as effective as it was conceived for. This responds to several factors like: 1.

Although the Advisory Council of STI is the highest instance of decision for STI policy-making, it lacks political power to implement its decisions, mainly because there are not enough legal instruments to implement the policies and initiatives proposed; 2. National program councils have generated unequal relations between its members (a strong and very active academic sector, a passive and practically non-existent productive sector, and an uncommitted and sometimes not adequately represented state); 3. Only some departmental councils are effective performing the goals they were created for, resulting in a lack of coordination between national and regional interests; 4. The flow of information amongst the public agencies that are part of NSSTI is limited; 5. The articulation in terms of budget planning and execution of state resources in STI is quite narrow, which is reflected in a disjointed and sectored budget that fails in the achievement of common objectives. (DNP, 2009)

It is important to highlight that the Colombian NSI is defined as such by law and reinforced by CONPES, decrees and government documents. As it was described in section 2.4, LAC countries followed the Organization of American Stares (OAS) and Organization for Economic Co-operation and Development (OECD) guidelines for promoting S&T as main factors for development. However, contrary to the cases of developed countries, the NSI approach was used in LAC region to build national innovation systems. It was the theoretical and practical base to build the Colombian S&T policy.

Although S&T laws are clear about the structure and functions of the system, instruments to apply those guidelines are poor and incomplete. There is a gap between launched laws and the instruments used to ensure their compliance. There is a lack of legal mechanisms in the NSSTI, resulting in an inadequate level of operation of the system (National Planning Department & Colciencias, 2006). A clear example of this is the lack of decrees to enact law 1286 of 2009. Up to 2011, the previous decrees to ensure law 29 of 1990 are in force. And if we also take into account that the implementation of law 29 of 1990 had problems in its instrumentation, the situation becomes even more complicated. This is clearly highlighted in CONPES 3582: "Although law 29 of 1990 provides mechanisms for coordination of scientific and technological activity, its implementation has not been easy or successful." (DNP, 2009, p. 16) Referring to the policies and instruments mismatches, the head of CECIF mentions:

> My opinion is that there is a problem between the definition of the policy and what follows - such decrees and laws - there should be consistency. If there are not decrees and laws that is where the applicability comes, the policy is incomplete, that's what I mean. This is a policy definition problem, and the fact that you present to the public an incomplete policy it's a failure. (Luz Elena Castrillón, personal communication, March 17, 2012)

This shows that beyond formal structures of definition, design and operation of the innovation system, there are barriers in the implementation of policies linked with governability and governance[21] issues. The next section explores the policy implementation processes in the light of the emerging categories[22] found during the research process.

4.3.2. From policy to action: A straightforward process?

In this section we present a contrast between a linear model for policy-making and other participatory models that highlight the messiness of the political processes around policy-making. In the former, once a problematic issue is tackled through a political rational choice, implementing the resulting policy or policies should be a straightforward process. In a utopian sense, policy-making should be an objective and infallible process that results in feasible and optimal solutions for the issue under analysis. However, since courses of action are always varied and depend on the policy-makers views, there is a multiplicity of possible outcomes. For the latter, policy-making is an iterative learning process where corrections are always made according to experimentation that goes beyond controlled, neat and accurate policy rationales. As it is clearly expressed by Rebecca Sutton (Sutton, 1999, p. 5), "policy,

[21] Governability is understood in this thesis as the formal power represented by the State or any public organization to govern any society aspect. On the other hand, governance is understood as the capacity of actors embedded in any social subsystem to set consensual rules. A deeper exploration of these terms is done in section 2.5.

[22] See Methodology Chapter, where the process of coding and categorization is explained.

and policy implementation are best understood as ‘chaos of purposes and accidents’”.

The linear model for policy-making still prevails in the Colombian context. This is why reshaping and adaptation processes from planning to implementation phases are limited or non-existent in the formal system. Figure 4.6. shows the linear policy-making rationale.

Understanding the policy issue or problem (agenda-setting)

↓

Exploring possible options for resolving the problem

↓

Weighing up the costs and benefits of each option

↓

Making a rational choice about the best option (decision-making)

↓

Implementing the policy

↓

Evaluation (possibly)

Figure 4.6. Linear policy-making model

Source: (Institute of Development Studies, 2006, p. 7)

In order to understand the alignment and misalignment of actors, agendas, expertise, values, interests, and views involved in policy processes; complexity, uncertainty and ambiguity are dimensions of incomplete knowledge that we have to deal with (Leach et al., 2010). In this sense, since there is not a single optimal pathway to construct policy and design instruments, multiple narratives and policy framings should be taken into account. Reality differs from the ‘optimal’ model, in the Colombian case, from a neat NSI. There have been successes and failures, and the learning curve has an upward trend, so political processes should be dynamically refined.

Since any political setting is context-dependent and influenced by historical trajectories (Edquist, 1997b), the policy implementation processes will be seen in the light of main factors that have defined the evolution of the Colombian NSI. These factors were found in the analysis process where documents, interviews and focus groups were used as sources.

4.3.3. Political Institutions

The reality of developing countries causes them to give political and economic priorities to unsatisfied basic needs (UBN) that have to be addressed immediately. Since basic needs such as education, housing, food security, and employment are not covered for a large proportion of the population[23], the structural setting to intervene in long-term strategies presents more difficulty for policy-makers. It does not mean that there are not strategic efforts for strengthening long-term initiatives based on the developing of internal capabilities, but that there is pressure from immediate, urgent and important problems that need to be solved. So in an effort to meet the immediate needs of their constituents, policy-makers legislate reactively to urgent problems and lose perspective and vision for the future of the country in the long run. However, there are national agencies as Colciencias, National Planning Department, National Research Institutes, and special programs within ministries in charge of projection a strategic country vision. Although there are few joint programs and initiatives between these agencies[24] there is not enough synergy, which has caused overlapping government policies, with a lack of consistent and transversal state policies[25]. Since building a long-term political vision is not the common practice[26], science,

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[23] According to the National Statistics Department (DANE) in 2013, 30.6% of the total population was under poverty conditions and 9.1% was under extreme poverty conditions. For the analysis of a multi-dimensional poverty indicator that determines if a person is poor according to five dimensions: education, childhood and youth conditions, employment, health, and housing conditions, 24.8% of the population was under poverty conditions. See: https://www.dane.gov.co/files/investigaciones/condiciones_vida/pobreza/pres_pobreza_2013.pdf

[24] Colciencias has started to work closer with different ministries and the National Planning Department (DNP) in an effort to collaborate and avoid replication of efforts. Some examples are the joint efforts between the National Program for Agriculture and the STI agendas for production chains developed by the Ministry of Agriculture and Rural Development and Corpoica. Also, the participation and collaboration between Colciencias, the direction of entrepreneurship and innovation within the Ministry of Industry and Commerce, the group in charge of S&T policies in the DNP, and Innpulsa as a funding agency.

[25] This is highlighted in the latest OECD review of Colombia's innovation policy: "Colombian system appears fragmented. It could achieve better use of resources and provide better service to customers through more co-ordination and coherence" (OECD, 2013, p. 28)

[26] To develop a country vision and promote development based on STI, there have been national exercises as: Visión Colombia II Centenario: Base growth and social development on STI; and other attemps with international cooperation as: SCOPE 2015, and 'Convenio Andrés Bello: Escenarios al 2020 de la educación superior para la transformación productiva, social y equidad en los países del Convenio Andrés Bello'. At sectoral and regional levels, there have been more exercises as the

technology and innovation policies are diluted in government agendas in terms of importance and therefore of funding. A strategic design of STI policies should have at least three main components: a long-term vision in alignment with other state systems; a strategy to achieve that desired outcome; and a set of priorities aligned with the proposed strategy (Morris Teubal, 2002). Since policy-makers are adaptive rather than optimisers guided mostly by immediate needs, the policy-design processes lack strategy.

> The most serious of all state problems in policy formulation and the implementation of educational reforms is the discontinuity of these policies and the administration of these reforms. (Consejería presidencial para el desarrollo institucional, 1995, p. 69)

Short-term planning was further enhanced by the change made in the 1991 National Constitution where the presidential government plan was enacted into law during the 4-year government period. Important national departments such as Colciencias, SENA and DNP depend directly on executive power, which make them respond to the government interests, so priorities change every presidential period. The recurrent change in policies and instruments generate confusion among actors and truncates long-term initiatives. Also, production of knowledge as a main variable for economic and social development has not been included in most of the government plans. It is not a matter of laws, it is a matter of political vision and political will to sustain successful policies and instruments in order to build an integral notion of the direction the country will follow for a given horizon of time. Related to this dichotomy, Hernán Jaramillo - current dean of the School of Economics in Universidad del Rosario, former sub-director of Colciencias and expert on S&T public policies- says:

> In the country there is not clarity about what are the strategic sectors, and there is not clarity because here policies are short-term defined. It is a dramatic problem because

creation of the National Program of Biotechnology; Construction of research agendas for agricultural productive chains, departmental prospective agendas (Valle del Cauca, Boyacá, Huila, Antioquia, Caquetá, Guajira, Caquetá, Amazonas, between others); health cluster in Antioquia; health cluster in Valle del Cauca. There have been 32 exercises with different scope and impact for building consensual long-term political vision, but this is not the norm. The impact of these exercises is also diminished by the discontinuity of the instruments designed for government lifetimes.

> institutions, policies, expected results are always defined and expected for the short-term. The political agenda is changing constantly. Each government changes the rules of the game and therefore there is not security for investors, for developing specific sectors, for producing relevant knowledge. (Hernán Jaramillo, personal communication, August 23rd, 2012)

Alignment of national interests and sustained effort depends largely on the strength of political institutions. The perception of science and technology as important factors to generate economic and social welfare is limited. That is probably the reason why a permanent strategy in most public documents has been the strengthening of political institutions[27], but building a stronger institutionality is a long-term process that should be sustained beyond each 4-years government terms. It requires a state vision and a higher valuation of S&T from actors within the system and broader society.

In terms of the governability, as it was seen previously, councils compose the coordination subsystem within the NSI. However, these councils are functionally and structurally weak. The national council has not had the political power to execute its decisions, or a budget designation. National program councils, designed following Sabato's triangle model[28], have unequal vertices, with the stronger being the research and academic vertex. There are stronger and more active departmental councils than others, according to the importance that local actors give to STI (Colciencias, 2008). Even being formally defined in their composition and functional setting by law,

[27] The National policy of S&T 1994-1998 had a explicit strategy to strengthen the National System of S&T (NSST) (DNP, 1994). The first objective of the endogenisation program proposed in 'Colombia al Filo de la Oportunidad' (Consejería presidencial para el desarrollo institucional, 1995) was "Strengthen the policy decision to promote science and technology as part of the strategy for development". In turn, CONPES 3080 includes as the first strategy of the national policy of S&T, institutional strengthening of the NSST (DNP, 2000). 'Visión Colombia II Centenario' also includes as a goal to support central skills of the vision, to consolidate the institutionality of the NSSTI (National Planning Department & Colciencias, 2006). In 'Colombia construye y siembra fututo', there are two strategies for capacity building for STI (including support for knowledge generation and institutional strengthening of agents of the SNCTI), and strengthening the institutionality of the NSI (Colciencias, 2008). The second strategy of CONPES 3582, the national policy of STI is again, strengthening the institutionality of the NSSTI (DNP, 2009).

[28] In 1960, Jorge Sábato, one of the emblematic members of the Latin American School of Thought (LAST), proposed a structure to describe the key actors in developing S&T policies. There are three vertices to compound a triangle: government, productive structure, and scientific and technological structure. Each vertex is related to each other, and to the external environment according its functional convergences.

members do not have a formal contract, do not follow defined guidelines, and largely depend on Colciencia's budget to execute their decisions (Various, 2013). There is also a problem of representativity. It is usual to find that members representing public, private, and academic sectors delegate their participation in people with no decision-making power. So even having a good and balanced structure from public, private, and academic sectors, the council's operation has not been optimal and could be improved based on more autonomy and consensual decisions.

We exposed several weaknesses in the development, governability and governance of the political institutions, which impacts directly in the NSI performance. Since the policy-making is neither linear nor completely rational, it cannot be expected to always get optimal results, however there are not enough feedback mechanisms to have policy learning and to correct the political pathways. Additionally, a lack of planning and long-term strategic vision creates instability and inconsistency in formal institutions, which affects and compromises the actions of actors and performance of components within the so-called National System of Science, Technology and Innovation.

4.3.4. Coherence between policies – Policy processes

We have seen previously that there is a disconnection between the definition and implementation of public policies. It seems that each public document on STI outlines diagnostics and strategies that insist on the same problems that still persist and goals that have not been achieved. Since there is a lack of continuity and coherence in the implementation of policies, strategies do not have continuous support, causing constant changes in the instrumentalisation of policies, which prevents a sustained development.

From the 1990s onwards, emphasis was put on having formal institutions in the form of laws, administrative acts, decrees, CONPES and so on. Laws have been reinforced with the assumption that through them an optimal operation of the NSI and its subsystems will be guaranteed. However, there are asymmetries between actors' relationships and the functional and structural dynamics of the system. The broader political space where the NSI is immersed has also coordination problems between industrial, financial, health, agricultural, commercial, mining, environmental, communications, transport and labour policies and programs. There is no coherence within and without the system, or effective coordination between actors and components.

Referring to the lack of coherence between national policies, Hernán Jaramillo says:

> There may be different institutes, there may be different ministries, there may be different models, but if there is not good coordination, integrated and complementary public policy, there is nothing. (Hernán Jaramillo, specialised focus group, May 17th, 2012)

Under the assumption that having a stronger department in terms of decision power, budget, and political participation, the coordination of the NSI would be better overall, Colciencias was upgraded to a National Administrative Department. However, Colciencias has not had the injection of financial resources that it needs, its political power is still very limited and, by presidential mandate, a new National Strategy for Innovation (ENI) was developed under the direction of DNP in 2011. This has generated confusion because innovation players do not know what entity is in charge of the science, of the technology, of the innovation, and even of the competitiveness in the country. By 2011, the ENI was declared as official and new entities became part of the NSI. This shows a lack of coherence in formal regulations, causing conflict between Colciencias, as head of the system, and other public actors that are part of the NSI Dr. Franciso Miranda, former head of Colciencias between 2006 and 2010, comments on this subject:

> There you have a concrete example, for a long term SENA tried to create an innovation system and to be head of the system arguing that they had more money to move things around. And that was an absurd sight. A new law is made [law 1286 2009] and the system is again reconceptualised and a year after, the law is not good enough and things are changed again. Not the law, but in practice, the system. And now SENA is an even more complex actor. Again the National Planning Department wants to redefine things outside the law, because law 1286 was very explicit. This is a very good example of how laws say something and people do

> exactly the opposite. (Francisco Miranda, personal communication, April 25th, 2011)

In this particular case, the executive power ignored a law enacted in 2009. This situation shows a deeper problem about the political formal and tacit institutions. Even when the existence of a science, technology and innovation system is declared as so by law (which is atypical), the formal institutions are overlapped and in conflict. Then, it is understandable that there are also discrepancies between the official system and what happens in the field. Instruments are manipulated according to the needs of each government and most of the time short time incentives and resources are used to show positive indicators in the international context. As it is noted by a public servant of DNP:

> Public policy is constructed through the national development plan, CONPES documents and all other policy documents that may arise. However, what we have to support are the priorities set in the National Development Plan 2010 - 2014. (Public servant, personal communication, April 24th, 2012)

Even public servants are sceptical about the definition and application of policies:

> Look, I believe that these policies [STI policies] have been more reactive that intentional and that they have appeared more for necessity than for prospective processes.(Catalina Gutierrez, personal communication, October 22nd,2012)

There is confusion among the system's actors about the policy definition and implementation. In terms of governability, there are strong public departments competing to lead innovation policies, so there are several guidelines and replication of instruments for the academic and productive sectors. As it was expressed by the latest review assessment of the Colombian innovation policy made by the OECD:

> Colombian system appears fragmented. It could achieve better use of resources and provide better service to customers through more co-ordination and coherence, for instance by regrouping some RTOs [research and technology organizations] into larger entities or by creating means of co-operation.(OECD, 2013, p. 28)

So having weak political institutions – both formal and informal – in addition to a general lack of coherence and coordination between public entities and failures in the operationalization of existent policies has affected the operation of the NSI. The policy-mix packet has failed to satisfy the needs of business sectors in supporting innovation processes. That is partially explained by the predominant linear model for policy-making adopted by the country that focuses on a narrow range of innovation models (OECD, 2013).

4.3.5. Accessibility to Resources, Incentives, and Instruments

Incentives and instruments to promote and support science, technology and innovation, can be grouped into four categories, independently of the public or mixed body that offer them (Figure 4.7). This set of instruments is conceived within the NSSTI in the form of competitive public grants or credits.

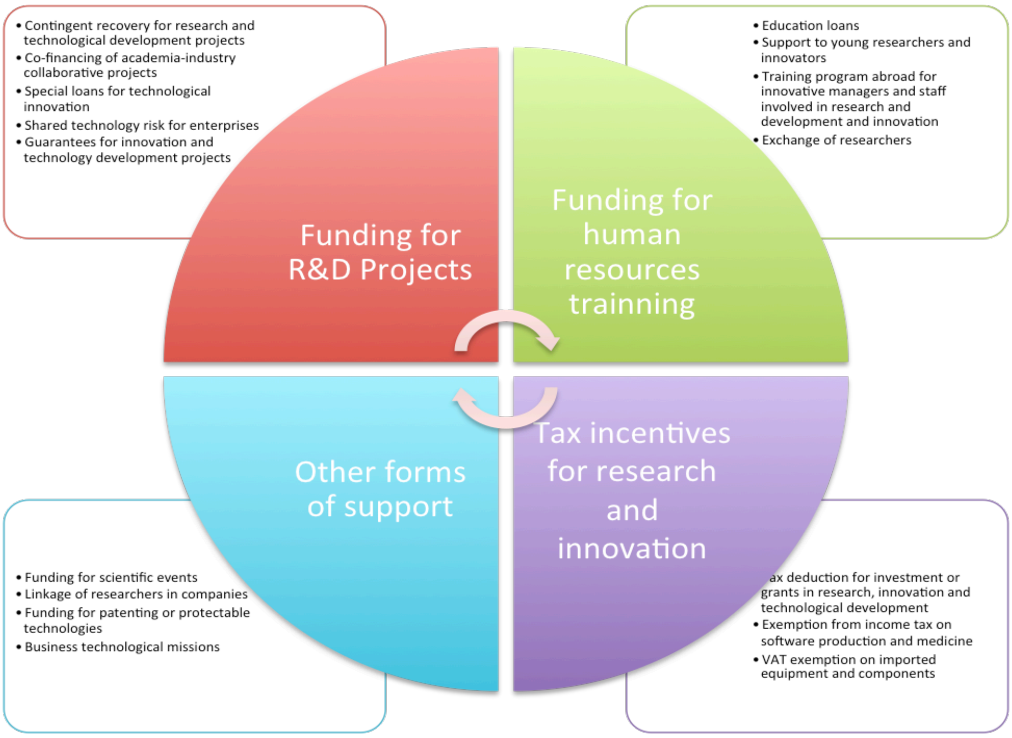

Figure 4.7. Instruments to promote STI in Colombia.

Source. Based on (Colciencias, 2008)

The incentives to promote innovation are something relatively new in the country. The first law for S&T in 1990 did not mention innovation at all. It was not until CONPES 2739 of 1994 when there was an explicit mention of innovation as a dimension to develop. From that CONPES forward, a set of instruments has been designed to overcome the so-called “valley of death” (Markham, Ward, Aiman-Smith, & Kingon, 2010) in the innovation processes.

However, as we can see in figure 4.7, most of the instruments to promote and support innovation processes are mainly directed towards the research or commercialization phase of the innovation cycle. This responds to the linear notion of research and technological development (RTD), and later on to the linear innovation model implemented in Colombian STI policies. This linear vision has created gaps in instrumentation to support RTD cycle: [basic research – applied research – development of products, processes or services – products, processes, and/or services themselves, and the market place] (Tait & Williams, 1999). The same situation happens with innovation. There are gaps among [invention – innovation – and diffusion phases](Godin, 2005).

The novice state of Colombia in the creation and implementation of innovation incentives is acknowledge by Mr Freddy Pulgarín, competitiveness manager of the Chamber of Commerce of Antioquia, the most innovative department of Colombia:

> We are very new to the subject of developing instruments for innovation because although it took a while talking about innovation, we’ve seen that it's important and we’ve worked a bit on the issue of the creation of culture, but we still have a long way to go before having instruments for the entrepreneurs (Fredy Pulgarín, personal communication, April 24th, 2012)

Also, Juliana Ossa, Executive of dynamic innovative entrepreneurship in Innpulsa, a governmental agency created in February 2012 to support and promote business growth led by innovation, says:

> From the point of view of tax deductions, I think that even though there is political will and incentives created, we have

a lack of tools to access these incentives (Juliana Ossa, personal communication, October 22nd, 2012)

Leaving aside the lack of incentives in crucial phases of the innovation cycle, existing instruments have not had a big impact on businesses to be more innovative. Results from the Survey of Development and Technological Innovation in Manufacturing VI (EDIT VI)[29] that presents results for years 2011 and 2012, shows that only 0.2% enterprises were strictly innovative; 21.5% were innovative in a broad sense; 4.7% were potentially innovative; and an overwhelming 73.6% were not innovative at all. 9,137 companies completed the survey from a total sample of 10.315.

One important question contained in the surveys of development and technological innovation in manufacturing is why companies do not apply for public resources and access to STI benefits. Innovative and potentially innovative companies that had the intention to fund science, technology and innovation activities using public incentives reported the following as the main obstacles to accessing public resources:

1. The ignorance of public funding lines, which means that there is not enough information about the existence of public incentives.
2. The lack of information on the requirements to compete for resources.
3. That processes are too complicated and too slow to apply, so firms prefer to use internal resources to have opportune results instead of going through a long and complicated process to access public incentives.

[29] In 1996 the National Planning Department (DNP) launched the first survey of technological development (EDT) applied to 885 industrial companies. Later, in 2005, a second survey of development and technological innovation in manufacturing (EDIT II) was done to 6.172 companies from the industrial sector for the period 2003-2004. This survey and subsequent was led by the National Administrative Department of Statistics (DANE). Up to now six EDITs have been done. EDIT III for years 2005 – 2006; EDIT IV for years 2007 – 2008; EDIT V for years 2009 – 2010; and EDIT VI for years 2011 – 2012. Companies strictly innovative are those that in the reference period had at least a new or significantly improved good or service for the international market; companies innovative in a broad sense are those that in the reference period had at least a new or significantly improved good or service for the national market or for the company, or that implemented a new or significantly improved productive process for the main production line or for the complementary production lines, or a new organisational form or commercialisation; potentially innovative companies are those that in the reference period did not have any innovation, but reported to have a process or have abandoned an innovation project to obtain a new or significantly improved good or service for the international or national market or for the company; no innovative companies are those that in the reference period did not have any innovation or reported to have a process or a project to obtain innovations.

Divulgation of calls for supporting STI projects and access to tax benefits is insufficient. Calls are launched on websites but there are no effective communication channels with associations, chambers of commerce, guilds and business and producers agencies to broadcast the calls. The process to apply for and gain access to resources is not clear which hinders the effectiveness of the incentives. And this not only happens for the business sector, it also happens for the Technology Development Centres (CDTs). Colciencias supported the creation of CDTs from the 1990s onwards, after the first law for S&T was launched, but not all of them had access to seed capital for their creation, and there has not been continuity in their support. The initial plan was to provide seed capital for a three year period, but centres got funds just for one or two years. As a result, CDTs without strong private support were not financially viable. Again, there is no consistency between policies and instruments for long-term periods (Barreto Bonilla, Bermeo Andrade, & Saavedra Moreno, 2008).

There is also an imbalance between large enterprises and SMEs. Although many instruments have been thought to favour and strengthen SMEs, most of public resources are going to large companies. 80% of total resources are going to large companies (EDIT VI). Referring to the higher access of large companies to public incentives to support innovation in the business sector, Mrs Gladys Turriago, advisor of the cross-sectional area of the presidency of the National Association of Industrials (ANDI), comments:

> Large companies are most aware of the existent incentives; they are the ones that take advantage of, I do not know if of the system as such, but basically of Colciencias. They are vigilant of these relationships, they know when calls are coming, and they are very sensitive of the issue. (Gladys Turriago, personal communication, August 23rd, 2012)

Also, taking this issue further and reflecting on the differences between the research and innovation policies, Dr. Mónica Salazar, executive director of the National Observatory of Science and Technology of Colombia, says:

> On the issue of the instrumentalisation of policies, I think the country has been successful in terms of research. The research policy of the country has been successful, but the innovation policy has been unsuccessful. IDB's[30] evaluation gives very good results, but just in 20 companies, we do not need good results in 20, but in 1000. Then, there is a very big problem of instrumentalisation. (Mónica Salazar, specialised focus group, May 17th, 2012)

Leaving aside the unbalanced access to STI resources amongst large firms and SMEs, there is another structural problem that hinders the effectiveness of incentives within the NSSTI. Colombia has an overwhelming percentage of firms in the informal economy, particularly small and micro enterprises[31]. According to Fedesarrollo[32] (Cárdenas S & Rozo V, 2009), business informality reaches 41.1%, so the actual implementation of instruments is beset with problems. This inhibits access to incentives for nearly half of the firms of the country. It means that in addition to insufficient incentives, the existent ones are not targeting a wide population of firms. This is a good example to illustrate the systemic nature of innovation. There must be equilibrium and good performance in other subsystems, so policies are geared to generate the intended effects.

Seeing things from a different angle, there have also been successes. SENA is the public organization more recognised by industrials for promoting science, technology and innovation activities (STIA)[33]. SENA works jointly with Colciencias, ministries, and other public and mixed organisations to allocate resources through public calls. This is not surprising given that from 1996 SENA has allocated 20% of its resources to developing programs for competitiveness and productive

[30] The Inter American Bank of Development (IDB) launched a project in April 2011 to support the design of an integral program to strengthen the Colombian STI policy. Colciencias was in charge to execute the project.

[31] According to Law 905 of 2004, a small enterprise has a personnel plant between eleven (11) and fifty employees (50); or has total assets worth between five hundred and one (501) and less than five thousand (5,000) monthly legal minimum wages. A micro enterprise has a personnel plant not exceeding ten (10) employees; or total assets excluding housing value, less than five hundred (500) current legal monthly minimum wage.

[32] The Foundation for Higher Education and Development (Fedesarrollo) is a private non-profit organization established in 1970. It is engaged in research on issues of economic and social policy.

[33] According to EDIT V results, during the period 2009-2010 innovative and potentially innovative companies consider the following organizations as key bridges to support the execution of STIA: SENA (678 companies); ICONTEC (568 companies), universities (537); sectoral guilds and chambers of commerce (482); PROEXPORT (391) and the Superintendency of Industry and Commerce (379).

technological development[34]. This has allowed long-term support to S&T initiatives directly aimed at the business sector. Dr. Maria del Pilar Noriega, Scientific Chief of the Institute for the Plastic and Rubber Research and Training (ICIPC) says regarding to the support given for innovation by SENA:

> For us it was very important when Law 344 came into force in 1996. This allowed business to have co-financing mechanisms, which was wonderful…We work with SENA, and I think we've worked with them about 50 projects. It works well… SENA is simply fulfilling its function of being a good financing entity with long-term policies. That is, it started in '96 with the law 344, and it has financed directly or it has transferred funds to Colciencias. Saying that in Colombia an entity from 1996 -we are in 2012- still has a path and results is a dream. In a developing country, this is good, and it must be said. (Maria del Pilar Noriega, personal communication, July 9th, 2012)

However, there is redundancy in the calls made by different organizations. There are either broad calls so any project can be adapted to the call terms, or there are very similar calls at the same time from different organizations. This reveals that there are coordination problems between public organizations and that functions of each body related to the promotion of entrepreneurship, innovation, S&T projects, and competitiveness, are not clearly defined. Further, there are administrative and planning issues in the execution of calls, causing delays in the assignation of resources and meagre management and assessment. Complaining about the inefficiency for assigning and giving resources after fulfilling all requirements, Mr César Echeverry, CEO of Supracafé, a private company for coffee production and commercialization, and ex director of technological development of the Ministry of Agriculture and Rural Development of Colombia, says:

> I was on the advisory board Colciencias, so I know well the dynamics of them. They open calls with great fanfare, and then allocate less than 10% of the resources they promised, because they do not really have them. If you take into account that filling out the formats and requirements for the Integral Project Management System is an exhausting

[34] See article 16 of Law 344 of 1996.

> process, one says as an entrepreneur, what a waste of efforts to get nothing. (César Echeverry, CEO Supraface, 2013)

Nevertheless, tax incentives and all sort of instruments are not a sufficient condition to innovate. If there is not an explicit will from the strategy of the firm to innovate, there will not be good enough incentives to move the companies in that direction. Incentives are mechanisms to support the growth and development of the mission and vision of companies to move forward. There is a problem of culture and market protectionism. Companies in Colombia do not perceive innovation as a key factor to succeed, so there is fear of investing in any activity of science, technology and innovation, and R&D, because the economic benefits are not seen in the short term.

4.3.6. Purpose and importance of science, technology and innovation policies

Previously we discussed how science, technology and innovation policies direct purpose is not alleviating UBN. Moreover, an innovation policy may imply in the short-term destruction of jobs (i.e. investment in some sectors over others, or the introduction of technology that automatize processes previously done by people). STI policies are not intended to solve immediate poverty problems; so having sensible social and economic policies is an essential requirement for providing welfare to the population. However, strategies to improve traditional sectors and to develop sophisticated sectors with higher value and therefore higher profits is a necessary condition to change the dependency inertia followed by Less Developed Countries (LDC) on industrialised economies. Central governments have not understood what the implications on having a national strategy focus on STI are, why that strategy is important for the country, and how to maintain it through time.

Research and reflection on the conceptual body for the construction of S&T policies is recent in Colombia, which has caused a lack of feedback to the public sector for having more comprehensive processes for the construction of sustainable political models, as it is highlighted in the latest book about the history of Colciencias (Various, 2013). Social and economic problems will not be solved in the short time with STI policies, but certainly a good long-term strategy to create, apply, and validate knowledge, will bring better living conditions for the population through the development of a stronger economy able to compete with high added value products.

> In Colombia the construction of an institutional setting for science and technology is a recent issue. In developed countries for more than two hundred years and with a higher intensity in the last fifty years, there is the conviction that the wealth of nations and its viability is associated more with the capacity that a society has to create, diffuse, and absorb science and technology products. (Various, 2013, p. 67)

Another issue commonly seen in the construction of Colombian STI policies is the unconsciously[35] use of the linear thinking of innovation where exists the assumption that having science and the creation of new knowledge, the natural course is having processes of development and application of science, followed by technological innovations, which in turn lead to economic growth and development, all in a linear an unidirectional relationship, as it is explained by (Tait & Williams, 1999). Referring to the use of this thinking paradigm (he calls it mode one of knowledge), Santiago Echavarría, head of the Science and Technology Centre of Antioquia (CTA) says:

> Even though it is said that in Colombia we are over the mode one of knowledge production, there's still a dominant paradigm in the implementation of policies, in the policy instruments to develop such policies, to favour endogenous production of knowledge, specially in research groups, with the assumption that you have to build capabilities, which is very important, but it is thought that somehow these capabilities will result in innovation. I think that our policies are still focus on this model, although we say we don't follow it. (Santiago Echavaría, personal communication, July 17th, 2012)

Although science policy has been more successful in terms of its discussion and evolution over time[36], there are shortcomings in the skills required to build

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[35] In any public document there is a mention about the use of the linear thinking model of innovation and during the interviews done to S&T policy makers, any of them acknowledge the use of this model for the Colombian STI policies.

[36] Since Colciencias constitution its activity has focused on the science and research side of the system more than on the technology and lately innovation side. This can be noticed in the calls for projects opened by Colciencias and the allocation of resources for science production.

sustainable production processes and the use of knowledge for innovative technological developments. The inclusion of innovation as a predominant factor in the industrial and service sectors is new to the business culture, so there is still a long way to go in this regard. Meanwhile, policy-makers continue to focus on government priorities, setting aside a sustained state vision. Innovation, competitiveness and productivity are often terms used interchangeably. Therefore the instruments designed to support innovation processes are unfocused. This point is clearly expressed by an official of Colciencias:

> I think there is no tension [between state and government policies] because we don't have state [STI] policies. I think we have to do a national exercise to think for a long term. At least 10 years later. What we want to achieve in terms of research and innovation. We can achieve that through traditional mechanisms like CONPES [National Council of Social and Economic Policy]. (Colciencias' official, August 23rd, 2012)

4.3.7. Politics of Policy

Colombia is a country where everything is very carefully formalised in law, however, Colombian society works very hard to circumvent these laws. Since everything is heavily formalised through all sort of legal devices, public and private actors try to find the exception to the norm. Negotiations between powerful actors can change the aim of a public incentive or intervene in public calls to favour certain public or private persons. That is why the process of policy construction is not a linear one and is always under constant negotiations. Having an operational and successful NSI depends less on the formal institutions behind it, and more on the common consciousness of players to have a win-win game with clear and transparent rules of game.

One recurrent claim made by system actors interviewed is that STI policies during the last 20 years have not been participatory and have only been negotiated between powerful political actors to favour particular interests. Academic and industrial sectors have been put aside in policy definition, which has caused misalignment between the formal and real system. This claim is clearly expressed by Dr. Emilio

Quevedo, ex national program director in Colciencias and a prominent academic currently working on studies of science and technology: “Now policy is defined top-down, and not bottom-up. That is part of the problem.” (Emilio Quevedo, personal communication, January 18, 2012). Also, Luz Elena Castrillón expresses it as a semi-private actor in the national system of innovation:

> We do not have any say at all, anywhere. At first at least we had voice, at least we participated in the design of policy, not now, they invite us to see what they [policy-makers] decided, it does not matter if we like it or not, whatever we do, whatever we say, they keep on. If you start looking recent plans for science, technology and innovation, you will see that they have consulted all stakeholders, but if you look deeper, or if you had been part of this system as I have been, we know that we are not called to participate in the design of the policy, they just call us to let us know, that's a completely different thing right? They call to inform us. (Luz Elena Castrillón, personal communication, March 17th, 2012)

Another factor that heavily impacts on the good functioning of the innovation systems is the political institutions weakness. Colombia has particular circumstances related to violence problems for the last 70 years. The existence of illegal armed groups has undermined democratic institutions, influencing the election of politicians with close nexus with these groups. This has caused public funds are embezzled by actors on the margin of the law preventing coherent strategies for long-term development. Of course, investment in science, technology and innovation, remain among the lowest priorities. It is a matter of mentality and cultural setting, where immediate personal gain premium on social benefits. An accumulation of political and economic scandals where politicians are involved has caused that Colombians do not trust their public representatives[37]. It is also a common practice that public positions are defined by influence peddling, and not by the suitability of the person to occupy it. This has caused a progressive weakening of political institutions (Gutiérrez, 2013).

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[37] “The survey conducted by the Latinobarómetro in 2011 revealed that Colombians considered that the most important factors to strengthen their democratic system would be reducing corruption (63%) and improving the transparency of the state (54%)” (Gutiérrez, 2013, p. 2)

Therefore, in the Colombian case, political analysis must go beyond the regular components of any innovation system. It is essential to analyse the cultural setting and the violence problem inserted in the evolution of the country for understanding the success or failure of policy initiatives. It is understandable that policy priorities have focused on solving immediate problems of poverty, insecurity, infrastructure, food security, education, among others, but this short-term vision has caused a vicious cycle devoid of an integral country strategy. There are many interests at stake and the fittest has dominated to support personal interests over collective interests. Although this has not always been the case, it has been predominant.

4.4. Policy Outcomes at the National Level

4.4.1. Legitimacy and Impact of Explicit and Implicit STI Policies

The national level policy development section included the evolution of STI policies in Colombia. Some international and national milestones were highlighted as explicit actions towards the development and consolidation of STI capabilities. Figure 4.8. shows a STI key events timeline:

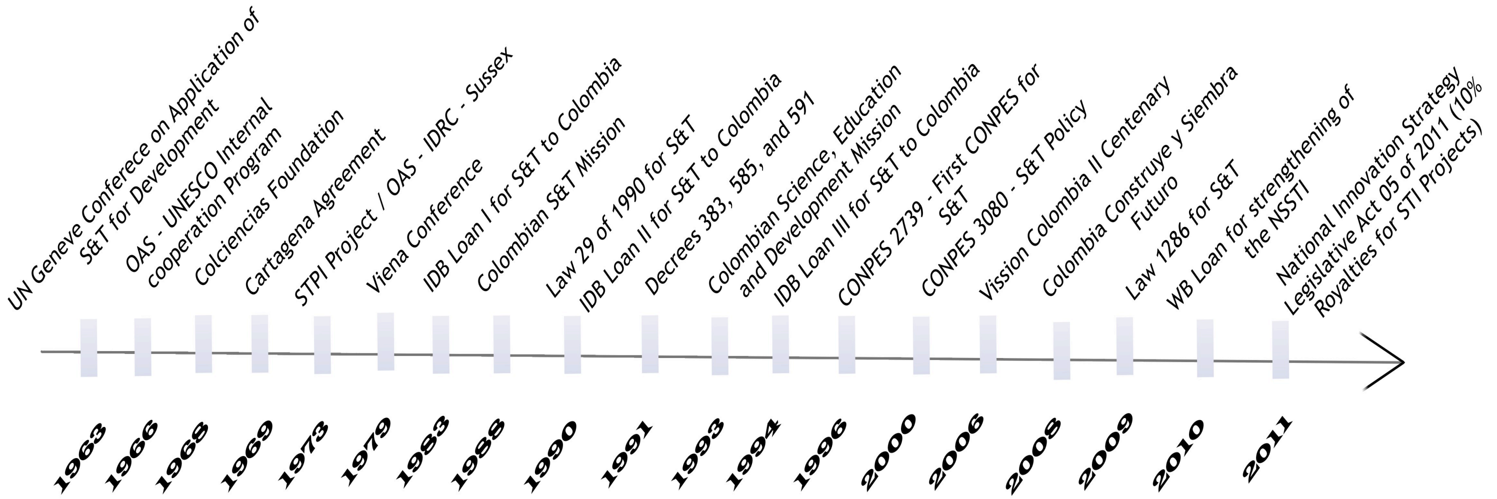

Figure 4.8. STI key events for construction of STI explicit institutionality.

Source. Information compiled by the author.

The development, implementation and outcomes of STI initiatives did not evolve and materialize through random actions. Colombia, as a LAC and developing country, was immersed in a regional trend to promote and support S&T initiatives as a way to generate better life conditions for Colombians in the mid- and long-terms. The strategy of policy-makers during the second half of 20th century revolved around the inclusion of STI mechanisms within economic, sectoral, industrial, and foreign trade policies, at least at the formal level. Debates around strategies to boost LAC national economies included higher investment in S&T and building suitable institutional settings to increase competitiveness in international contexts. So before the first law for S&T was promulgated in 1990, there were implicit policies in progress promoted by Colciencias' policy-makers.

The approach followed from the 1960s until the 1990s was essentially one of science-push and demand-pull. The regional movement known as Latin American Structuralism Approach (LACSA) influenced Colciencias during these decades. The maximum expression of this movement was the boom of an industrial period characterised by an import substitution strategy (ISI). There was a focus on generating capabilities within the national and regional firms to produce goods and services usually imported from developed countries. This period – from the late 1960s until the late 1980s – had an explicit strategy on strengthening the domestic market through fiscal policies like subsidies to strategic industries, protectionist trade policies, nationalization of firms, and tax benefits. This economic package had the intention to reduce foreign imports, creating a sophisticated domestic market with the inclusion of local innovations. Development was state-led, with a heavy centralism. It was thought throughout the entire LAC region that strengthening domestic markets, dependency between "centre" and "periphery" would be broken[38]. The central assumption was that the gap between centre and periphery had a deep root on the labour division. Whilst centre countries were specialised on capital-intensive goods, periphery countries had their core on labour-intensive goods. Economists and

[38] This is part of the "dependency theory" where the key idea is that rich and developed countries (core states) enrich themselves through the extraction of resources from poor and less developed countries (periphery states). The main authors developing this theory were Hans Singer and Raúl Prebisch. The latter was the Economic Commission for Latin American Countries director in 1948 (OECD, 2013, p. 32).

politicians concluded that the market itself would be unable to reduce the gap so implementing a planned and aimed policy to improve the mechanisms for allocating resources, would be the best option (Munoz, 1981). Therefore, LAC could only grow insofar as the industrial sector was protected, at least during the initial stages of development (Garay, 2004). In this way, the group of academics and politicians part of the LACSA movement expected to build effective bridges between universities and national research centres and the business sector. The assumption was that once a stronger knowledge generation subsystem was built, the benefits of this knowledge would flow to the economic sector as part of a natural process (Martínez Vidal & Marí, 2002). However, it was not that easy.

One main indirect STI policy was decree 444 of 1967 about the international exchange regime and foreign trade. Through this decree the trade and foreign exchange policy was controlled by giving priority to the internal construction of capabilities in focalised sectors. The decree adopted the crawling peg system[39], eliminated multiple exchange rates and strengthened the control over capital flows derived from imports and exports. During the period 1967 – 1974 exports of finished products were promoted, together with a strengthening of the domestic industry. In 1969 the Cartagena Agreement was signed so conditions were created to have industrial imports substitution and have a dynamic intraregional trade[40]. The main intention was to close the gap between wealthier countries and the region through an ambitious bet on the generation of internal capabilities of science, which it was believed, would bring technological development, and therefore innovation. It is relevant to remember that Colciencias was founded in 1968, as part of the Ministry of Education. This was the result of a long process started by Colombian academics and technicians that were part of LACSA. Colciencias was a formal entity within the government to fund, promote, coordinate, and execute scientific and technological development projects. In 1968 the Colombian Institute for the Promotion of Higher Education – ICFES – was founded too. ICFES promoted the insertion of scientific

[39] Crawling peg is an exchange rate regime to regulate depreciation or appreciation in an exchange rate. The system is shaped to peg at a certain value but at the same time is designed to "glide" to response to external market uncertainties.

[40] However, results were insufficient, because although it partially liberalized intra-regional trade, there was an extensive list of exceptions, disagreements among Andean pact members, and failure of sectoral industrial programs.

and technological skills in the Higher Education Institutions (HEIs) accordingly with the productive sector demands.

After the creation of Proexpo (1967), Export Promotion Fund, Colombian fiscal policy had an even stronger concentration on exports. Through Proexpo, preferential loans were given to sectoral non-traditional industries[41] jointly with a favourable exchange rate. However, from 1978 after a change in government, there was a revaluation process of the local currency, the Colombian Peso, which seriously affected exports (excluding coffee exports), going against the plan of turning Colombia into a leading exporting country in the LAC region. The adverse exchange rate added to a low diversification in exporting products caused a further 10% drop of exports between 1980 and 1983. The situation was worse for minor industrial exports, which fell on average over 114% per year due to their lower capacity to resist financial breakdowns (Garay, 2004). Then, in 1981 there was an agreement between INCOMEX (National Institute for Foreign Trade) and Colciencias to promote capital goods. From that moment on, technological disaggregation for large investment projects of the State was mandatory. In 1983, through the first Inter-American Development Bank (IDB) loan for promotion of S&T capabilities, S&T projects were funded, especially those related with the modernization of research systems and technological services in the productive sector.

Conversely, the second half of the 1980s experienced an increasing economic growth produced by an increase in the volume exported and better price conditions of coffee (which by 1986 represented more than 50% of total exports of the country) and oil exports. In 1989, following a change in the government structure, a process of market deregulation started gradually changing the protection strategy towards economic openness. This process was finally materialized with derogation of decree 444 of 1967. Law 9 of 1991 removed exchange controls made by the Bank of the Republic, the foreign investment regime was freed, and equal rights between domestic and foreign investors were declared. At this time, several research institutes

[41] Industries different from mining, coal, coffee and other commodities.

were opened[42] to fill the gap of R&D in the country. However, there was not a systematic process led by an integral S&T strategy. In 1988 the first S&T mission in the country was formed; its aim was to reflect on the design and implementation of S&T strategies at the national and sectoral levels. Main reflections revolved around the construction of a formal institutionality. As a result, the first law of S&T was launched in 1990.

New institutionality was structured to respond to the economic change. In 1991 the Ministry of Foreign Trade was created; Proexpo was restructured and was transformed into the Bank for Foreign Trade (BANCOLDEX), to provide preferential loans access to exporters; and Proexport was created as a unit to provide opportune information on international markets to Colombian exporters. But these measures to improve the trade balance, and encourage exports as the engine of national economy were counteracted with increased imports of consumer goods (on average a 33% increase between 1990 and 1996), and a low contribution of exports to GDP (on average 20% during the same period). There was an increase in domestic demand, but fulfilled with imports[43].

> This diversification has taken place in an environment that has not been altogether conducive to an expansion of export-oriented production. A lack of financial resources and the underdevelopment of the domestic capital market limits both the ability of the Government to finance support services such as research institutes, market identification services, and mineral prospecting, and the capacity of the private sector to finance large-scale projects. (UNCTAD, 1994, p. 7)

In November of 1990 -short after the first S&T law was promulgated- Colciencias, the National Institute for Science and Technology, gained power by being ascribed to the National Planning Department (DNP). Also, the political strategy was focused on the constitution of a National System of Science and Technology (NSST). The message was clear – at least formally -, S&T would be key elements in the

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[42] Colombian Petroleum Institute (1985); Centre for Biological Research –CIB- (1970); International Centre for Medical Research -CIDEIM- (1989); Research Centre for Sugar Cane (1977); International Centre of Physics –CIF- (1985); among others.

[43] DANE trade balance data. Retrieved from: http://www.dane.gov.co/index.php/pib-cuentas-nacionales/cuentas-trimestrales, in 26-05-2014.

development of the nation, and its promotion and regulation would be State issues. To support this strategy, besides domestic inversion in S&T, the third IDB loan was released. "IDB resources II and III executed during this period were of the order of 140 million dollars and a counterpart of the national government of 118.5 million dollars, which were implemented in the construction of the NSSTI." (Plata, 2013, p. 96)

In 1995 a National System of Innovation (NSI) is declared as part of the NSST. This system is defined in CONPES 2875 of 1996 as follows:

> The National System of Innovation is conceived as an iterative model of creation and application of knowledge. It includes various actors associated with technological development and its link to production systems, in a process of continuous quest of sustainable competitiveness and improvement in the quality of life of the population. This system is part of the National System of Science and Technology.

However, from 1996 to 1999 there was an important downturn of the Colombian economy (see Figure 4.1. GDP at constant prices). This corresponded to a revaluation of the exchange rate, and a significant increase in public spending. This generated profound macroeconomic imbalances. This instability added to the wider international financial crisis in 1998, which produced a negative growth of the GDP of 5.2 in 1999. Recuperation came with a major expansion of the tradable (industry, mining, agriculture exports), and non-tradable (construction and services) sectors by 2003 (Kalmanovitz, 2004). Afterwards, imports and exports kept focus on goods rather than services. Goods exports were mainly coal and oil (Tables 4.4 and 4.5).

Percentage of GDP	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Total Exports	**15.2**	**14.9**	**16.5**	**16.7**	**16.8**	**17.3**	**16.5**	**17.5**	**16.3**	**15.8**	**18.8**
Goods	13.1	12.7	14.6	14.7	14.8	15.5	14.7	15.8	14.5	14.3	17.3
Services	2.1	2.2	1.9	2.0	1.9	1.8	1.8	1.7	1.8	1.6	1.5
Total Imports	**16.2**	**15.7**	**17.5**	**16.9**	**17.0**	**18.7**	**18.0**	**18.3**	**16.4**	**16.3**	**18.5**
Goods	12.5	12.3	14.0	13.6	13.7	15.3	15.0	15.4	13.4	13.5	15.7
Services	3.7	3.4	3.5	3.4	3.3	3.4	3.0	3.0	3.0	2.8	2.9
FDI* in Colombia	**2.6**	**2.2**	**1.8**	**2.6**	**7.0**	**4.1**	**4.4**	**4.4**	**3.0**	**2.4**	**4.0**
Colombian OI**	**0.0**	**0.9**	**1.0**	**0.1**	**3.2**	**0.7**	**0.4**	**0.9**	**1.3**	**2.3**	**2.5**

Source: Banco de la República

* FDI: Foreign Direct Investment.

** OI: Overseas Investment.

Table 4.4. Main external sector indicators 2001-2011.

Source. (Fog, Salazar, Nupia, & Vesga, 2012, p. 22)

Percentage of GDP	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
TOTAL	**12.6**	**12.2**	**13.9**	**14.3**	**14.5**	**15.0**	**14.4**	**15.4**	**14.0**	**13.9**	**17.1**
Coffee	0.8	0.8	0.9	0.8	1.0	0.9	0.8	0.8	0.7	0.7	0.8
Coal	1.2	1.0	1.5	1.6	1.8	1.8	1.7	2.1	2.3	2.1	2.5
Ferronickel	0.2	0.3	0.4	0.5	0.5	0.7	0.8	0.4	0.3	0.3	0.2
Oil	3.3	3.3	3.6	3.6	3.8	3.9	3.5	5.0	4.4	5.8	8.4
Others	7.0	6.8	7.5	7.7	7.4	7.7	7.6	7.2	6.4	5.1	5.1

Table 4.5. Goods exports by sector 2001-2011

Source. (Fog et al., 2012, p. 22)

During crisis periods there were cuts to the S&T budget, however, the emphasis on competitiveness and technological development was maintained through SENA's support for firms and technological development centres; development of regional S&T agendas; the establishment of six centres of excellence; and the latest STI law in 2009. In the government plan 2010 – 2014 innovation is included as fundamental and cross-sectoral for social and economic prosperity. Finally, legislative act 05 of 2011 transfers 10% of natural resources royalties for STI projects.

After failing to develop the planned domestic S&T capabilities to meet regional and national markets through industrial protection came the economic liberalisation during the latter 1980s and early 1990s. It was expected that the exposure of national firms to international markets would make them more competitive. It was exactly the inverse assumption of the previous decades. In order to survive, companies should lower production costs, improve quality, introduce new products and services, and have a proactive feedback with customers. However, the gap in terms of technological capabilities and innovation with companies from developed countries was bigger than in the 1980s, so it was very hard for enterprises to catch up. Competition was fierce and only the strongest companies survived[44].

On the other hand, firms' expenditure on Science and Technology Activities (STA) has been limited and stagnated during the last 10 years, as can be seen in Table 4.6. The business sector, being the backbone of any SI besides national and international investment and incentives, should have a co-responsibility and awareness of the investment in R&D.

Tabla 1.6. Inversión en ACTI de las empresas –ejecución, 2002 - 2012
Firms STA expenditure, 2002 - 2012

Tipo de actividad Type of activity	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2002 - 2012
I+D / R&D	22,61%	22,61%	20,18%	23,66%	20,40%	22,41%	27,14%	30,24%	29,05%	29,05%	29,05%	25,62%
Actividades de innovación Innovation activities	77,39%	77,39%	79,82%	76,34%	79,60%	77,59%	72,86%	69,76%	70,95%	70,95%	70,95%	74,38%
Total ACTI / STA (millones de pesos de 2011 / million COP of 2011)	543.484	574.832	729.691	577.899	641.523	930.674	1.117.949	737.520	876.870	943.487	1.003.551	8.677.482

Fuente: DANE - EDIT II, EDIT III, EDIT IV Y EDIT V
Cálculos: OCyT

Table 4.6. Colombian Firms STA expenditure 2002 - 2012

Source. (Jorge Lucio et al., 2012, p. 24)

Comparing Colombia's overall expenditure in R&D with leading Latin American Countries and the regional average, it can be seen that the country is far beyond desirable investment, and much more from OECD countries (Figure 4.9).

[44] According to the annual survey of manufacturing firms applied by DANE from 1992, during the 1990s there was a strong decrease in the number of SMEs, especially between 1992 and 1996. However, the number of large companies remained nearly constant during the same period with a slow decrease between 1997 and 2000.

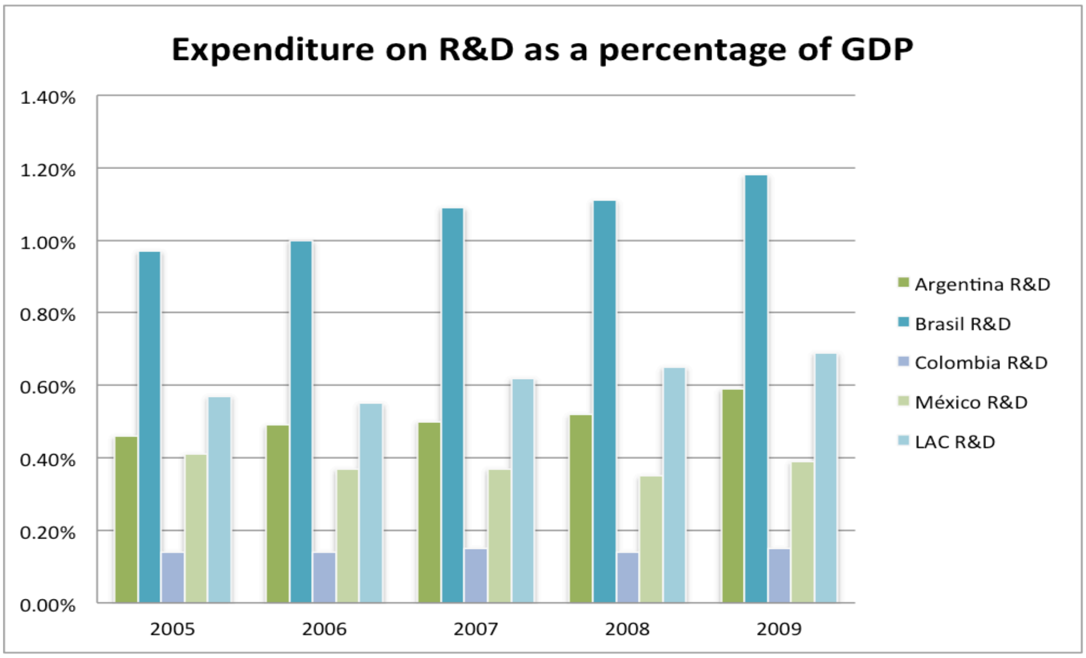

Figure 4.9. Expenditure on R&D as a percentage of GDP for selected countries.

Source. Information compiled by the author based on RICYT indicators.

However, this is not a peculiarity of the Colombian business sector. Whilst it is not debatable that presence and synergy between different key actors within the so-called innovation systems (public sector, business sector, academic and research sector, intermediaries) is fundamental, what has been understated is the extent to which each one of them should intervene in the innovation pathways. A major responsibility has been put on State's shoulders to boost the performance of the IS, but the business sector has taken a more parasitic approach in taking advantage of public investment without a constant and committed counterpart; known as 'socialization of risk, and privatization of rewards' (Mazzucato, 2013). So, more investment is required for STA at all levels. That factor is well acknowledge in the OECD review of the Colombian innovation policy, where firms are at the centre of the system and should build internal capabilities: "International evidence suggests that the most important source of business innovation is firms' own efforts." (OECD, 2013, p. 28)

One example of an implicit policy that burdened a better building of S&T capacity in the flowers productive chain within the agriculture SI is that of tax exceptions and income protection for exporters with high dependency on foreign currency earnings. The aim of the policy was to protect the sector from the progressive revaluation of the Colombian peso from 2003 to 2008, but it caused the sector to become largely reliant on the incentives and a low investment in critical factors to increase productivity through S&T. Thus, there are mismatches in the policy mix within the Colombian context. The institutional setting lacks a stronger coherence between national, regional, and sectoral policies and a tension between short and long term policy programs. This is an important barrier for the successful functioning of SIs (H. Jaramillo, Villaveces, & Cantor, 2013).

4.4.2. Results pathway. Issues for consideration

Regardless of the policy model for building STI policies used during different stages of evolution, there have been divergences between intended pathways and obtained results. There are fundamental factors underlying the success of STI initiatives that will be explore in this section. Consequently, this section will be focused on four aspects we found as crucial for the performance of the so-called Colombian NSI. 1. Funding STI activities is the engine to produce changes and to promote certain sectors according to national strategies. 2. Building capabilities to support the strategic STI pillars. Without a critical mass of human resources to produce and absorb scientific and technological knowledge, it is extremely difficult to have innovation in the productive sector. This aspect takes us to the third important factor. 3. If society does not consider the construction of S&T capabilities as relevant and important, it is less likely that knowledge will be perceived as a key progress factor in the social structure. Therefore, the insertion of scientific education within the education cycle is fundamental to have a broader appropriation and appreciation of knowledge. Not just in terms of scientific capabilities, but also in the development part of the research, where social problems can be effectively tackled through innovative technologies. 4. Since competition in the world market is fierce, it is imperative to channel resources and efforts to the promotion of certain strategic sectors. This process of selection should be consistent with medium and long-term strategies to generate the capacity to compete internationally (See Figure 4.10).

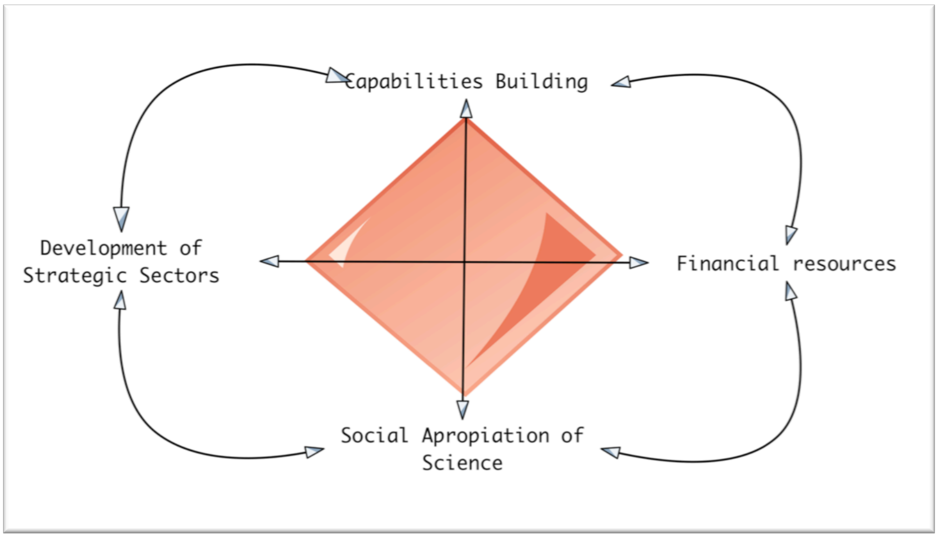

Figure 4.10. Key factors for performance of Colombian NSI

Source. Made by the author.

A good analysis on the performance of the so-called national system of science, technology, and innovation is CONPES 3582. In this public document there is a comprehensive outline of the principal weaknesses and constraints of the Colombian NSI (DNP, 2009):

1. Low levels of innovation in enterprises
2. Weak institutionalism of the system
3. Scarcity of human resources for doing research and innovation
4. Lack of focus on strategic areas
5. Low social appropriation of knowledge
6. Regional disparities in scientific and technological capabilities
7. Low capacity to generate and use knowledge

These weaknesses are consistent with our documentary analysis of the system and the interviews and specialised focus groups we developed as part of this research. We found that capabilities building and social appropriation of science are fundamental factors related directly with embedding social action towards resilient and sustainable solutions based on S&T capacity. Meanwhile, financial resources and the development of strategic sectors impact directly on the viability and purpose of the system. All of them are inter-related and depend on each other to support the innovation pathways. We will now turn to examine these key factors in detail.

4.4.2.1. Shortage of financial resources for STI

Weak political institutions and lack of coherence between policies – previously studied in the policy implementation section - have impacted on the allocation of financial resources for STI. One of the most important studies on S&T planning at the national level was "Colombia: Al Filo de la Oportunidad", (Colombia: On the edge of opportunity). The guiding principles for having a prosperous and equalitarian Colombia were science, education and social and economic development. This was a seminal project that declared a specific program for the endogenisation[45] of science and technology as main variables for sustainable development.

The program for the endogenisation of science and technology had five specific objectives. The first objective to promote S&T stated: "Substantially increase the investment in science and technology, breaking the traditional pattern of small annual increases, to reach at least 2% GDP investment." (Consejería presidencial para el desarrollo institucional, 1995, p. 104)

This goal should have been achieved in the next 5 years: "It is proposed, as a minimum goal, that in the next five years before 2000, there will be an increment in the current level of 0.4% of GDP to 2% of GDP to support research and scientific and technological development programs."(Consejería presidencial para el desarrollo institucional, 1995, p. 106)

This has been the evolution of the investment in R&D and Science and Technology Activities (STA) as a percentage of the GDP, according to the Colombian Observatory of Science and Technology:

[45] This was the word used in the document to express the necessity of developing internal capabilities in science, technology and education as the bases for the economic and social development of the country.

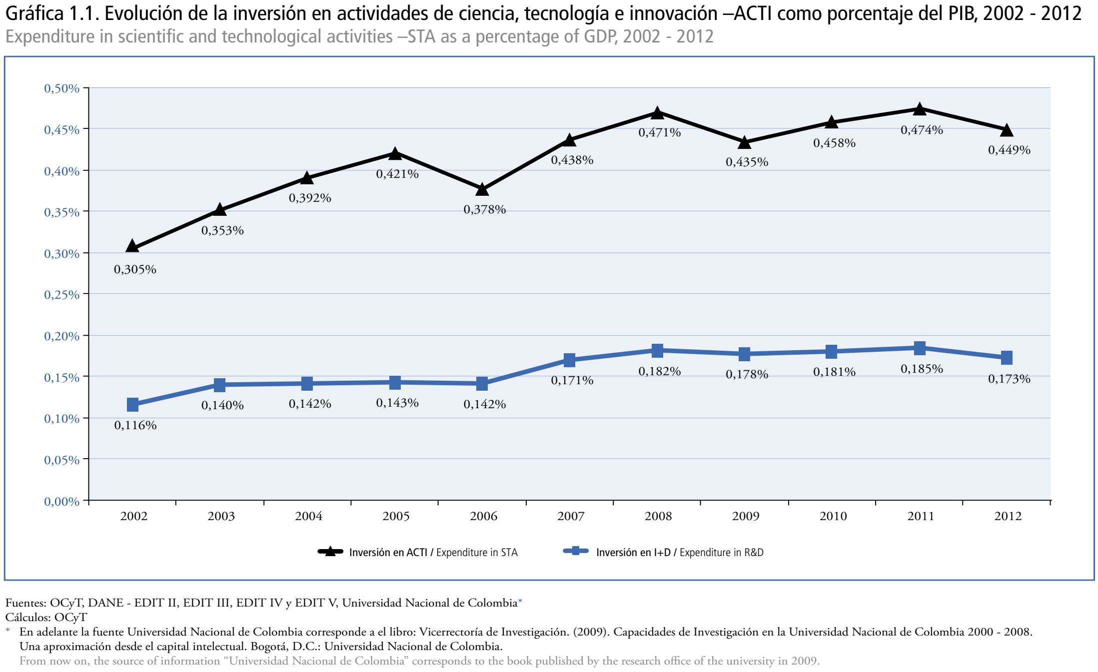

Figure 4.11. Expenditure in scientific and technological activities – STA as a percentage of GDP, 2002 -2012

Source. (Jorge Lucio et al., 2012, p. 18)

In 2012 the joint expenditure in STA and R&D was only 0.62% of GDP. From this document, subsequent government documents have stated that it is crucial to invest more in STI. The latest presidential government plan insists on increasing the public investment for STI. The goal is that for 2014 the investment in STI as a percentage of the GDP should be 1%. This constant deviation on the expected vs. real public investment on STI may imply a lack of commitment from governments to build S&T capabilities as economic and social engines to promote sustainable welfare.

Table 4.7 shows investment thresholds proposed by five different national documents related to promotion of science, technology and innovation.

	CONPES 2739 of 1994	**Colombia al Filo de la Oportunidad**	**Visión Colombia II Centenario**	**Colombia Construye y Siembra Futuro**	**CONPES 3582 of 2009**
Investment in S&T as % GDP	1% in 1998	2% in 2000	1% in 2010 and 2% in 2019	1% in 2010 and 2% in 2019	2% in 2019

Table 4.7. Investment in S&T as percentage of GDP proposed by several public documents.

Source. Information compiled by the author.

It has been clear that an increase in the investment for S&T is an overriding concern, at least in white papers, but after almost 25 years, the country has not even achieved the conservative goal of 1% of investment in S&T. Since R&D and STA investment is important for the proper functioning of SIs to provide incentives to innovating organization and innovation processes, this is a key factor to observe (Edquist, 2004).

This situation is acknowledge by the national planning department (DNP) in the previously mentioned CONPES 3582: "Progress has not been as expected, today, many of the limitations identified in previous diagnoses persist" (DNP, 2009, p. 7). It can be noticed that even when different governments have commissioned specialised studies to diagnose Colombia's performance in terms of S&T capabilities and proclivity to innovation, and there have been several recommendations about investment in S&T, results show little progression from 1990 until now.

Going further, and questioning the reasons why a repetitive goal about investment - known by policy-makers, and reinforced by international best practices - has not been achieved, we can hypothesise that the economic growth of the country has not been good in the last decades so the STI budget has been consequentially reduced, or that STI are not perceived as important factors to develop social welfare. However, looking at Figures 4.1, 4.2 and 4.3 – within the macroeconomic environment section -, it can be seen that even having difficult periods, there has been a positive GDP and a positive total factor productivity. This may imply that there is a low valuation of STI by the Colombian society, and mostly by politicians and policy-makers. This is acknowledge by Colciencias:

> The system has two major limitations, scarce and unstable financial resources and a low valuation of the STI in Colombian society. This ultimately has important consequences on the competitiveness of the Colombian economy. (Colciencias, 2008, p. 10)

This situation can also be seen in the private sector. Businessmen do not perceive S&T as key factors to increase productivity, competitiveness, and consequently profits. Evidence of this is the low investment in STIA and R&D by the business sector[46] (see Table 4.6 – Colombian Firms STA expenditure 2002 - 2012). This fact is highlighted by the WB in a S&T policy assessment made in 2006:

> Total investment in technology and R&D is low and unstable. Private sector capacity and spending in R&D is limited and the scientific and technological base is insufficient, and public governance of the Innovation System seems out of touch with needs for increased emphasis and coordination. (World Bank, 2007, p. 17)

The structure to allocate public financial resources is also problematic for emergent long-term STI projects. Research and innovation programs require at least a two-year cycle to develop products and/or services. Afterwards, there are processes of translation, testing, adaptation, and validation of these new products or services for the productive sector (Beard, Ford, Koutsky, & Spiwak, 2009). Having incentives that depend on annual term budgets, inflict inflexibility and threaten the success of such projects.

> Besides the difficulty in obtaining resources, there is a significant barrier to execute them because the total public resources for STI are subject to the national budget rules, which are provided for annual terms. This imposes rigidity to resources, which is at odds with the nature of the research and innovation projects that are characterized for being of long-term, high-risk, and staggered. (DNP, 2009, p. 18)

The limited financial resources has also meant that NSSTI actors have to fiercely compete for scarce resources, forcing them to do many things that are beyond their expertise so they can earn the STI calls for projects. Private, public, and mixed organizations transform themselves to be able to compete in open public tenders ("convocatorias"), so they can fulfil the requirements of funding agencies. This is a major problem, as it further disfigures the functional structure of the system. There is no consistency between the roles of the actors.

[46] STA and R&D funding by resource type 2002-2012 shows that variation from 2002 to 2012 in STA funding by public sector was of 52.36%, while private sector had a 44,07%. On the other hand, R&D funding in the same period by public sector was 54.73%, against 40,30% from private sector (Love, 1980).

Overall investment in S&T has been deficient over the last 70 years. The importance of building S&T capabilities as fundamental factors to generate social and business innovation has been a recurrent strategy. In order to achieve the goals highlighted in white papers to strengthen the nation's innovation capacity, more commitment to long-term investment by public and private sectors is needed. However, tension between implicit and explicit policies; changes of governments that change priorities in the short-term with impact in the medium and long terms; lack of long-term sustained planning and execution; and a low valuation of S&T as important developmental variables, have led to a low investment in innovation.

4.4.2.2. Capabilities Building

Emphasis has been placed on building scientific capacity. Creation and enforcement of technological capacity has been mostly left to the business sector and enhanced by technological development centres (TDC)[47]. Colciencias has invested most of its budget and efforts to strengthen the knowledge generation system. With this aim, most calls for projects have been directed to research groups in universities and research centres. Therefore, strengthening of research groups has been a main issue in the scientific capabilities building process[48]. It has been from 2009, with the modification of the S&T law, that design of new instruments has been a priority to encourage innovation in the business sector. However, this is a gradual process and effectiveness of these strategies will not be seen after at least five to ten years. So it

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[47] "These centres arose as private and non- profit institutions oriented to the offer of technological services as well as applied Research and Development (R&D) to the productive sectors through, among others, the performance of projects aimed at the transfer, application and diffusion of knowledge produced by universities, research centres and themselves" (Various, 2013, p. 19)

[48] The notion of research groups and centres is set from Law 29 of 1990 for S&T. Colciencias built a conceptual model jointly with the scientific and academic community to classify research groups in the country. Under this policy, the "research group" is defined as the core or basic unit of the NSSTI to generate knowledge from research. Groups were ranked every year by a committee of experts on a scale from 'A' to 'D', with 'A 'being the highest rating. From 2000 on, categories of groups were obtained by an index. Thus, category 'A' corresponded to the first decile of the index. In 2008 a new model of classification was designed based on the weight of products of the research group. The maximum index score is achieved if the group's production is equal or more than 8.5 out of 10. According with the score obtained and the age of the research group, it can be ranked into five categories: A1, A, B, C, D. A group is registered when it is inscribed in GrupLAC, the national platform to register research groups. A group is acknowledge if demonstrates verifiable results derived from research projects; has at least two members: has a declared age of at least one year: is endorsed by an institution registered in InstituLAC, the national platform to register research institutions; has a research project underway; the group leader has an undergraduate, master, or PhD degree; has at least one product per year; and has a production of social appropriation and circulation of knowledge.

is save to say that the Colombian NSI is more a research system than a technology and innovation one. We acknowledge that science, technology and innovation happen in an iterative cycle, so it is not our intention to separate their domains inextricably, however the emphasis in terms of funding and capabilities building has been put on the research side, following a linear approach to innovation.

According the National Observatory of S&T (OCyT) indicators book 2012, this is the distribution of research groups up to April 2012:

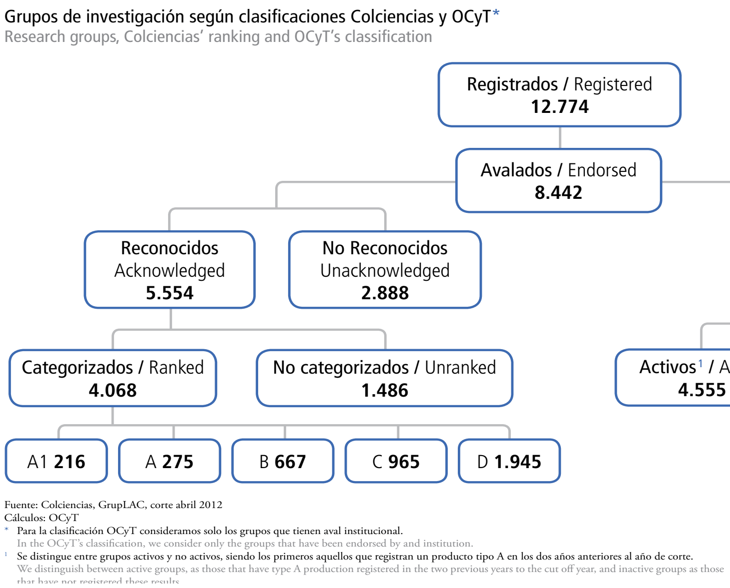


Figure 4.12. Research groups according Colciencias and OCyT's classification

Source. (Lucio et al., 2012, p. 50)

The distribution of ranked groups by the National Science and Technology Program (NSTP) can be seen in the following table:

Tabla 3.2. Grupos de investigación reconocidos según Programa Nacional de Ciencia y Tecnología (PNCyT), medición 2011

Recognized research groups by National Science and Technology Program (PNCyT), measurement 2011

Programa Nacional de Ciencia y Tecnología National Science and Technology Program	A1	A	B	C	D	N.C.[1] Unranked	Total
Ciencias sociales y humanas Social sciences and humanities	65	91	242	334	697	516	1.945
Ciencia y tecnología de la salud Health sciences	39	55	106	130	226	213	769
Ciencias básicas Basic sciences	32	36	92	119	194	169	642
Ciencias del medio ambiente y el hábitat Environmental sciences	10	20	45	69	159	103	406
Estudios científicos de la educación Scientific studies of education	12	13	26	67	161	110	389
Electrónica, telecomunicaciones e informática Electronics, telecommunications and informatics	8	11	47	70	147	95	378
Desarrollo tecnológico industrial y calidad Industrial technological development and quality	16	13	37	54	150	84	354
Ciencia y tecnologías agropecuarias Agricultural sciences and technologies	18	15	29	60	90	73	285
Biotecnología Biotechnology	4	8	9	19	44	32	116
Investigaciones en energía y minería Research in energy and mining	8	7	16	20	33	29	113
Ciencia y tecnología del mar Marine sciences	3	4	16	10	10	16	59
Sin clasificar Not classified	1	2	2	13	34	46	98
Total	**216**	**275**	**667**	**965**	**1.945**	**1.486**	**5.554**

Fuente: Colciencias
Cálculos: Colciencias
[1] N.C.: No categorizados.
Unranked.

Table 4.8. Recognised research groups by National Science and Technology Program 2011.

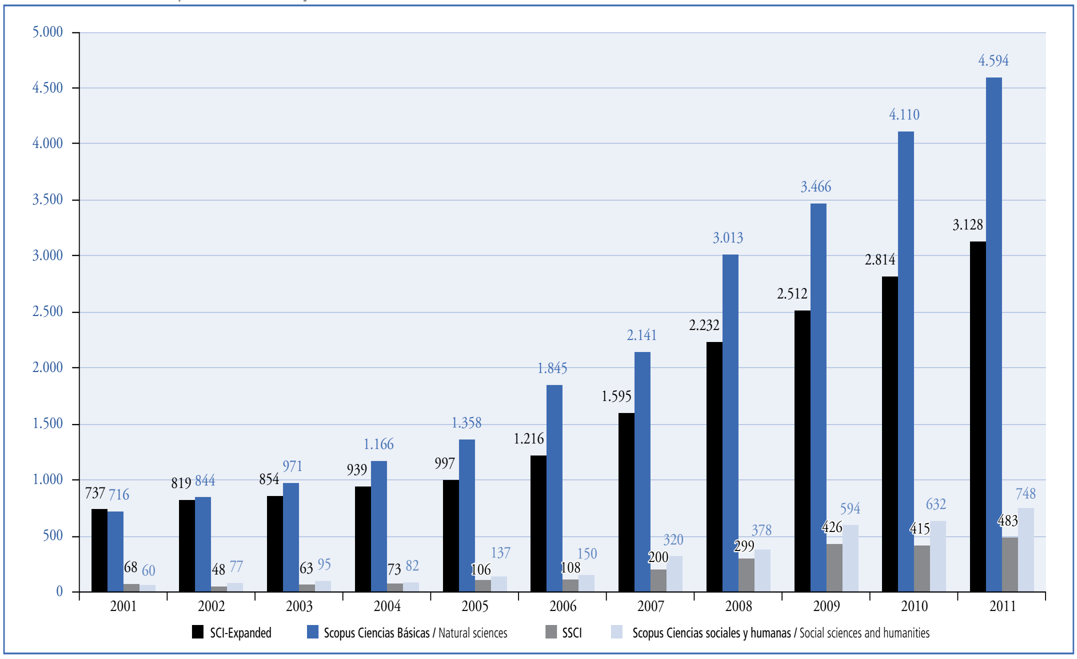
Source. (Lucio et al., 2012, p. 54)

The amount of groups has increased steadily from 2002. In 2002 there were 544 acknowledged research groups and 1,520 registered groups. In 2012, there were 12,744 registered groups and 5,554 acknowledge groups. The amount was almost multiplied tenfold in only ten years. However, the concentration tendency of research groups according to their research area keeps being led by social and humanities, with a low participation of biotechnology, electronics, telecommunication, informatics and research in energy, and mining. This can be partially explained by the political and social conflict between illegal armed groups and army forces, with the subsequent problems of population displacement, higher rates of unemployment, low levels of education and a social problem of reintegration of members of criminal groups to civilian life. Social sciences and humanities have played an important role to study the roots of the social conflict and to provide mechanisms to find feasible and thoughtful solutions to the multiple problems derived from a sustained situation of violence (Orozco, Ruiz, Bonilla, & Chavarro, 2013).

Scientific and academic production of researchers within acknowledged research groups in Scopus and ISI Web of Science from 2001 to 2011 is shown in figure 4.13:

Gráfica 4.6. Producción de documentos de autores vinculados a instituciones colombianas publicados en revistas indexadas en Web of Science y Scopus, 2002 - 2011*

Web of Science and Scopus documents by authors affiliated to Colombian institutions, 2002 - 2011



Fuente: Web of Science, consulta septiembre 2012
Scopus, consulta septiembre 2012
Cálculos: OCyT
* Scopus ciencias básicas incluye physical sciences, life sciences y health sciences.
Basic sciences category in Scopus includes physical sciences, life sciences y health sciences.

Figure 4.13. Web of Science and Scopus documents by authors affiliated to Colombian institutions 2001 – 2011.

Source. (Lucio et al., 2012, p. 85)

Capabilities have been built around scientific production. Having a more comprehensive standard to measure research groups' productivity and quality favoured the academic production of Colombian researchers in top-tier international citation indexes. The average growth percentage of published documents from 2001 to 2011 in ISI and SCOPUS can be seen in table 4.9:

Average growth percentage SCOPUS Natural Sciences (2001-2011)	21%
Average growth percentage SCI (2001-2011)	16%
Average growth percentage SSCI (2001-2011)	26%
Average growth percentage SCOPUS Social Sciences & Humanities (2001-2011)	33%

Table 4.9. Average growth percentage of published documents 2001-2011 in international citation indexes.

Source. Based on (Orozco et al., 2013)

The change of ranking standards for research groups in 2008 had a great impact on the information update in the national research information system. From 2007 to 2008 there was an important increment in publication rate, mainly produced by the information update process. However, Colombia is still well behind OECD countries and leading countries of LAC region, as it is clearly stated by the OECD review on the Colombian innovation policy:

> The traditional measures of STI output are also modest. The volume of scientific publications has been growing in recent years, but at about four publications a year per 100 000 population, Colombia is about two-thirds as productive as Latin America overall and well under the OECD average of a little less than nine. Like the scientific output of most Latin American countries, Colombia's is far less frequently cited than that of OECD countries and lags [behind] most comparable Latin American and Caribbean (LAC) countries. While the national system naturally has some strong points, Colombia faces a strong challenge in terms of scientific production, productivity and quality. The picture is much the same for patents and trademarks. Colombia ranks behind a number of LAC countries in terms of patents granted per capita as well as trademark applications at the US Patent and Trademark Office. (OECD, 2013, p. 5)

Looking into the patents application and granted patents according to main national sectors, we can clearly see which sectors are more active in terms of R&D leading to commercial innovations. The pharmaceutical chemistry sector has the highest patents applications and patents granted. However a major part of this sector is composed by MNEs, which means that most R&D is produced in its headquarters, leaving aside the internal industrial capabilities building.

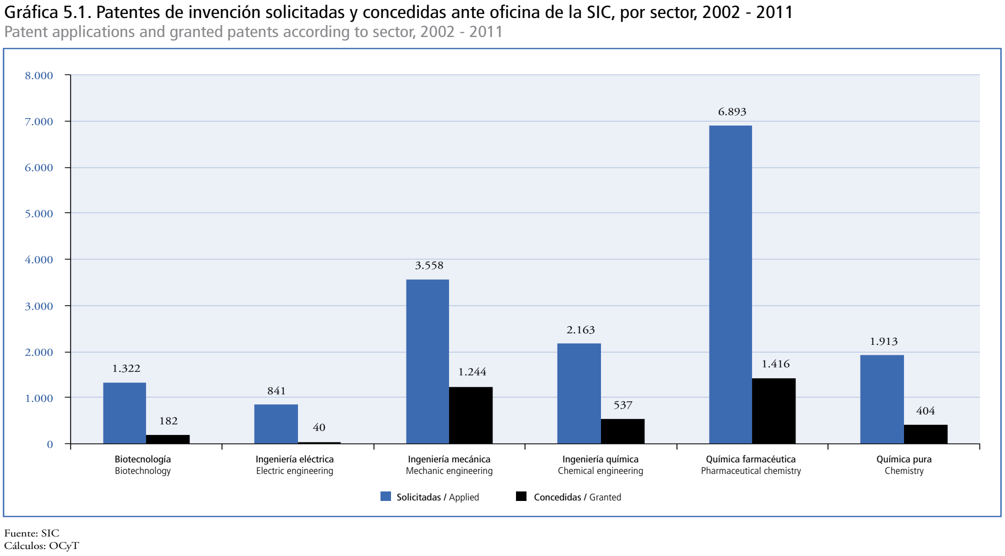


Figure 4.14. Patent applications and granted patents according to sector, 2002 – 2011

Source. (Jorge Lucio et al., 2012, p. 92)

The dependency rate of patents[49] granted from 2002 to 2011 have been decreasing over time, but it is still high, as can be seen in next figure:

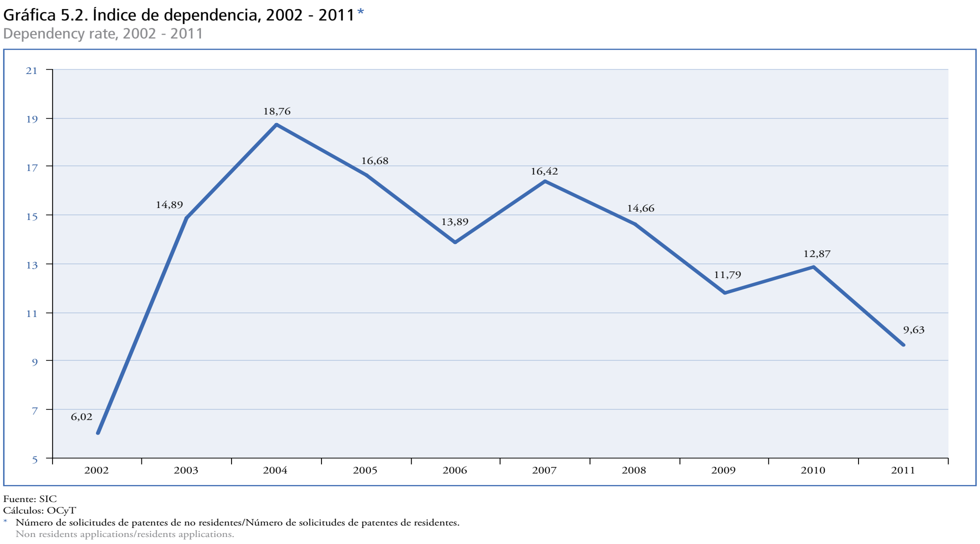


Figure 4.15. Dependency rate 2002 – 2011

Source. (Lucio et al., 2012, p. 95)

Self-sufficiency rate[50] and invention coefficient[51] have shown progress, but Colombia still has low levels of internal capacity for technological development and

[49] Non resident applications / residents applications.

a low number of patents per one hundred thousand inhabitants (See figures 4.16 and 4.17).

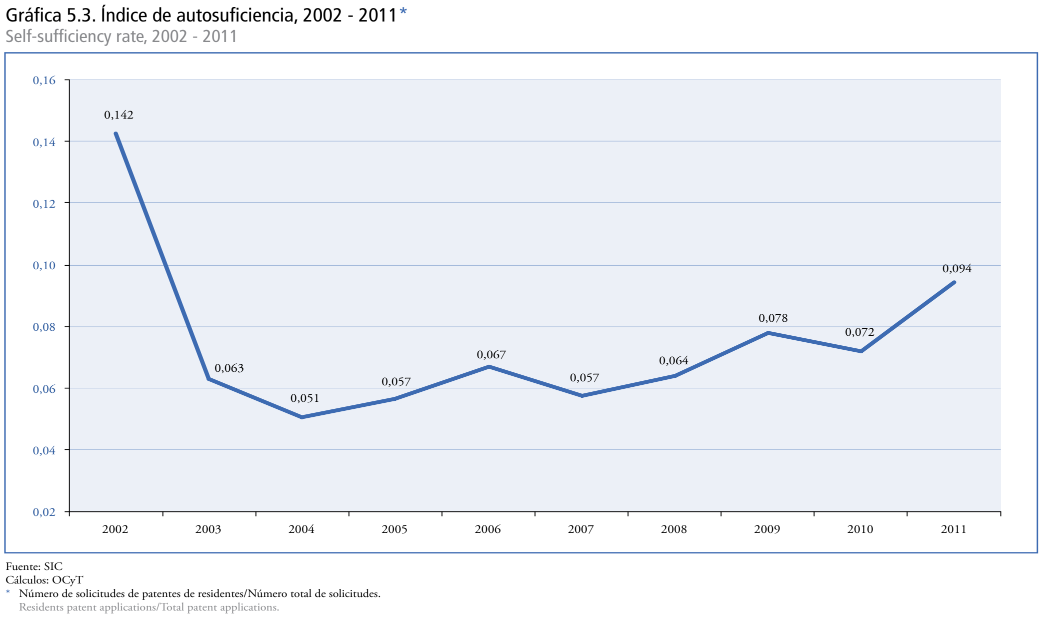


Figure 4.16. Self-sufficiency rate 2002 – 2011

Source. (Lucio et al., 2012, p. 96)

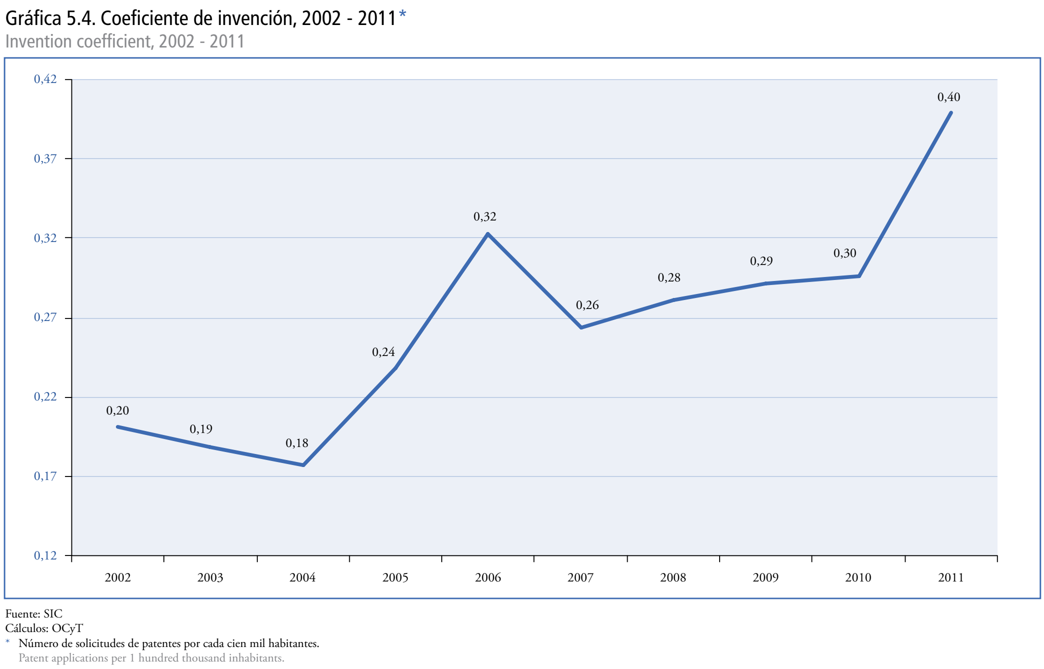


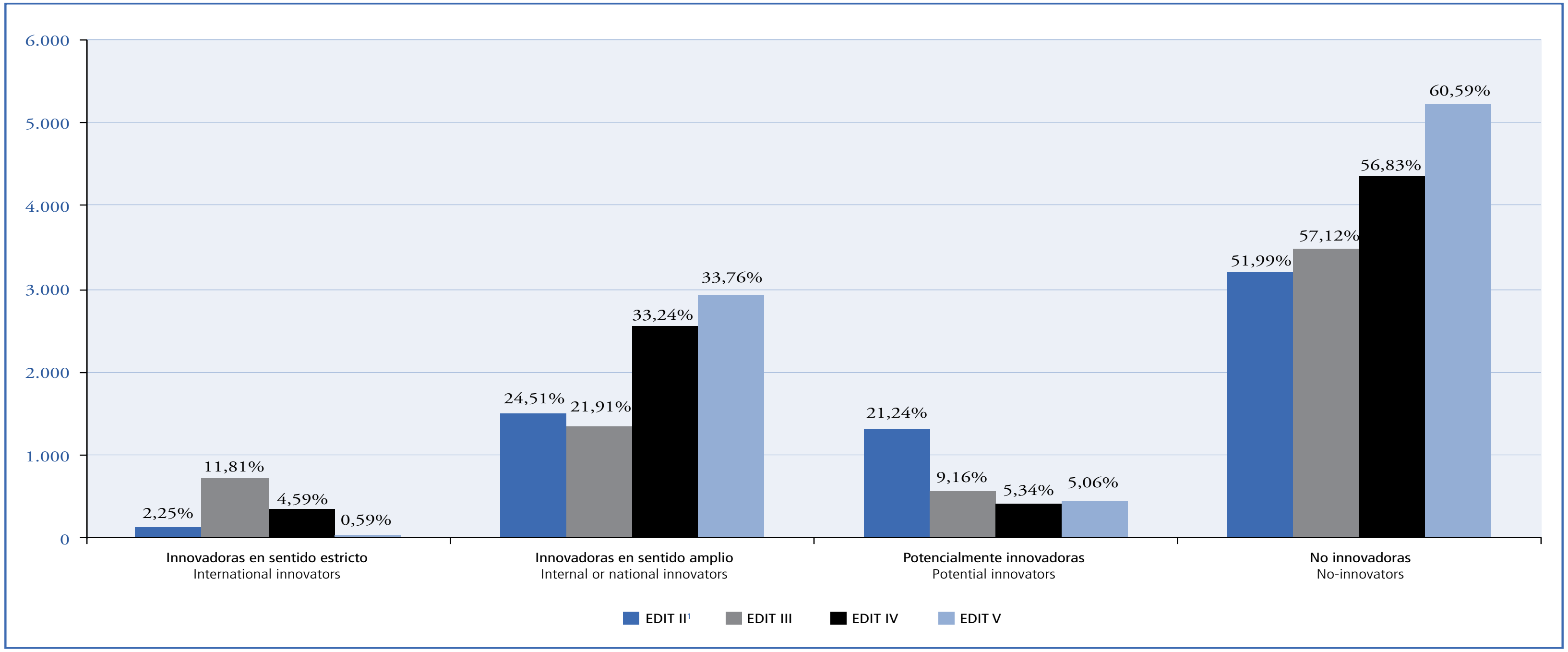
Figure 4.17. Invention coefficient 2002 – 2011

[50] Residents patent applications / Total patent applications.
[51] Patent applications per 1 hundred thousand inhabitants.

Source. (Lucio et al., 2012, p. 97)

These results are expected looking at the distribution of firms according their level of innovation measured in the Surveys of Development and Technological Innovation in Manufacturing (EDITs):

Gráfica 6.2. Distribución de las empresas que respondieron a la EDIT II, III, IV y V según grado de innovación*
Distribution of firms that responded the EDIT II, III, IV and V according to degree of innovation



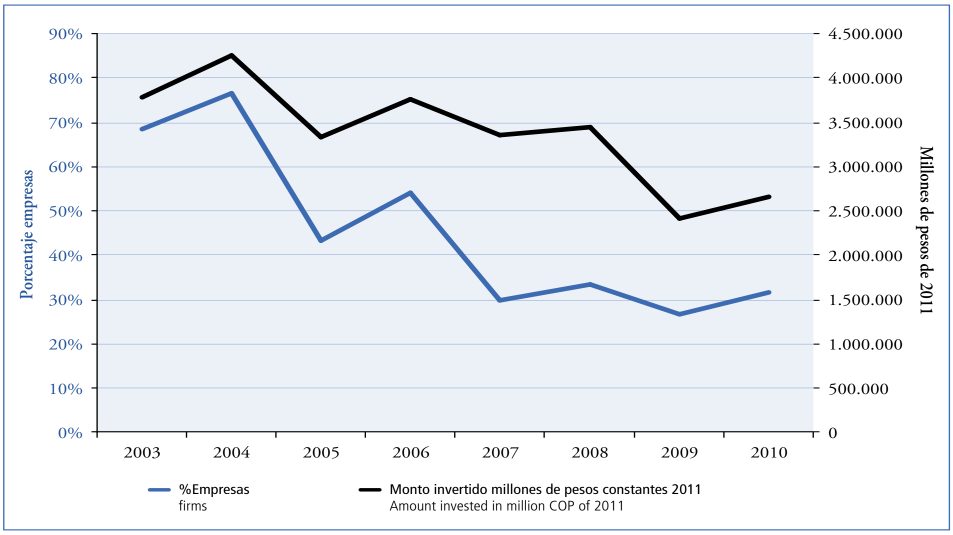
Fuente: DANE, EDIT II, EDIT III, EDIT IV. Boletines de prensa EDIT V
* Tomamos los grados de innovación calculados por el DANE.
We take the degree of innovation estimated by the DANE.
[1] En la EDIT II, solo 6.172 empresas, de las 6.222 que respondieron la encuesta, son clasificadas por grado de innovación.
Only 6.172, of 6.222, firms were classified according to their degree of innovation in EDIT II.

Figure 4.18. Distribution of firms according to degree of innovation according EDITs

Source. (Lucio et al., 2012, p. 103)

In EDIT V 60% of companies surveyed were not innovative at all, having an increasing rate from EDIT I to EDIT V. It is true that more firms have been part of the latest surveys, but the results are disappointing anyway. If we compare this rate with the investment level of enterprises for innovation activities, we can understand at least looking at this single factor, an explanation for this phenomenon. Figure 4.19 shows the investment made by Colombian firms in innovation activities from 2003 to 2010:

Gráfica 6.3. Empresas que invirtieron en actividades de desarrollo e innovación tecnológica y montos invertidos, 2003 - 2010
Firms that invested in innovation activities and amount invested, 2003 - 2010



Fuente: DANE, EDIT II, EDIT III, EDIT IV. Boletines de prensa EDIT V
Cálculos: OCyT

Figure 4.19. Firms investing in innovation activities and amount invested 2003 – 2010

Source. (Lucio et al., 2012, p. 104)

Another problem faced in the innovation side of the system is that instruments for funding and supporting innovation in enterprises have not been effective enough. For different reasons mentioned in the previous section, companies prefer to fund their innovation initiatives themselves. Taking into account that there is not a strong innovation culture in the Colombian business sector, besides low investment levels in STA and R&D made directly by companies, a weakness can be detected in the systemic nature of the Colombian NSI. Only 30% of total R&D is performed by the business sector, which results in low levels of productivity and a scarce relationship with public and private research centres. It is a major challenge and an imperative for the Colombian NSI to put producers at the centre of the system.

Tabla 6.8. Distribución de la financiación de las actividades de desarrollo e innovación tecnológica según fuente de los recursos, 2003 - 2010
Distribution of funding for innovation leading activities, 2003 - 2010

Fuente de recursos Funding source	2003	2004	2005	2006	2007	2008	2009	2010
Empresariales Own	67,09%	64,89%	68,83%	67,18%	76,92%	79,19%	80,51%	76,14%
Públicos Public	6,87%	4,11%	5,29%	4,18%	0,72%	0,72%	0,71%	0,82%
Banca privada Banking	24,13%	27,56%	21,22%	24,11%	21,43%	19,74%	17,69%	21,60%
Sector externo Foreign	0,15%	0,14%	4,64%	4,51%	0,06%	0,05%	0,01%	0,07%
Otros Other	1,77%	3,29%	0,01%	0,02%	0,86%	0,30%	1,07%	1,38%

Fuente: DANE, EDIT II, EDIT III, EDIT IV. Boletines de prensa EDIT V
Cálculos: OCyT

Table 4.10. Distribution of funding for innovation leading activities 2003 – 2010

Source. (Lucio et al., 2012, p. 112)

There are different kinds of incentives and tools to trigger the NSI, and particular sectoral and regional systems. However, fiscal incentives can be unpredictable sometimes and cause the opposite desired effect. One of the cases studied in this research stands as a good example of this. For maintaining and support the flowers sector, the government gave fiscal incentives to flower growers for the currency exchange deficit. Then, when the US dollar experienced a deflation causing huge loses to flower enterprises, the government compensated giving subsides to the sector. It was maintained for a long time causing lack of competitiveness and low investment in S&T. This is an example of how a policy designed to strengthen a sector, actually caused the opposite. It also reflects important elements of the Colombian cultural setting, where innovation is not within business priorities and where there is a tendency towards short-term planning. This is directly related with the second aspect studied, the social appropriation of science.

4.4.2.3. Social appropriation of science

Appropriating the science, the technology, and the innovation is a social process that permeates all population levels. In the case of the public sector there must be a conscience in all government instances that STI is a long-term commitment that involves political will and a country vision. The academic sector is committed to scientific development, but a stronger commitment to knowledge and technology transfer is needed to generate innovation and build bridges with the productive sector. A wider vision about the roles of universities and research centres in the knowledge exploitation system has to be strengthened. Expenditure on S&T is perceived as luxury. This can be clearly seen in the EDITs made for the last 6 years.

But the problem cannot only be reduced to a low valuation of S&T as an exogenous element of the society; it is necessary to dig into the causes of this low valuation. Besides the high dependence and reliance on imported knowledge, teaching of science and technology in primary and secondary education is insufficient. To improve this situation, Colciencias has been implementing the "Programa Ondas" (Wave program), whose main objective is to promote civic and democratic culture in STI among Colombian children and younger population using research as a pedagogical strategy. The wave program is part of a broader strategy to build capabilities in all levels of education and age groups, as can be seen in Figure 4.20:

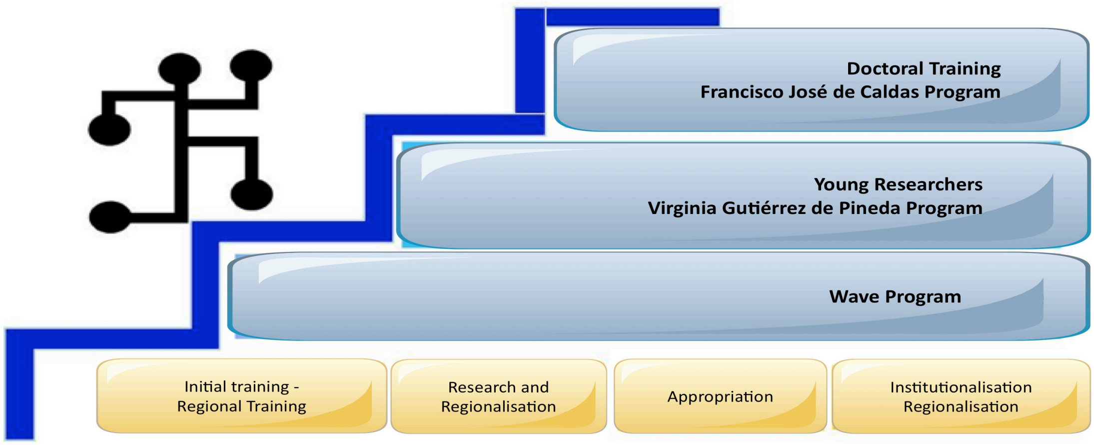


Figure 4.20. Colciencias multi-level strategy for building human resources capabilities.

Source. Adapted from Colciencias' website:
http://www.colciencias.gov.co/programa_estrategia/programa-ondas

As part of the program, there is a special line for training school teachers on research and scientific understanding so they can transmit this knowledge to their students. There are also science and technology fairs aimed at engaging with young people, so processes of knowledge generation, transformation and exploitation can be socialized amongst the local, regional, national and international levels. The idea is to have a comprehensive teaching and learning cycle transversal to elementary and secondary education.

However, low levels of social appropriation of science and technology are still a burden for the endogenisation of S&T. Science is a subject that interests few people, so it is perceived as remote solution for current problems (Lucio et al., 2012, p. 112). The general public do not see both a relationship between S&T and the political, economic, and social development of the country.

It is usually argued that having public spaces for the understanding, reflection, and debate of solutions for social, political, economic, and cultural problems in which the generation and use of scientific and technological knowledge is very important (Consejería presidencial para el desarrollo institucional, 1995). However, in a society where generation and exploitation of knowledge are still emerging systems, to build public understanding of the importance of scientific and technological capabilities to solve everyday problems is both challenging and mandatory. We believe that a change in the cultural attitudes towards science, technology and innovation is the first step to have a sustained effort to have a systemic system of S&T. Demand of knowledge could be more active in terms of business solutions using domestic research capabilities. This can be encouraged through strategic public investment in particular sectors and through effective instruments to energise traditional industries so they can successfully implement innovation networks producing new knowledge and adapting foreign S&T capabilities. We argue that in order to have a more effective demand-pull of science and technology from society, a set of policy systemic mix instruments could be implemented. Isolated strategies do not generate solutions; on the contrary they generate frustration and a waste of efforts and money. Related to this, Professor Emilio Quevedo, ex Colciencias public servant and currently director of the research group for the study of science, technology and professions says:

> On the one hand a stronger and clearer link is required with the public, and with the civil society, to understand and appropriate the meaning of science and technology. On the other hand, it is also required that the state is really aware of what research and innovation mean for the growth of the country. It is not about that one government or other has more or less interest in it, but to have a state policy really interested in building a synergic system. (Emilio Quevedo, personal communication, January 18th, 2012)

However, a constrain remains related with the trained professionals to lead and execute programs for the public understanding and appropriation of S&T. Colombia does not offer graduate programs in public communication of science, and it is not very common to find researchers dedicated to think about public understanding of science (Daza-Caicedo & Lozano-Borda, 2013). Therefore, this is another action area that has extensive potential to develop.

Another important aspect, that has been left aside, is the necessary participation of different stakeholders in the policy-making process. That is one recurrent complaint made by actors within the system. This is particularly relevant for building sectoral policies and designing public incentives. More effective mechanisms to give voice to main actors of the private and academic sectors in policies related to STI build engagement and social construction of solutions at the national and sectoral levels. Although there are mechanisms to give participation to these actors in the national and regional councils, the effectiveness of them is very limited. This aspect is acknowledge in the Colombian S&T law: "Scientific communities and the social and productive sectors will participate in the formulation and determination of general policies on science, technology and innovation in the areas determined by the Administrative Department of Science, Technology and Innovation, Colciencias." (DNP, 2009). However, there have not been effective mechanisms to translate the law into feasible participatory mechanisms.

While science, technology and innovation are perceived by people as elite issues outwith lay knowledge and completely distant from everyday problems and necessities, there will not be pressure groups calling for the importance of investing in strategic sectors to be more competitive in the local and global markets. Programs directed towards children and youth to recognise the potential of science and technology in solving all sort of problems is necessary but not sufficient.

4.4.2.4. Development of strategic sectors

It has been argued in this chapter that having a long-term national vision is fundamental for having progressive social and economic dividends, taking as a base the generation and use of knowledge. Having well-defined STI policies unlinked with the social, economic, and industrial policies has seen many implementation problems. It is important then, to build good links and transitions between the S&T policies with effective and well-oriented industrial policies. Currently, the productive and innovation policies have been disconnected. The National Strategy for Innovation (ENI) has strongly emphasised this connection. Responding to this aim the unit Innpulsa[52], as part of Bancoldex, was created. Nonetheless, the ENI legitimacy and continuity is questionable[53]. The strategy ignores the current policy for science and technology and weakens the formal and informal political institutions.

There has been agreement, to some extent, on the importance of certain specific sectors in most public documents and initiatives. Since 2005, in order to strengthen the system, public institutions have developed several studies[54] to identify strategic areas and sectors to invest in and to generate innovation in the productive sector. Although the studies have suggested diverse strategic sectors, what all of them have agreed upon is that the productive sector must undergo a radical change in order to integrate the learning processes required 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 (Congress, 2009) considered four essential areas for the development of competitive advantage (biodiversity, water, health, peace and social cohesion). However, these are broad sectors and specific programs to develop these areas have not been designed.

On the other hand, the Ministry of Trade, Industry and Tourism has defined 16 strategic sectors for the country within the so-called "Programa de Transformación Productiva" (Productive transformation program). Besides these national priorities, Colciencias has gradually defined 12 national programs for S&T that represents the

[52] As it was mentioned in the STI policy implementation section, Innpulsa is a governmental agency created in February 2012 to support and promote business growth led by innovation.
[53] Look a the section *Coherence between policies – Policy processes* in the policy implementation chapter.
[54] 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 strategic sectors.

national priorities for development using S&T as a base. Furthermore, the current government defined 5 “locomotives” for development, 3 as development sectors (agriculture, mining, housing), and two cross-sectoral ones supporting the other 3 (infrastructure, innovation). This picture shows that there is a lack of focalisation in specific sectors. We do not say that the state should follow a “picking winners” strategy or should be completely restrictive on the sectors to support, but a lack of strategic investment is harming technology specialisation and therefore the economic trajectory of Colombia. The human and financial resources are limited and a lack of medium and long strategy to obtain a competitive advantage in certain economic areas is worsening the technological backwardness of the nation.

> There are indications that certain aspects of regional and sectoral planning could be improved to facilitate national coherence. There is so far limited co-ordination amongst the regions and not just in terms of their royalty projects. The Private Competitiveness Council recently analysed regional innovation and industry priorities and found a total of 80. At the national level, too, strategic priorities proliferate. The DNP sets out five “locomotive” priorities. The Productive Transformation Programme of the Ministry of Trade, Industry and Tourism has gradually defined 16 priority sectors. In practice, therefore, the extent to which there are strong national thematic priorities is not clear.” (OECD, 2013, p. 32)

This may imply that there have been difficulties in defining strategic sectors. Differences between ministries, DNP, Colciencias, and regional competitiveness committees on the methodology to define sectors have been notorious. Some appeal by the strategy of ‘picking winners’, others by the ‘create winners’ through private – public partnerships. However, there is agreement on choosing biodiversity and its derivatives as a strategic and competitive sector, given the country’s wealth in natural resources. In the case of sectors like agriculture, health, environment, industrial development, those are sectors that are strategic and part of the core of priorities of most countries. The challenge is on defining those different sectors that could differentiate and make Colombia highly competitive. Referring to this problem, Iván Montenegro, a Colciencias advisor says:

> I do not know if you've seen this lack of concordance, lack of consensus on the issue of the priority areas. Then there's like a confusing mix of sectors called world class sectors, strategic research areas, and the innovation sectors in the development plan (Iván Montenegro, personal communication, August 25th, 2012)

Several studies have been conducted with international experts collaborating to define a long-term investment agenda for strategic sectors[55]. Different approaches have been used as technological and innovation foresight, clusters methods, econometric models, global chain models, among others, but this has resulted on the proliferation of even more strategic sectors. This problematic situation also shows power battles between public agencies that want to be in charge of the innovation policy and want to overpass the authority domain of their peer agencies.

4.5. Policy Development and Implementation in the Agro-industrial Sector

4.5.1. Regional and national evolution of the Colombian agriculture sector

Land ownership and land distribution has been a major issue in the history of Latin America. Inherited from European colonisers in the region, the concept of private property ownership was introduced during the colonial period (c. 1492-1800). Owning land has been an indicator and projection of social status and political power from this period onwards (Meade, 2010). The late 19th and early 20th centuries saw a continued and extensive demand for fertile ground that resulted in a progressive search to find suitable land for agriculture and livestock. This was consistent with the expansion of urban development and the attendant increase in demand for food from

[55] Prospective studies have been widely used in Colombia. As a result, there are now 30 regional and city development plans, 20 strategic plans for universities, and 25 S&T regional agendas. In 2009, the Ministry of Trade, Industry and Tourism hired Mckinsey consultant for a consultancy on the definition of the sectors to invest. As a result, 8 sectors, in which the country already has tradition, went into a process of. On the other hand, 4 sectors defined as 'new and emerging' have been developed within a so-called productive transformation program. There was also a study made by Hausmann and Klinger in 2007 on strategies that Colombia should follow to achieve export-led growth in Colombia. Another study was conducted by the Productivity Consulting Centre of the Chilean Universidad Adolfo Ibañez to help build a national innovation strategy. This study also mentions some sectors with innovative potential.

a growing population. High international demand for sugar and coffee resulted in an intensive production of these crops in Brazil, Colombia, Mexico and Costa Rica, whilst Argentina specialised in beef, mutton, and wool. Latin America specialised its exports on primary and raw agricultural commodities being a rich region in natural resources with low technological capacity (Sedrez, 2011). The Latin American role in the international trade landscape was focused on the production of food and raw materials for industrialised countries, mainly coloniser countries as Spain, Portugal, England, France, and the emerging market in North America. This maintained a perpetuation of economic exploitation and an unequal structure of social institutions.

4.5.1.1. The starting formal institutionalisation process: 1900 - 1989

Latin American economy relied mostly on agricultural commodities during the colonial time. This tendency was sustained during the independence process of the colonial countries in the 19th century. During this century the main production unit was the *hacienda*, a large portion of land owned by a single landlord. Exploitation labour systems inherited from the colonial times were preserved. A small and emergent dominant class had the economic power to own the material production, copying colonial extractive economic institutions where wages were paid in kind (food and a place to stay) under asymmetrical power relationships. Servitude relations with no rights of ownership over the cultivated land by small farmers remained throughout 19th and 20th centuries (Kalmanovitz & López Enciso, 2005).

The international demand for higher crops volumes was a trigger to modernise the agricultural techniques and production structure of the region. It is in this context that the first agricultural research stations were installed in various Latin American countries at the beginning of the twentieth century as part of the nascent ministries of agriculture. However, it was not until the 1930s and 1940s that there were formal research departments within the ministries' organisational structure. These departments were successful precursors towards a modernisation of the agriculture sector. Later on, these research departments would evolve into National Agriculture Research Institutes (INIAs for their Spanish acronym). Transnational organizations such as the World Bank, the Economic Commission for Latin America and the

Caribbean (ECLAC), the Inter-American Development Bank (IDB), and the United States Agency for International Development provided technical and financial support to these institutions throughout the 1960s and 1970s. Further, they supported the creation of international agricultural research centres in some countries of the region such as the International Center for Tropical Agriculture (CIAT), the international Maize and Wheat Improvement Center (CIMMYT) and the International Potato Center (CIP) (Echeverria, 1998). This was consistent with the structural changes promoted by the Latin American Structuralism movement during the 1950s to 1980s, where the key objective was to encourage a gradual transition towards greater industrialisation. For Raúl Prebisch, one of the most influential actors within the Latin American school of thought, the industrialisation of LAC countries was the only way to have technical progress and to improve the life quality of the population (Prebish, 1986). This was accompanied by a growing pessimism about the future of the Latin American countries given its strong reliance on natural resources. On this regard, Kuntz says:

> "This critical stance towards the role of foreign trade evolved in what came to be known as 'export pessimism', or the notion that primary exports were detrimental to those economies that specialized in their production. Export pessimism found its roots in the beginning of the Great Depression in 1929…The Depression exhibited the vulnerability of those economies that relied on primary exports to sustain their growth processes" (Kuntz Ficker, 2005, p. 147)

Progress was the goal and the promotion of technology-based sectors was the aim of most of the countries in Latin America. But given the abundance of natural resources, the installed infrastructure, the long expertise acquired in the agro sector, and the lack of training of agricultural labour in other sectors, agriculture kept as a key economic sector for the LAC countries. The main concerns for the Latin American economists was the high reliance on Natural Resources (NRs):

> "On the demand side, they highlighted two problems: (a) NRs face relatively low income elasticity, so countries heavily specialised in NRs would not benefit from increases in world demand associated with world income growth, and (b) their demand growth was slower than that for

> manufactures, because technological progress in the manufacturing sector tends to be raw-materials saving. On the supply side they also identified two problems: (a) that NRs were not favoured by technological progress, which was concentrated mostly in manufactures…and (b) that the little technological progress they experienced did not translate into larger demand or greater profits but in reduced prices, benefiting consumers in foreign countries and not producers in developing countries supplying the NRs." (Marin et al., 2009, p. 4)

This tendency would change during the late 20th and 21st centuries. The changes in the production patterns with more specialised consumer-producer relationships and the existence of global value chains promoted a shift in the behaviour of trading commodities.

Agriculture keeps being a strategic sector, not only because of obvious reasons like food security for domestic needs, but also because 11% of the value of food production is concentrated in Latin America and the region has 24% of the world's arable land[56]. Moreover, current studies have shown how natural resources (NR) based industries, in a context of global value chains, have evolved to have higher market volume with specialised demand business niches and a higher connectivity through the intense use of ICTs. This shift in the market patterns, has changed business based on NR, and has opened broader opportunities to the Latin American countries (Marin et al., 2009; Perez, 2008).

4.5.1.2. Creation of public and private agricultural organisations

In 1819 farmers associations were officially established in Colombia. These associations were the antecedent to what would be the Agricultural Society of Colombia (SAC[57]). The SAC was founded in 1871 largely for the representation of farmers to government in order to discuss economic and social agricultural policies. In 1879 the first agricultural research institute for acclimatisation of livestock was

[56] This according to the Inter-American Development Bank in: http://www.iadb.org/en/topics/agriculture/latin-american-agriculture-statistics,2342.html. Retrieved in 10-01-14.

[57] Sociedad de Agricultores de Colombia

created to monitor the adaptation process of imported cattle breeds. The Ministry of Agriculture was founded in 1913 as the "Ministry of Agriculture and Commerce", and in 1926 it created the first experimentation station in Palmira (part of the Cauca Valley department) to study costs of agricultural production, improve seeds, weather monitoring, pest control and soil analysis. The aim was also to do technology transfer through technical training to farmers (Valencia Llano & Acevedo Tarrazona, 2010). Given the success of the first station and the need to support regional agricultural development, several stations were created afterwards[58]. In 1948, after several restructurings, the Ministry of Agriculture invited the Rockefeller Foundation to create a cooperation program for crops production, following the same model applied already in Mexico. Then, in 1950 an Office for Specialised Research (OIE[59]) was debuted in cooperation with the Foundation and located in the School of Agronomy of *Universidad Nacional* in Medellín. At the beginning, research was focused on wheat and corn, and then it was extended to more crops and livestock. Afterwards, extending the support given by the Rockefeller Foundation, an Agricultural Research Division (DIA[60]) was opened in 1955 to manage all the experimental stations. This division evolved to be the Colombian Agriculture Institute (ICA[61]) in 1962, integrating research, extension, and agricultural training. During the 1980s the ICA was restructured into two main divisions, one for R&D and the other for services related to norms and standardization, animal and crop health, and the coordination of sectoral development. Since the two divisions were growing in terms of responsibilities and capacity[62], in 1993 the institute was split and the Colombian Agricultural Research Corporation (Corpoica[63]) was created to lead and perform

[58] In 1932 a new station was created in Armero, Tolima for cotton research. In 1934 another experimental station was created in Medellín, Antioquia.
[59] Oficina de Investigaciones Especiales
[60] División de Investigación Agropecuaria
[61] Instituto Colombiano Agropecuario
[62] The coordination and communication between researchers and farmers along the country was outstripping the administrative capacity of the institute. By the end of the 1980s there were 66 regional centres for training, transfer and diffusion of technology. In addition to these centres, there were 25 research centres all along the country. However, there were not enough financial resources and the national government restricted the entrance of international funds and loans from organisations as the World Bank. In 1990, two additional research areas were included in the research agenda of the institute: biotechnology and natural resources. Then, in order to make more efficient the institute and the research process and impact, ICA was divided into two institutes.
[63] Corporación Colombiana de Investigación Agropecuaria

research for improving productivity and competitiveness within the agricultural sector (N. Beintema, L. Romano, & P. Pardey, 2000).

Corpoica[64] required joint efforts from the national government, producers' associations, universities and regional institutes for its operation. One of the main objectives with the creation of Corpoica was to have greater flexibility for collaboration with the private sector and international networks. That is why the corporation has a mixed nature, which means that it has public and private capital in its constitution. This provides flexibility to the corporation to compete for public and private funding. The research agenda is set according to the regional research needs and the necessity of knowledge and technology transfer for the Colombian farmers and agricultural firms. The main research lines developed by the corporation are: livestock (cattle breeds, pests and diseases control, vaccines development, milk production), biotechnology (bio products, quality and safety, molecular biology and genetics), annual or seasonal crops (seeds production and control for corn, cotton, and soy), permanent crops (seeds production and control for oil palm) (Corpoica, 2007). However, since its creation, Corpoica has had financial problems due to cuts in public resources for the corporation, and because of the cost of a functional model based on a large group of full-time researchers depending from the corporation. Besides the financial problems to support the structure of the corporation, there have been problems with other research groups and entities from universities and agriculture research centres since they perceive Corpoica as a competitor, not as a research partner. Also, actors within the agriculture sector criticise the applicability of the research results and the processes of knowledge and technology transfer from the corporation. Supporting this view, Claudia Uribe, coordinator of the science, technology and innovation agricultural observatory SIEMBRA, says:

> Corpoica has generated 70% of total research in the agricultural sector. If we look at the results that have been

[64] The Colombian Agricultural Research Corporation, Corpoica, is a non-profit decentralized public entity of mixed participation, aimed at developing and executing research, technology transfer and promote technological innovation processes for the agricultural sector. The Corporation follows up on the national agenda for research, development and innovation, and promotes the subsystem of agricultural technical assistance (SSATA) to support the Ministry of Agriculture and Rural Development in the task of being engine, Actor & Support (MAS) for the National Agroindustrial System of Science and Technology (SNCTA).

> actually helpful to improve the productive sector, the percentage is really low. Actors of the agriculture system don't trust the corporation. (Claudia Uribe, personal communication, December 21st, 2011)

Or the perception of Dr. Fernando Cantor, Dean of the School of Basic and Applied Sciences of *Universidad Militar Nueva Granada*:

> I think that Corpoica should play a more important role to organise and to coordinate the system, but instead, I perceive it as a competitor…Corpoica should have a national vision, but because they have a fiscal deficit, they have taken all the public research calls to pay their own researchers and to shape the national research agenda according to their own interests. (Fernando Cantor, personal communication, January 22nd, 2013)

Also, the lack of integration of Corpoica with important research partners like the agriculture research centres is one of the weaknesses of the institute. Dr. Jerhson López, Chief of Biotechnology laboratory - National Sugar Cane Research Centre (CENICAÑA), says:

> I am completely unaware of the role of Corpoica. We [Cenicaña] don't have a direct integration with Corpoica and in the biotechnology area is zero. (Jerhson López, personal communication, February 18th, 2012)

However, Corpoica has adjusted its structural and functional setting in order to survive the central government institutional changes and to tackle the lack of trust of the agriculture sector. Corpoica is changing its role to be support and engine for the agricultural development in the country. It is an on-going process, but the board of the corporation knows that a shift in the model is needed, and is acting accordingly. In words of Juan Lucas Restrepo, executive director of Corpoica:

> We need to adapt the traditional [organisational] model to current needs of the sector. We are having a shift from being actors of the system [Agro-industrial innovation system] to be the engine of the system. We are strengthening our research networks to become an interface and facilitator of the system to generate research, development and Agro-industrial innovation. (Juan Lucas Restrepo, personal communication, May 3rd, 2012)

Producers' associations have been a main actor in the agricultural research system. The Colombian Coffee Growers Association founded in 1927, went on to create Cenicafe, the Colombian coffee research centre in 1938. This centre was the first crop-dedicated agricultural research centre in the country. Fedearroz, the national rice federation, was created in 1948, and between 1962 and 1963 the producers' associations for cacao, oil palm, and cereals were established. In 1974, VECOL, the Colombian Enterprise for Veterinary products was founded, followed by Cenicaña, the sugarcane research centre, which was created in 1977. In 1976, the Colombian Association of Flower Exporters was started, Asocolflores, creating a technical division in 1987 within the association, and finally Ceniflores, the flowers research centre, in 2004 (N. Beintema et al., 2000).

Producers' associations are a differential characteristic of the Colombian agriculture system. They represent nearly a third of the agriculture GDP, and have a good portion of researchers specialising in agriculture. They have an applied research orientation that has brought important achievements for the sectors they represent in terms of higher levels of productivity. In turn, this has been largely positive in terms of allowing Colombia to compete in international markets. Producers' associations are strong actors in the sectoral innovation systems and a network hub with other actors within the agricultural and national SIs, making strategic research alliances with national actors such as Corpoica, ICA, Colciencias, and the Ministry of Agriculture.

4.5.1.3. The Globalisation period. Liberalisation of the markets: 1990 onwards

After dismantling the import substitution industrialization (ISI) policies, all countries in the region started a process (at different paces) of market liberalisation and reduction of protectionism for the agriculture sector. According the ECLAC (Sotomayor, Rodríguez, & Rodrigues, 2011), during this period there were three main stages: a first stage where countries went through extensive macroeconomic and microeconomic structural changes, reducing State intervention in the domestic and international trade; in the second stage there was an emergence of agricultural development programs for technology transfer, strengthening of international marketing channels through regional free trade agreements as MERCOSUR (1991) and the North American Free Trade Agreement (NAFTA, 1992)[65]; and special projects supported by transnational organizations as the World Bank and the Inter-American Development Bank (i.e. the Integrated Rural Development Project in Colombia in 1976) and cooperation with international organisations as the Rockefeller Foundation, that we explored in the previous section. Finally, from 2000 onwards, there was a process of institutional reconstruction and transformation following the structural changes implemented after the Import Substitution Industrialisation. The strategy was to strengthen sectoral policies and instruments to improve the competitiveness and productivity of the LAC countries.

The openness to global markets during the nineties started when most LAC countries were in a vulnerable economic situation. Then, most governments opted for having a balance between liberalisation of markets and certain economic restrictions to protect domestic markets and firms' evolution. The precarious situation for the countries of the region after the recessionary inertia of the 1980s made governments to be cautious in the allocation of public expenditure. There was a pessimistic attitude towards the development of Natural Resources (NR) based commodities since the export of these goods was less dynamic than other industrial sectors, and they experienced higher trade barriers in the target international markets. This corresponds with the budget cuts made to agricultural research centres during the 1990s and the precarious research advance at the start of the 21st century (Economic Commission for Latin America and the Caribbean ECLAC, 1990). However, the first sector in the Colombian economy that developed a structured innovation strategy was the agriculture one. This is highlighted by Dr. Fernando Chaparro, ex director of Colciencias and Corpoica:

[65] After twenty years that the agreement have been in place, there are mixed criticisms about the economic benefits that the agreement has brought to Canada, United States of America and Mexico, the country members. Some defenders of NAFTA show the increase of exports and imports between the countries and the benefits that resulted profits have brought to the economies. Others argue that the profits have not been as high as were expected and that the agreement has caused a massive lost of employment, mainly in the United States of America. More information about the current controversy can be followed in http://www.businessweek.com/articles/2013-12-30/nafta-20-years-after-neither-miracle-nor-disaster

> The most structured sector in Colombia is agriculture. It has an integrated sectorial system that comes from the evolution of National Institutes of Agriculture, INIAs[66], to what were later called National Agricultural Research Systems, SNIAs[67]. The Colombian SNIA was established during the 1990s and it had the ICA and in 1993 Corpoica, and afterwards it integrated an expanding network of research centres, the CENIs and the Agro-industrial schools in public and private universities. This is how the Agro-industrial system of innovation became a mature system, long before building a national innovation system. (Fernando Chaparro, personal communication, May 22nd, 2012)

Although the Agro-industrial system of innovation is far from perfect, it has had a long tradition that has allowed the actors within the sectoral system to build strong relationships. The research and development cycle contains integrated results from basic and applied research to final transfer processes. As it was mentioned by Hernán Jaramillo, dean of the School of Economics of *Universidad del Rosario*, in the Colloquium of sectoral STI public policies done as part of this research:

> The agricultural sector has had a complete research cycle for a long time. Research is totally integrated within the sector. If I need to solve a variety problem, I have to do molecular biology, and then I have to think how to transfer that technology to the farmer. It just simply makes no sense to develop this kind of research to leave it in the laboratory. (Hernán Jaramillo, personal communication, May 17th, 2012)

Next section will explore the so-called Agro-industrial system of science and technology, the formal and informal institutions behind it and some contrasting visions from actors of the system.

4.5.2. Agro-industrial Science and Technology System

Consistent with the creation of the National System of S&T, law 607 of 2000 officially promulgates the existence of an Agro-industrial National System of S&T (SNCTA):

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[66] Institutos Nacionales de Agricultura
[67] Sistemas Nacionales de Investigación Agrícola. The English acronym is NARS.

> Through the present law, the Agro-industrial National System of Science and Technology is established, which has the overall aim to contribute to agribusiness knowledge, methods, technologies, and technological products needed for a good performance according to national requirements and the international environment. (Colombia, 2000, p. Art. 3 (d)).

The main system components are the so-called production chains[68]. There are 37 production chains[69], which aim to improve the competitiveness of all processes around the chain product[70]. Since there is only one production chain for each product, all the product producers and stakeholders have to work within the same chain in order to receive recognition from the Ministry of Agriculture and Rural Development (MADR[71]), benefits such as participation in calls for projects and access to preferential tariffs for export, access to funding and technical assistance given directly from the MADR or the regional entities in charge of technology transfer and assistance[72]. Members of the productive chain should offer their organisations' research and commercial capacity for the benefit of the chain instead of competing against each other. The last goal is to achieve a better economic performance both individually and collectively preserving the autonomy of each firm represented within the chain. There are internal agreements among the chain partners to define cooperation projects with the intended results. The concept of production chains comes from the strategic planning theoretical branch. It is a mixture of two different approaches. The first one comes from the early work of Albert Hirschman[73]

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[68] Law 811 of 2003 defines the production chains as the set of activities that are linked technically and economically from the beginning of the production and processing of an agricultural product to its final marketing. The chain may be formed by agreement at national level, at the level of a production zone or region, producers, employers, trade associations and organizations representing both agricultural production, livestock, aquaculture, forestry, fishing, and the processing, marketing, distribution and service providers and inputs.

[69] For detailed information about the production chains and their performance, see: http://www.siembra.gov.co. Retrieved on 10-08-14.

[70] According to law 811 of 2003, the production chain should at least cover the following aspects: improve productivity and competitiveness; development of goods and factors of the market chain; reduction of transaction cost between different actors in the chain; development of strategic alliances; improvement of information among the chain actors; linking of small producers and entrepreneurs to the chain; management of natural resources and environment; training of human resources; research and technological development.

[71] Ministerio de Agricultura y Desarrollo Rural

[72] This topic will be developed further bellow in this chapter.

[73] The concept was first introduced in Hirschman's book *The Strategy of Economic Development* first published in 1958.

about consumption, production, and employment linkages expressed at different levels: horizontal, vertical, forward, backward, and lateral. These linkages are used to understand the decision-making process between different actors around production processes of products and services. The second is the concept of 'value chain' proposed and developed by Michael Porter[74]. It comprises all the links from the suppliers of raw materials and inputs to the final consumer of any product or service. During the 1990s LAC countries included the term "production chains" as part of their sectoral and industrial policies using elements from both theories (Isaza, 2008).

The strategy developed and pursued by the MADR from 2006 onwards has focused on the construction of research, technological development and innovation agendas through prospective exercises[75]. In 2011 Corpoica led the process of having a consolidated and unified research, technological development and innovation agenda for each one of the 37 productive chains. To support the construction and assessment mechanisms of this national agenda, the Observatory of the Agro-industrial National System of S&T[76] was launched on the same year to support the design and production of STI indicators for each one of the system chains. The observatory's purpose is to have centralised and up-to-date data to allow the central government to track, monitor and evaluate mechanisms for the agriculture SI.

Corpoica acts as the coordinator entity of the SNCTA. The formal institutional structure of the SNCTA can be seen in Figure 4.21. The SNCTA is part of the NSSTI, and work to a similar structure as the NSI. There are specialised organizations for promoting S&T; for providing technical assistance; for training, and for institutional and financial support. In this sense, the system has three main functional blocks: A research block, a technical assistance and transfer block, and a regional network for agricultural innovation (Gallego, 2011).

The Subsystem of Agricultural Technical Assistance (SSATA) provides services for suitability of soils; planning of farms production; application and use of appropriate

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[74] Michael Porter, *Competitive Advantage,* 1985.

[75] The latest project doing prospective exercises was sponsored by the Ministry of Agriculture, Colciencias and the WB. It was called: *Proyecto Transición de la Agricultura*. It developed prospective research agendas for 25 production regional and national chains.

[76] The observatory is called 'Siembra': http://siembra.gov.co.

technologies and resources; access to funding sources; marketing of produced goods; and promotion of producers' associations[77]. The direct rural technical assistance is a mandatory and a subsidized public service for small and medium farmers. This rural technical assistance is provided by the municipalities in coordination with departmental and national authorities, and is regulated by the MADR (Colombia, 2000). The SSATA operational units are the Technical Assistance Service Providers (EPSAGRO), and Technical Assistance Municipal Units (UMATA).

Up to 2013, the SNCTA has 279 agribusiness firms; 130 universities and R&D centres; and 182 trade unions. Regarding technological linkage institutions, there are 937 EPSAGRO registered in the agriculture secretariats; 40 EPSAGRO authorized by the MADR; 525 UMATA; and 38 Provincial Agribusiness Management Centres (CPGA) (Contreras Pedraza & Uribe Galvis, 2013).

There are different actors that are part of the Agro-industrial system of innovation. As it is seen in figure 4.21, there are S&T organizations that support the research side of the system in terms of production and transfer of technology and knowledge. These organizations have different roles according to the production chain that they interact with[78]. Production chains that have their own research centres or CENIs, interact less with NGOs, Corpoica, and Technology Development Centres different from the CENI of the chain. The same pattern can be seen in the case of the technical assistance. When the producers are well organised and have a strong producers association, there are internal mechanisms within the chain to provide transfer, appropriation and validation of K&T. Organizations as BANCOLDEX[79], PROEXPORT[80], ICFES[81], and ICETEX[82] provide commercial, financial and training support to producers associations organised in production chains.

[77] The National Constitution establishes in the Article 64 the obligation from to State to provide access to technical assistance. Laws 101 of 1993 and 207 of 2000 establish that the rural technical assistance is a public decentralised service subsidized for small and medium producers.

[78] Production chains that have a strong union behind and are well organised in terms of interaction between growers, producers and consumers usually interact in a better way with sectoral and national actors and organisations to generate innovation.

[79] Bank of Foreign Trade, in Spanish, Banco de Comercio Exterior.

[80] Now known as PROCOLOMBIA, it is the organisation in charge of the promotion of Colombian exports, tourism and foreign investment.

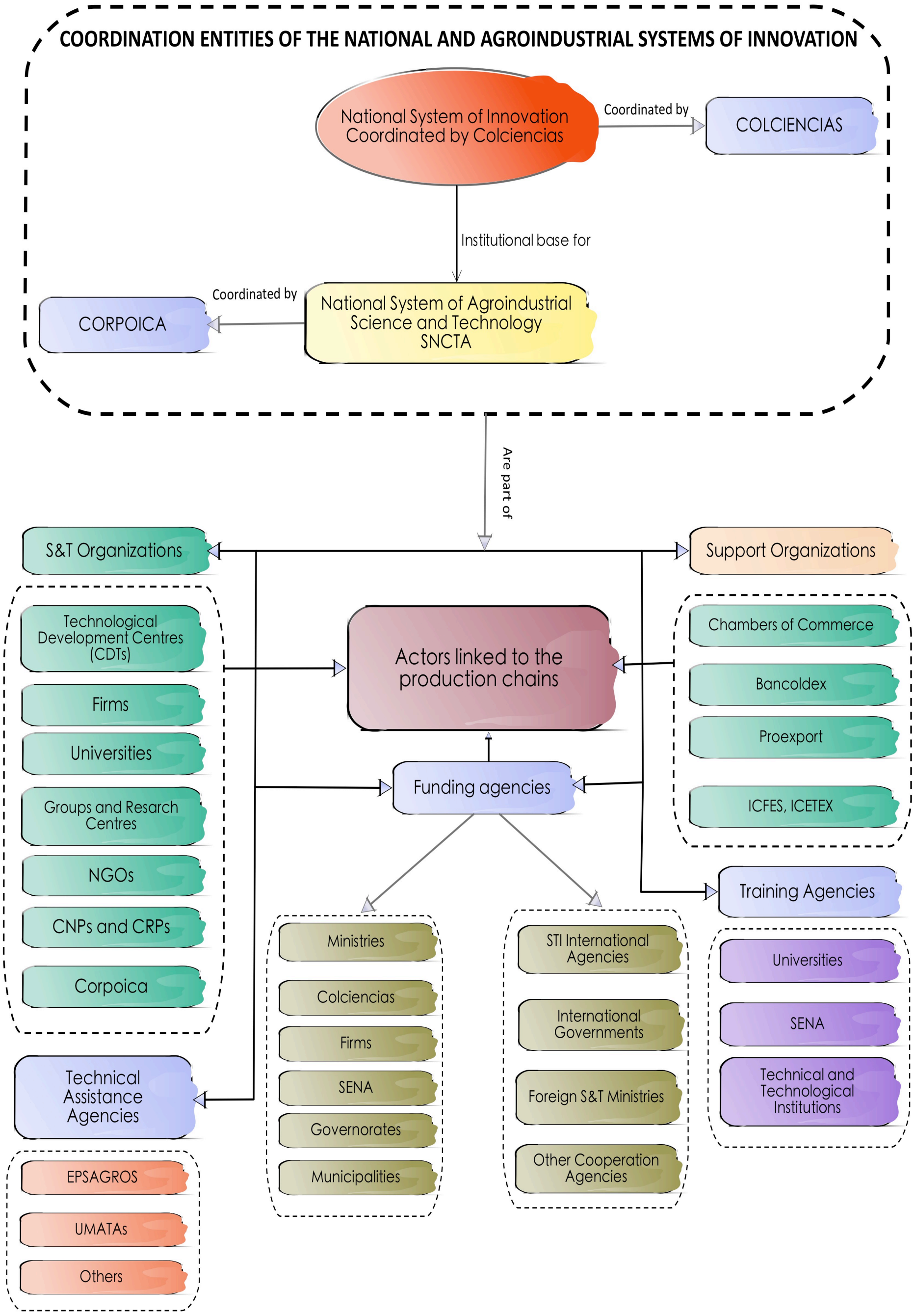


Figure 4.21. Actors of the National Agro-industrial System (SNCTA)

Source. Adapted from (Contreras Pedraza & Uribe Galvis, 2013, p. 15)

[81] Colombian Institute for the Promotion of the Higher Education, in Spanish Instituto Colombiano para el Fomento de la Educación Superior.
[82] Colombian Institute for Education and Technical Studies Abroad, in Spanish Instituto Colombiano de Crédito Educativo y Estudios Técnicos en el Exterior

As it was mentioned before, the Agro-industrial innovation system is composed by three different subsystems. The research system function is to produce pertinent knowledge and technology according to particular needs from growers and producers within the system, and to produce cutting edge knowledge from agricultural research centres, research groups based on universities or international research organisations (i.e. CIAT, International Center for Tropical Agriculture) to be implemented in the different sub-sectors. This transfer of needs to the research system can be done by representatives of the production chains or directly from *extensionists* or technicians that are part of the technical assistance system. As it can be seen in figure 4.22, the technical assistance system provides three different technical assistance approaches according to the needs of the recipients. The characteristics of the basic, intermediate and advance services of the sub-system are illustrated in table 4.11:

Type of Technical Assistance	Recipients	Services
Basic	Subsistence small growers and producers.	Support in production, commercial, marketing and enterprise management.
Intermediate	Small producers in transition to a firm model	Formulation and execution of business plans. Training in business practices and in land and crops technical practices.
Advance	Small producers with high specialisation levels, medium and large producers.	Specialised technical assistance in specific crop problems.

Table 4.11. Agriculture technical assistance types

Source. Based on (Gallego, 2011)

The way the system captures the producers and growers needs and has a link with the primary stage of the sector is through the production chains. The production chains are regional and work as clusters bringing together all actors involved in the production and commercialization of the crops.

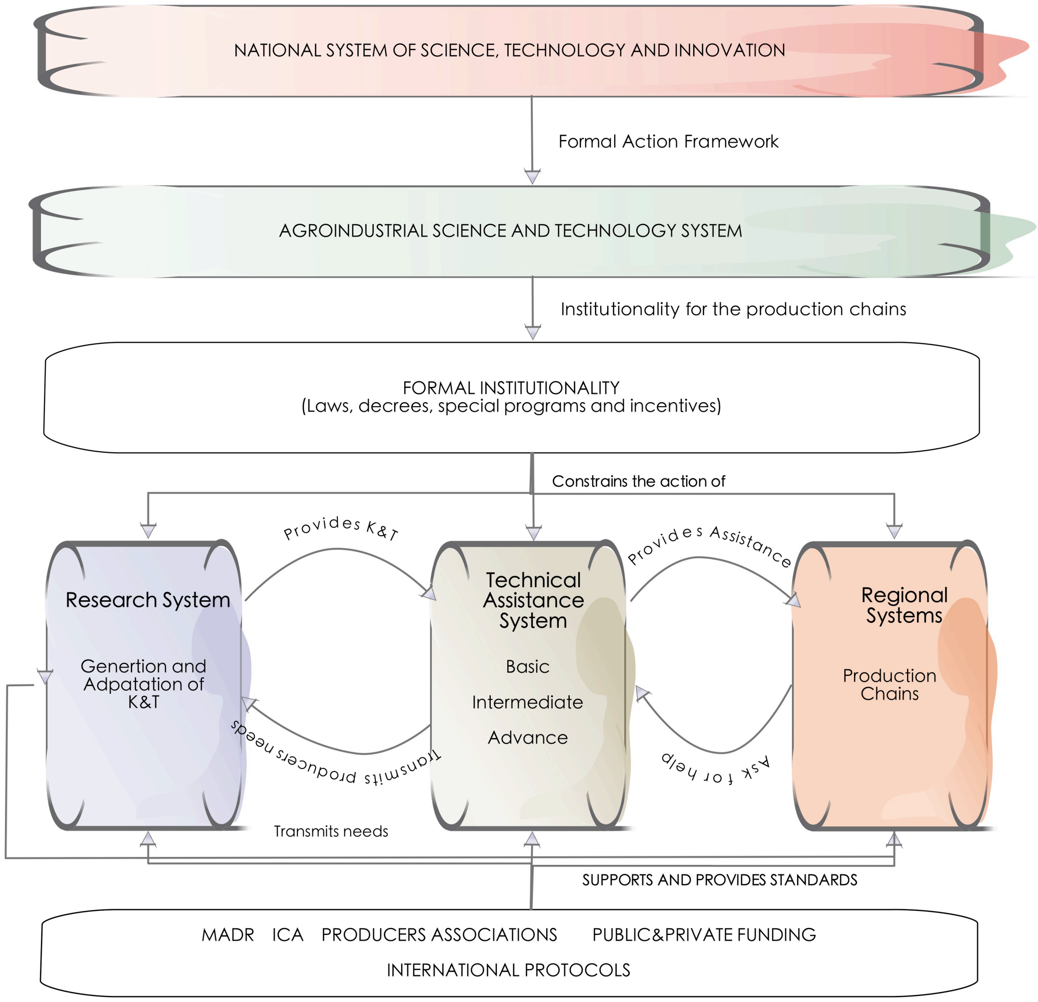


Figure 4.22. Structure of the Colombian Agro-industrial system of innovation

Source. Information compiled by the author.

However, the Agro-industrial IS has shortcomings that have been difficult to overcome. The subsystems do not always deliver the expected results, the institutional setting does not meet the functional dynamics between the components of the system and the support infrastructure represented by public and private organisations is not always effective. One of the main problems that remain unsolved is to provide an effective technical assistance. There is confusion at the municipalities level about who are the actors providing this service. It used to be the UMATAs, but when the law changed and introduced the EPSAGROs, some municipalities adopted the change, some did not, and some dismantled the UMATAs, but did not replace them with a technical assistance service provider. Referring to this problems within the system, Claudia Uribe, coordinator of the

National Observatory of Agriculture and coordinator of the Agricultural Transition project, says:

> The biggest rupture can be seen between the knowledge generation and its adoption. First at all because there may be knowledge but not relevant in terms of what the sector needs or in terms of its applicability; second of all there may be available technologies but too expensive, so the producer cannot afford them, or technologies that cannot be applied in field. The bridge between knowledge and technology generation and its adoption is failing. There is a gap in terms of the available institutionality to support the technical assistance of the system. (Claudia Uribe, personal communication, December 21st, 2011)

This means that the interaction and functional dynamics of the basic blocks of the Agro-industrial IS can be improved, mostly in the production, pertinence, transfer and adoption of K&T. These issues were highlighted by the expert team from the UNCTAD that visited Colombia in 1996 and made a review of the Colombian agricultural sector. The team found deficiencies in accessing to financial resources, poor performance of ICA and Corpoica as key actors of the Agro-Industrial SI, an inefficient technical assistance system, and a weak NSI supporting the agricultural production chains (UNCTAD, 1999).

4.5.2.1. Operation of the SNCTA

The contribution of the agriculture sector to the national GDP has grown substantially between 2000 and 2009, having an overall average of 27.4% of growth. Similarly, agribusiness exports represent on average 30% of total exports of goods in the country. This sector has been fundamental for the social and economic development of the country (Flórez M, Morales, Uribe G, & Contreras Pedraza, 2012).

Agriculture has had a long trajectory and has been a key economic sector for the LAC region and for Colombia. However, the participation of the sector in the overall country GDP has decreased over the past years, and so does the Agriculture GDP growth (Figure 4.23).

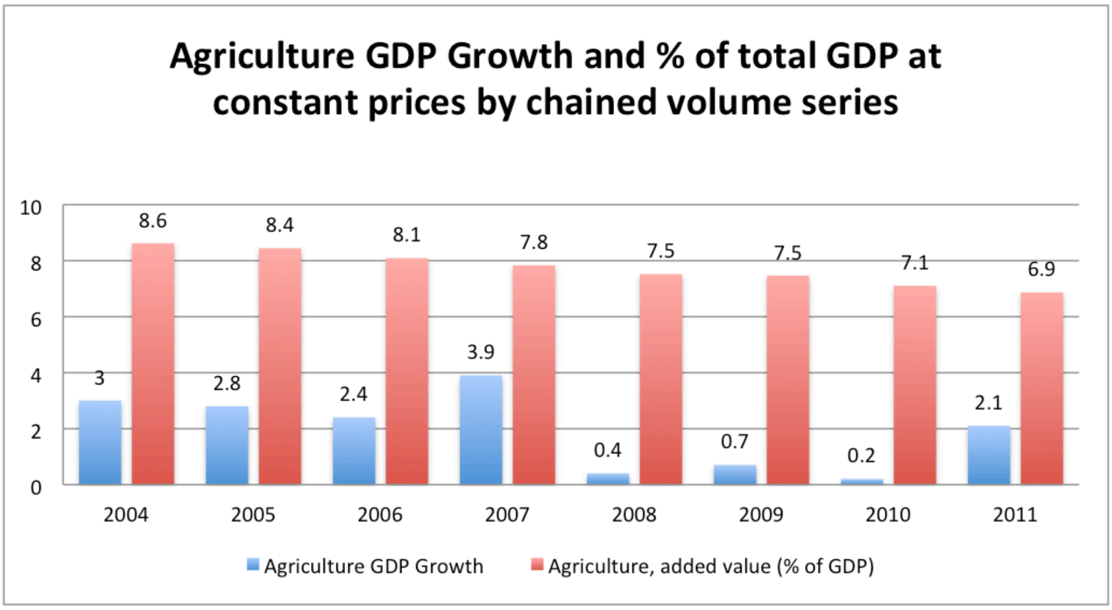


Figure 4.23. Agriculture GDP Growth and Participation of total GDP

Source. Information compiled by the author. Agriculture GDP Growth (DANE, 2013). Agriculture added value as % of GDP (WB, 2012).

This is partially due to a decline in coffee exports over the past 40 years, to a substantial diversification in the composition of exports, and to internal conflicts with illegal armed groups that has caused a large displacement of growers from their lands to capital cities[83]. Figure 4.24 shows the evolution of exports composition during the last years. Traditional growth represents the oil and coal expansion supported by government incentives. The non-traditional exports account for export products different to coffee, oil, and minerals.

> Average annual growth of non-traditional exports between 1970 and 2005 not only was 5.3 times higher than overall average annual export growth, but also was characterized by increasing exports of manufactures of medium and high knowledge content. (Meléndez A & Harker R, 2008, p. 20)

[83] Colombia has the second largest number of displaced people in the world with about 3.6 million people forced to flee their homes and off their lands. This has caused a strong impact on the development and performance of the agriculture sector of the country. (PNUD, 2011)

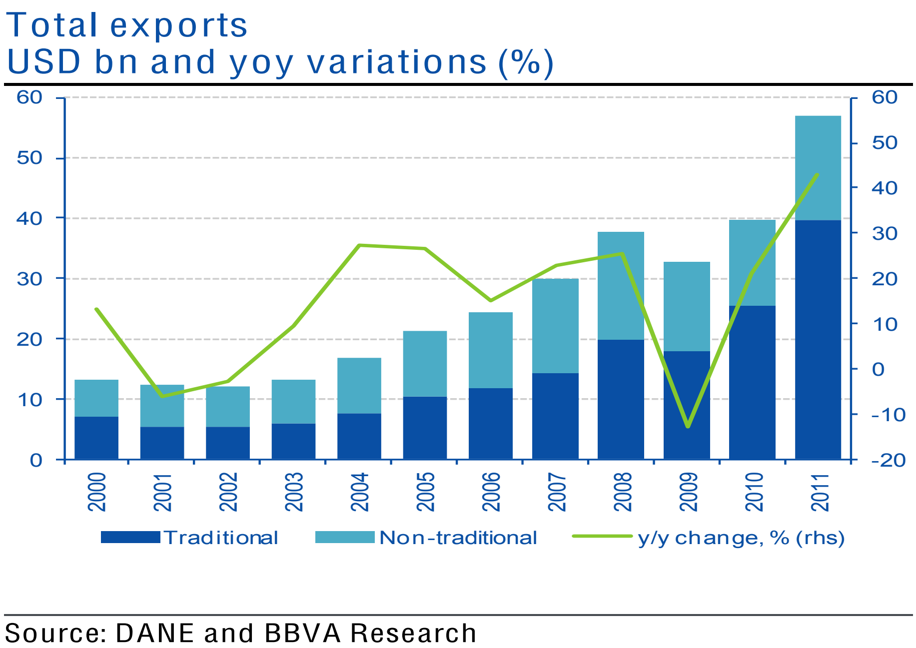


Figure 4.24. Composition of exports 2000-2011.

Source. (Hernández, 2012)

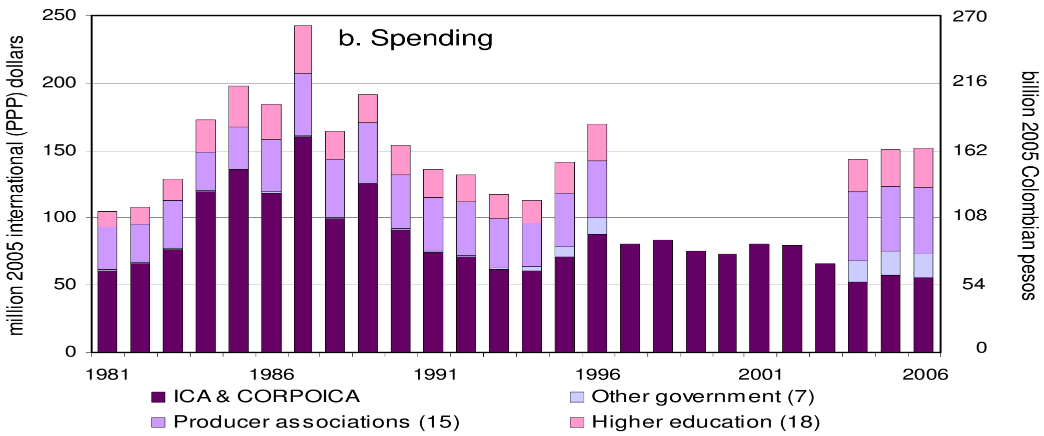
The importance of the agriculture sector has fallen during the past 20 years. The decreasing share of agriculture in overall GDP and exports has been taken up by the industrial and services sectors. Nevertheless, it remains a key sector, not only for the economic growth, but also for the employment levels the sector generates (Stads & Romano, 2008).

There are 285 agriculture research groups recognised within Colciencias classification, which accounts for 5% of the total number of research groups within the national S&T programs[84]. Looking at OECD statistics, it can be seen that 6% of the total active research groups in Colombia are within the agriculture studies area. However, given the importance of the sector for the social and economic development of the country, more effort should be made in terms of building capabilities.

The funding sources distribution in this sector has also changed during the past 20 years (Figure 4.25). Currently there is a higher private investment in S&T activities mainly accounted by producer associations. Some producer associations have their

[84] For having detailed statistics on every National S&T program, look (Jorge Lucio et al., 2012)

own research centres (CENI) funded mostly through production taxes (cesses) paid by producers themselves[85]. There are 7 CENIs in the country: CENICAFE (Coffee), CENICAÑA (Sugar Cane), CENIPALMA (Oil Palm), CENIFLORES (Flowers), CENIACUA (Fishing), CEVIPAPA (Potato), CENIVAM (Tropical Medicinal Aromatic Plant Species). CENIs have been created by strong producers associations for promoting the generation and absorption of applied knowledge by small, medium and large producers[86]. However, only 7 production chains out of 37 registered chains have their own research centre.



Sources: Compiled by authors from ASTI survey data (IFPRI 2007–08), Beintema, Romano and Pardey (2000), and a number of agency websites.

Figure 4.25. Composition of R&D Spending.

Source. (Stads & Romano, 2008, p. 6)

Expenditure on agriculture can also be seen in the evolution of the overall and distributed number of researchers in the private, public, academic, and mix sectors. “In 1981 ICA/CORPOICA researchers accounted for 71% of Colombia’s total agricultural R&D staff. This share has gradually fallen over the years to 53% in 1991, 36% in 2001, and just 27% in 2006. Concurrently, the share of R&D staff at the producer associations increased substantially, from 15% in 1981 to 35% in 2006.” (Stads & Romano, 2008, p. 6)

[85] Agricultural products paying cesses currently are: coffee, sugarcane, oil palm, cotton, raw sugar, cocoa, and fruits.
[86] Looking at official statistics from DANE and MADR, it can be seen that the productive chain that have a CENI supporting them have experienced a larger growth in terms of productivity and exports sharing.

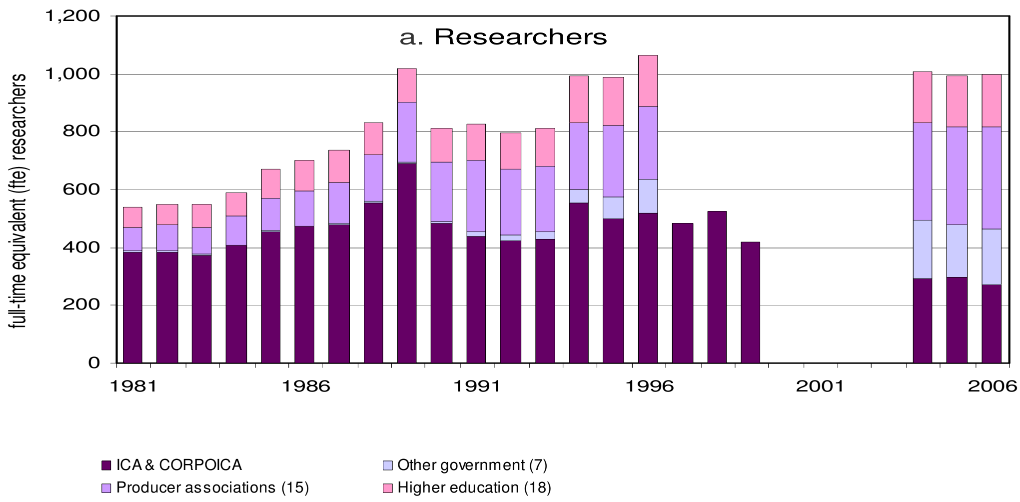


Figure 4.26. Composition of R&D staff

Source. (Stads & Romano, 2008, p. 8)

At the public level, the principal funding bodies are the MADR, Colciencias, SENA, and regional governments. Funding come mainly from the national budget, royalties and external loans. There have been two important cooperation loans with equal counterpart from the Colombian government: National Program for Agricultural Technology Transfer (PRONATTA, 1995 – 2003), and the Agricultural Transition Project (2005 – 2009), both hosted by the World Bank. The total budget for the former was US$56 million and US$30 million for the latter. The main objective of both programs was to facilitate the regional access of small and medium farmers to environmentally sustainable, equitable and competitive technologies. Also, there is a National Fund for Agricultural Financing (FINAGRO) whose aim is to provide funding and support to the sectoral and regional agricultural policy through special loans to small, medium and large producers[87]. The fund was established on the 22nd of January 1990 as a second-tier bank. It was created due to a necessity in the rural sector for an independent and specialized organization that could concentrate several resources in one fund, rather than having credit resources dispersed in several

[87] Finagro, Fondo para el Financiamiento del sector Agropecuario, was created through the law 16 of 1990. Its aim is to stimulate the creation of new production, marketing, and processing of agricultural and fishery products companies, by investing in specific projects. At least 40% of the national government funds for incentive of rural capitalization must go to projects registered by small producers.

organisms. It works as a complementary variant of the political economic of the Colombian Central Bank[88].

Increasing diversification of funding and research agencies has changed the institutional setting for the agriculture system. CORPOICA's budget has been sharply reduced from 2002 as a result of its strong reliance on national government funds[89], which has been compensated with the participation of other government agencies, higher education institutions, producer associations and special projects and programs with international cooperation bodies. However, the contraction of the investment in agricultural R&D in the last 10 years can be seen in the fall of FTE researchers, and the total spending as a percentage of agricultural output[90].

4.5.2.2. Main obstacles and problems in the agriculture sector

From its emergence, the agricultural sector has faced a number of factors that have jeopardized its stability in the short, medium and long term. While each subsector of agriculture has a large number of specific problems, there have been identified five major cross-sectoral problems: lack of legal clarity about the use and land tenure; lack of adequate infrastructure for competitiveness; high cost of agricultural inputs; fall in the price of agricultural commodities; and an exchange rate appreciated against the countries of the region that are agricultural competitors like Argentina, Brazil, Chile and Peru (Asocaña, 2014a)

In Colombia owning land is a symbol of status and wealth, so it is common to find landowners that do not use it for commercial purposes. "Land ownership as a symbol

[88] Information retrieved from https://http://www.finagro.com.co/qui%C3%A9nes-somos/overview. Retrieved 20-05-2014, 2014

[89] After the national economic crisis in 1998, there was a fiscal deficit that produced a cut in government expenses in several sectors, especially for agriculture. "The disbursement of government funds to CORPOICA has also changed over the years, moving away from a virtually exclusive reliance on open-ended block-funding arrangements toward more time-bound research contracts" (Stads & Romano, 2008).

[90] The total number of PhD-qualified agricultural researchers in Colombia is very low (96 PhD's out of 999 FTE's in 2006) compared to other countries in South America with much smaller total agricultural research capacities. In 2006 Colombia invested \$0.50 in agricultural research for every \$100 of agricultural output, which was lower than the corresponding ratio in 1996 (0.61) but slightly higher than the 1981 ratio (0.43) (Stads & Romano, 2008).

of social status and political power; the 'rent-seeking' that is characteristic of some of the more affluent social groups in the country, and the lobbying power of the landlords in Congress in Colombia, explains this systematic sabotage to the attempts to make a genuine agrarian reform" (Fundacion Agenda Colombia & IICA, 2005, p. 13). Regulation on distribution of land in Colombia remains unclear, which has caused a poor distribution of the land for having productive projects towards a better land use. Figure 4.27 presents intended and actual use of Land in Colombia, according to the National Geographic Institute, Agustín Codazzi.

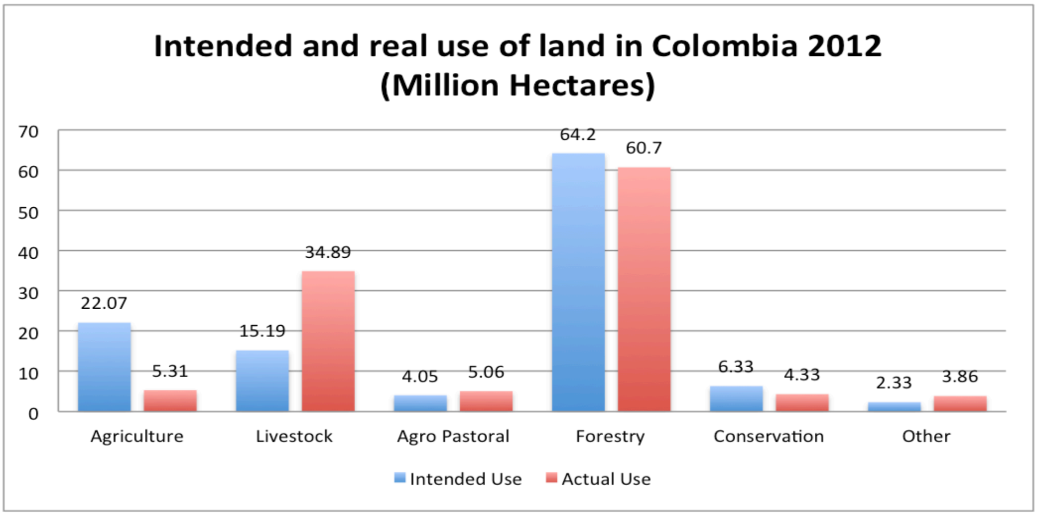


Figure 4.27. Intended and real use of land in Colombia 2012

Source. (Asocaña, 2014a, p. 27)

Transport has been always a main burden in the insertion of Colombian products to international markets. Fluvial transport was mainly used during the nineteenth century, connecting the north coast part of the country with the centre through Magdalena River (the most important and bigger river of the country). However, there was not an enabling infrastructure in terms of ports and steamboats to respond adequately to the local and international trade demands. Construction of railroads was not exempt of problems either. Regional and central governments did not have strong budgets to support the building process. By 1883 there were 150 kilometres of track built, with a final length of 1,120 kilometres by 1915. Then, during the late nineteenth and early twentieth centuries, mules remained as the principal transport mean for the coffee transportation from farms to the central markets and ports.

(Palacios, 1980). Colombia has continued having poor quality in the overall infrastructure[91]. According to the global competitiveness report 2011-2012, Colombia is ranked in the position 95, out of 142 countries. This is accounted by an almost inexistent railroad infrastructure (99), few commercial and small commercial ports (109), and high transactional cost in the air transportation (94). As a result, travel time and costs associated to transport of raw and finish products hinders the country capacity to be competitive in the world commercial trade. This especially affects the agriculture sector that relies heavily on the mobilization of products both for domestic and international markets.

The contraction in international demand due to the global economic recession of 2008 and 2009 originated in the USA caused a slowdown in the production of agricultural commodities and a fall in exports. Given that the USA is the main destination country for agricultural exports, the Colombian agriculture sector suffered more intensively the crisis. Also, the fall of dollar, with strong fluctuations between 2006 and 2009 has been a substantial burden for the international trade and final direct profits for Colombian agricultural producers. The Colombian economy still relies heavily on the North American market. With the fluctuation of the exchange rate, profits associated to the agriculture production have fluctuated as well (MADR, 2013).

Sectoral agricultural policies are not only focus on the economic performance and productivity of the production chains. A main concern is the social equity and improvement of living conditions of small and medium producers. In that respect, the sector can still improve working conditions of labour. Figures 4.28 and 4.29 show the Quality of Life Index (QLI) and Unsatisfied Basic Needs index (UBN) for the main productive chains in the country. Sub-sectors as sugarcane provides better conditions for labour force than the national average. The ideal would be to elevate these two indicators for the labour force of every production chain (Arbeláez, Estacio, & Olivera, 2010).

[91] Infrastructure data can be found in http://www3.weforum.org/docs/GCR2011-12/14.GCR2011-2012DTIIInfrastructure.pdf

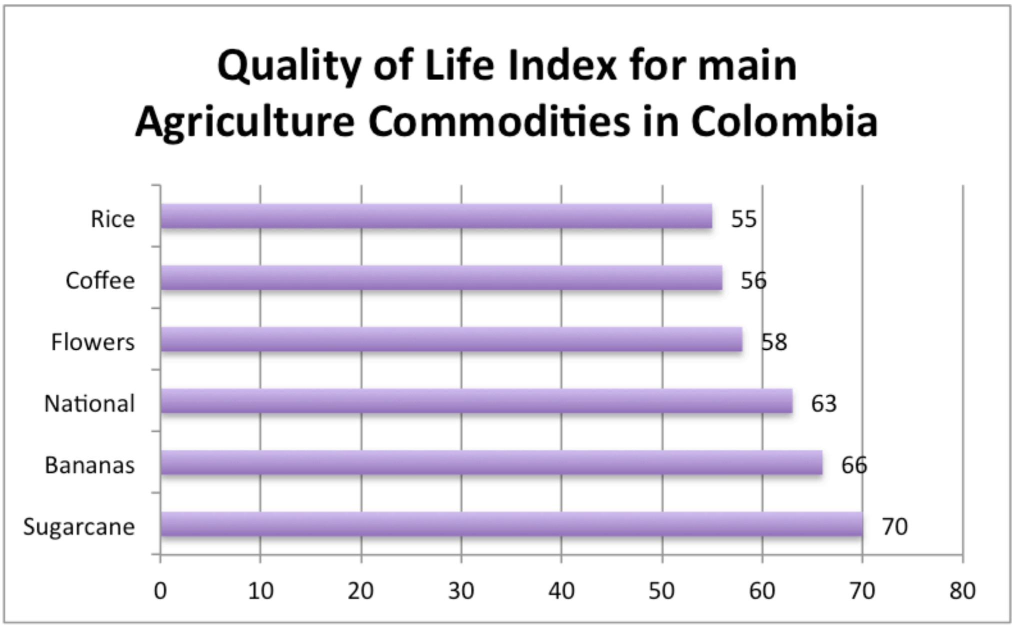


Figure 4.28. Quality of Life Index for main producers Agriculture Commodities in Colombia

Source. Based on (Arbeláez et al., 2010)

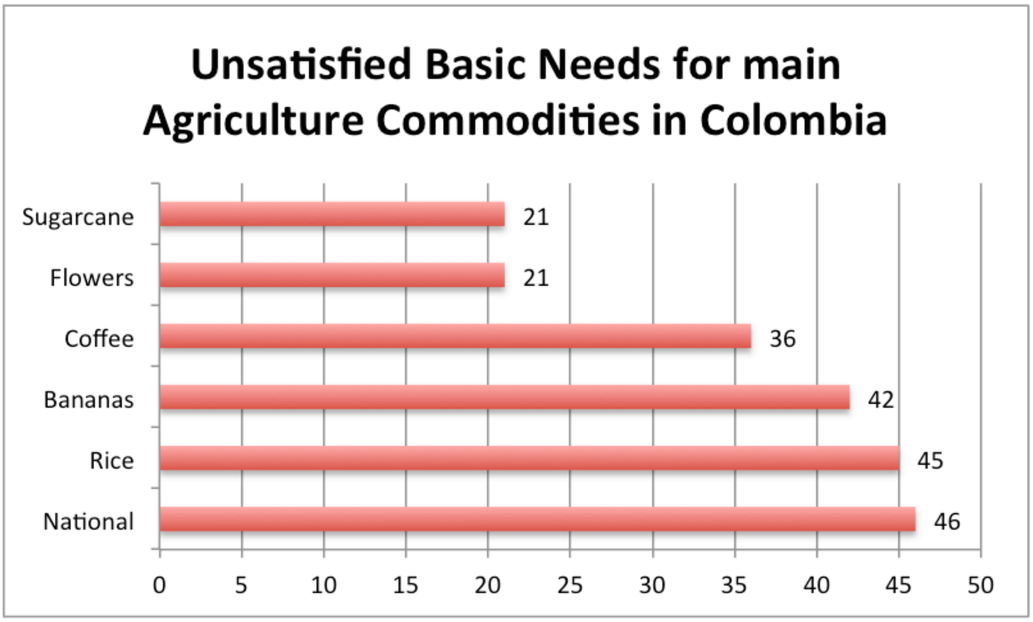


Figure 4.29. Unsatisfied Basic Needs for main producers of Agriculture Commodities in Colombia

Source. Based on (Arbeláez et al., 2010)

4.6. Conclusion

There is certainly a formal framework in Colombia that supports the existence of a National Innovation System, which at most represents an atypical case taking into account that the NSI is a framework to promote innovation within countries more than a normative law scheme[92]. The legal structure links enabling policies in order to generate a positive atmosphere to build and sustain relationships between firms and public and private research institutions. However, when it comes to the implementation and instrumentalisation of these enabling policies the desirable outputs have not been achieved. In this chapter we discovered that there is a gap between the ideal model proposed in policies and whitepapers and the real interaction between actors to encourage innovation processes.

Even though officially is said that there is a systemic vision of innovation, the policy mixes built upon innovation show a linear view of innovation. There is an unbalance between the emphasis put into the scientific and technological system and the innovation side of the policies. Most of the efforts have been directed to strengthen the research side of the system under the assumption that with public investment in research, knowledge exploitation happens as a natural reaction. We conclude that Colombia and Latin America are locked-in into the NSI approach, and even though there are criticisms about the way the approach has been understood and applied, discussions remained within the same framework.

When we turned our view towards the Agro-industrial sector, we found there are still many challenges that need to be addressed. The insertion of agriculture products in Global Value Chains and the enhancement of local capacity are pressures that can trigger production chains productivity. A greater diversification in R&D funding sources has been beneficial for the sector, but a larger expenditure needs to be done both to have more researchers and to fund special projects for small, medium and large producers. Products like flowers, potatoes, exotic fruits, bananas, and rice are important in the country's total crop value, but there are limited capabilities built in those chains, so greater support to producer associations should be provided by the government. The agro-industrial sector remains as a strategic sector for the country and the social impact of the sector requires more attention from the national side to encourage effective governance systems.

[92] See section 2.3.2.

5. SECOND THEMATIC STRAND: INNOVATION DYNAMICS AT SECTORAL LEVEL

5.1. Introduction

As we have explained in the introduction and the methodology, we developed our study into two thematic strands. In this chapter we present the second pathway where we examine innovation dynamics in three agro-industrial sub-sectors. The coffee, sugarcane and fresh-cut flower production chains are studied using the sectoral systems of innovation lens and a complex adaptive view of the relationships between growers, firms, associations, public organisations and research centres. For each industry we followed the same structure, analysing: the industrial setting, technological evolution, and dynamic complementarities; demand types; the characterisation of sectoral organisations; and the knowledge and technology transfer, adoption and validation patterns.

5.2. Sectoral Cases – Coffee

Coffee has been central for the economic and social evolution of Colombia. It was the main export product until the 1990s and the production and exports of the crop still shapes the macroeconomic behaviour and stability of the country. It has been argued by several authors[93] that the production and commercialization of coffee shaped the socio-political structures of Colombia given its hegemonic tradition in the country's historical pathway.

However, it was not until the 1980s that Colombia evolved from having small and dispersed coffee productive land units to extensive coffee production dominating the exports of the country. From 1730, with the earliest evidence of coffee cultivation in Colombian territory, until 2005 when Colombian coffee was the first product in the country to have a protected designation of origin, this crop and its derivatives have remained a central product upon which the economy relies. The privileged position

[93] The classic studies about the economic and social impact of coffee on the national and regional development has been summarised and analysed by Ramírez Bacca (RamÍrez Bacca, 2010), (M. Arango, 1977, 1982; Bejarano, 1980; Bergquist, 1981, 1986; Brew, 1977; Calderón, 1978; Deas, 1976; Errázuriz, 1986; Jiménez, 1981; Machado, 1975, 1977; Palacios, 1980; Parsons, 1961; Samper, 1988; Zambrano, 1977)

of the country on the equator, plus the presence of the Andes Mountains, the Atlantic and Pacific oceans and the vastness of the Amazon, cause exceptional climatic conditions and rainfall regimes that allow for coffee production during all months of the year. As a result, Colombia is the only country that can offer fresh coffee to the market continually.[94]

Colombia is today the third coffee producer in the world, and the largest producer of washed Arabica coffee. The sector is currently going on a recovery phase after a sustained rainy season during 2010-2011, which caused the spread of one of the most harmful diseases for the coffee, the coffee rust. In 2013, after renovating 80% of the coffee plantations for young coffee groves and adoption of technical production systems, besides a 61% of the coffee plants resistant to coffee rust, the productivity increased by 27% rising from 11.1 coffee bags[95]/ha in 2012 to 14.1 bags/ha in 2013. The most important Colombian coffee export destination is the U.S. representing 44% of the total international trade, followed by Europe with a sharing of 31% and Japan having 11% of the total exports. However, during 2013 the international and domestic coffee price fell by 28% due to three factors: increase in world coffee supply coming from Brazil, Vietnam and Colombia; a larger reserve of coffee in the importing countries; and the instability in the world macroeconomic conditions led by U.S.A and Europe during 2013 (F. N. d. C. d. C. FNC, 2014). These fluctuations in the market have put pressure on the national coffee industry and have threatened the viability of it, creating a social crisis for more than 560,000 Colombian families that depend on the coffee business.

5.2.1. Industrial Setting, technological evolution, and dynamic complementarities

The Italian botanist, Prospero Alpini, made the first reference to a coffee plant in Europe in 1591 after living in Egypt for 3 years. In 1713 the French naturalist Antoine de Jussieu described the coffee plant as a jasmine, but it was Carolus Linnaeus in 1737 who reclassified the plant as a genus with one unique species, the

[94] Information gathered from the Colombian Coffee Growers Federation webpage: http://www.federaciondecafeteros.org/particulares/es/nuestro_cafe/el_cafe_de_colombia/. Retrieved in 11-10-14.

[95] The standard bag has 60 Kg of green coffee.

Arabica Coffee. Today up to 126 species of coffee have been classified, with *Coffea Arabica* and *Coffea Canephora* being the most popular for consumption (Estrada, 2011). It is believed that Dutch colonists brought the first coffee plants to South America in 1714 to the Dutch Guiana. From there, French colonisers took the first plants to the Caribbean islands in the first half of the 18th century and from there it entered Colombia and Brazil.[96]

The production cycle of coffee has a time span of five years on average from planting the coffee groves until the first commercial harvest is obtained. Plantations are usually replaced every 8 years. Colombia produces 100% *Arabica* coffees. The *Café de Colombia* is characterised as a clean cup drink, with medium/high acidity and body, and pronounced aroma. The main varieties of *Arabica* coffee that are grown in Colombia are: *Typica, Bourbon, Maragogipe, Tabi, Caturra* and *Castillo* varieties. The Castillo variety was formerly known as *Colombia* variety. The selection of plant material is developed in Cenicafé, the national research centre for coffee.[97]

According to Estrada (Estrada, 2011), the evolution of the coffee sector can be analysed within three different development stages: 1. Consolidation of the coffee economy (1850 – 1910); 2. The coffee boom period (1910-1950); 3. Formation of class and regional alliances and instability within them (1950 – 2010). However, we consider that the last period can be divided in two different stages, given that from the 1990s the development of the sector has focused on the stabilisation of domestic production to cope with both climatic variations and the fluctuations of international coffee prices. In that sense, we describe and analyse a fourth stage, the ups and downs in the coffee industry and modernisation of the marketing strategies.

During the first stage, the predominant production unit was the *hacienda*, a large area of land with a strong hierarchical work system and inherited colonial institutions. The second stage reveals the shift from a single and powerful landlord with a vast

[96] A broader historical context can be found in: http://www.cafedecolombia.com/particulares/es/sobre_el_cafe/el_cafe/el_cafe/

[97] Information gathered from the Colombian Coffee Growers Federation webpage: http://www.cafedecolombia.com/particulares/es/el_cafe_de_colombia/un_cafe_sobresaliente/. Retrieved in 11-10-14.

holding of land to the partition of the haciendas into small production units (land parcels of 3 hectares in average) with small landowners or *campesinos*[98]. The third stage is characterised by the positioning of the Colombian Coffee Growers Association (FNC – for its acronym in Spanish) as the sole coffee producers association with an active involvement in the coffee production chain, from cultivation until commercialisation. Finally, the fourth stage has been focused on generating a sustainable and competitive sector in a changing environment shaped by other competitors, specialised customers, climate change, and scarcity and surplus of world coffee production.

The importance of coffee in the national development goes beyond the economic benefits that it brings to the macro and micro economic structures. It stimulated reflexion and discussion among the political elites about the development of inclusive social institutions, and even the establishment of democracy in the country. Colombian democracy was born in the rural areas through the political impetus of a working class composed of small farmers. Not to mention the broad impact in the development of port cities, revitalisation of domestic markets, employment generation, and industrialisation that the coffee sector has had in the evolution of the Colombian economy (Posada Carbó, 2012).

5.2.1.1. Consolidation of the coffee economy (1850 – 1910)

Three regions were producing coffee by the end of the nineteenth century: the north-east (Santanderes), the centre and south-east (Boyacá-Cundinamarca-Tolima), and the west (Antioquia). During the second half of the century, given the agrarian nature of the country, three agriculture products dominated: coffee, tobacco, and indigo. The economic capital for coffee plantations came mainly from the tobacco trade and mining. By this period, the economic performance of Colombia was modest, even compared with countries of the region (Palacios, 1980).

[98] We use the term *campesino* instead of peasant to differentiate it from the notion of an "estate-like, caste-like, corporate or subordinated social group, characterized by specific restrictions on geographical or social mobility, limited rights, and obligations to provide services and perform particular deference behaviours for superordinate groups." (Edelman, 2013). A *campesino* is a small farmer who makes a living from agriculture.

Between 1870 and 1930 Latin America followed an economic development pathway characterised by an export-led and outward-looking development based on agriculture and mining products. However, the export boom in Colombia did not start until 1910 mostly accounted by the predominance and strength of the coffee production. The rise in coffee demand from 1870 onwards shaped the future domination of this commodity in the Colombian exports (Palacios, 1980).

> Coffee introduced greater variety to the agricultural structure. It was grown in the temperate zones — heights between 1,000 and 1,800 metres above sea level - alongside traditional crops, whose production had evolved considerably since colonial times. The most important of these crops was sugar-cane, which was crudely processed in rustic *trapiches* which extracted the *miel* to make *guarapo* and *aguardiente* (fermented drinks), and fabricated *panela* (loaves of unrefined sugar). (Palacios, 1980, p. 12)

The main production unit during the nineteenth and early twentieth century was the coffee '*hacienda'*. The landowner was the supreme authority and under his command he had a work system where labour classification was made according to factors of class and race. Since the landlord was absent much of the time, he had an administrator (usually a middle-class white man) and the administrator usually had a groundsman or *mayordomo* who was in charge of the *campesinos*. A semi-servile system of work was in operation with a strong hierarchical structure, where the *'indios'* or indigenous people were the last ones in the command line. In order to be resilient to internal and external economic fluctuations, haciendas adopted a multi-crop fields strategy to respond to market price changes, to supply domestic market demands, and to buffer against the cyclical rise and fall of coffee prices (Palacios, 1980).

5.2.1.2. The coffee boom period (1910 – 1950)

Big *haciendas* ceased to be productive during the first part of the 20th century, additionally unequal distribution of land brought social unrest. Also, a diversification in the commodities exports structure was needed to deal with the international macroeconomic environment. Workers previously employed in small farms or *fincas* in the mountains started to take part in their own right in the coffee market. Although the *haciendas* survived the civil war[99] of the end of nineteenth century -*la guerra de los mil días (the war of the thousand days)*-, they could not stand the pressure of an extensive export market. *Campesino* families started to trade with retailers and marketers that had connections with North American and European markets (Estrada, 2011).

This change in the land structure was more prominent from 1930 onwards. Small landowners started to dominate the production of coffee, making their own families the main source of labour. This labour structure has survived until the present day. The development of the coffee sector promoted the birth of a regional working class that would be taken as a model by other sectors in the country (Posada Carbó, 2012). However, the average income level of these small landowners did not increase accordingly with the profits rate, which has been the cause of instances of social discontent and strikes during 20th and 21st centuries.[100]

Trade balance by the end of the First World War improved dramatically, as can be seen in Figure 5.1. By 1927 Colombia was the fourth South American country in terms of foreign trade volume. The department of Caldas[101] produced a third of the national coffee volume, consolidating its position as the most important coffee region. Colombia's economy relied on coffee as the main export product and one single dominant market, the United States of America. During the 1920s there was a strong presence of North American roasters in the domestic market, buying cheap raw material and exporting higher value-added coffee to external markets. This generated an expansion in Colombian coffee international trade based on traditional agriculture techniques, with low introduction of technology, low productivity, and inequitable distribution of profits. Intermediaries and storekeepers captured the main benefits and profits. (Palacios, 1980)

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[99] Civil war that took place between October 17th of 1899 and November 21st of 1902 held by the two traditional Colombian political parties, Liberals and Conservators, to gain political dominance.
[100] The latest protest directly made by the Colombian coffee growers took place in February 2013 and last for eleven days with strong confrontations between the Colombian police and the growers. The Colombian Coffee Growers Federation rejected the protest. The coffee growers were asking for more subsides from the government given the poverty conditions in which they live because of the low production and low prices of coffee through the years.
[101] Colombia is politically divided in departments. Department is homologous to state.

Table 29. *Colombia: index of growth of foreign trade, 1905–29 (U.S. dollars)*

Three-year period	Annual averages (1905–7 = 100)		
	Imports (c.i.f.)	Exports (f.o.b.)	Coffee exports
1905–7	100	100	100
1916–18	221	270	352
1927–9	1,150	902	1,473

Source: Banco de la República, *XLII y XLIII Informe Anual del Gerente a la Junta Directiva* (2 vols., Bogotá, 1965–6), vol. 2, p. 190.

Figure 5.1. Index of growth of foreign trade 1905 – 1929

c.i.f. stands for Cost, Insurance and Freight; f.o.b. stands for Free OnBoard

Source. (Palacios, 1980, p. 207)

After the great depression, in 1930, the price of coffee fell by 50% and many production labourers lost their jobs. Colombia depended greatly on the United States market and much of the macroeconomic stability of the country was depending on loans and foreign participation for the key national economic activities. English investors that were dominating the domestic and international market lost power and control, giving way to their North American competitors (Sevilla Soler, 1992).

As an effort to regulate and characterise the sector, the Colombian Coffee Growers Federation (FNC) conducted the first official Coffee census, including the totality of coffee regions, in 1932. This was the first official statistical work made about coffee production and trade. However, the data was not completely reliable in terms of the technical accuracy of the statistical measures and of the veracity of the information itself (Fernández-Muñoz, 2014). This census differed greatly from previous partial statistics for the sector.[102]

5.2.1.3. Class and regional alliances and instability among them (1950 – 1990)

Coffee demand is driven by habit, not necessity. In that sense, there is always demand for the product but with different volume rates, which determines the

[102] Coffee statistics can be found in: "Anuario de Estadística de Colombia" published in 1875; Boletín de Estadísticas de Cundimarca, published in 1923; Economía y Estadística, published in 1929; Estadísticas de Antioquia, 1914; and Colombia Cafetera, 1927. There are clear inconsistencies between these previous regional censuses and the first oficial Coffee Census. Palacios (Palacios, 1980) argues that these divergences can be explained by the manipulation of data done by the FNC given its strong influence in the definition of sectoral policies.

elasticity and term of the supply cycles. The production of coffee depends mainly on the climatic and soil conditions, although low technical development has hindered productivity. On that subject, Palacios explains (Palacios, 1980, p. 238):

> [U]ntil 1970, the average differential productivity of coffee land cannot be attributed to the fact that some 'efficient' units use fertilizers, better cultivation methods, and superior botanical varieties, but rather that they are located in better lands and climates.

However, productivity has been always a major issue, particularly because of the prevalence of small farmers based on subsistence economy and a traditional family division of labour. The average coffee productivity by unit of production in 1970 in the Colombian coffee regions was 541 kg/ha, well below the world average productivity of 1000 kg/ha for the same year (See Figure 5.2.).

	Number	%
Less than 300 kg/ha	3,281	18.1
301–375 kg/ha	2,903	16.0
376–500 kg/ha	4,939	27.3
501–750 kg/ha	4,648	25.7
751–875 kg/ha	869	4.8
876–1,000 kg/ha	472	2.6
Over 1,000 kg/ha	955	5.2
Total	18,067	99.7

Source: FNCC, *Boletín de Información y Estadística*, no. 45 (1971), p. 34.

Figure 5.2. Distribution of national coffee production in 1970

Source. (Palacios, 1980, p. 240)

In 1960 the FNC started a market strategy for competing through differentiation. The Colombian coffee would be promoted as different from the other world coffees. *Café de Colombia* was introduced in the international market as a quality standard. In 1982 a broader marketing campaign was launched using a distinctive seal for the Colombian coffee as the “finest coffee in the world”, with the signature *100% Café de Colombia*. Shortly after, the *Juan Valdez* icon was added to integrate tradition to the quality seal. This was a strategy to protect the product against the increasing tendency of big roasters to combine different coffee beans without differentiation. Colombian coffee would be identified through tradition, effort, and the artisanal work of *campesinos* to produce “the best coffee in the world” (R. Arango, Taniguchi, Johnson, Tamayo, & Petit, 2010).

Also from the 1960s the "*Program of Development and Diversification*[103]" was launched by the FNC as a response to a low world production of coffee, which resulted in a coffee supply crisis during 1957 – 1962. The key program strategies were to increase productivity for the whole agriculture sector, to provide food security for the country within the early globalization movement, and specifically for the coffee sub-sector, to stimulate the creation of manufacturing industries. Welcoming the recommendation of the Coffee International Organization (CIO), the FNC promoted the renovation of old coffee groves with new varieties and better cultivation techniques and management of units of production. However, changing the cultural setting of traditional *campesinos,* introducing the idea of the renovation of their plantations for newer, more productive ones (according to technicians from the Federation), was a shocking process given that a new coffee grove takes between 3 and 5 years to have the first harvest according to the variety, soil and climate conditions. By 1974, only 10% of the total planted area had renovated their coffee groves (Palacios, 1980).

There was an important coffee bonanza between 1975-79 characterised by a prominent rise in the international coffee price, combined with higher inflation in the country and a lower rate of devaluation of the Colombian peso. Although this period was good at a first glance for the sector, it was not for other tradable goods. This high income of foreign currency produced a higher relative price of non-tradable products, and a price reduction of other tradable goods, affecting the overall competitiveness of the economy (Edwards, 1984). However, as Raju and Melo argue (Raju & Melo, 2003), since coffee booms have had a positive real output for the macroeconomic conditions of the country and visible long-run effects on reducing the country current account and government deficits this economic effect should not be understood as a Dutch Disease effect.[104] This boom was followed by other ones in 1986 and 1995.

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[103] The program was underway during the period 1973 – 1978 as a broader strategy for all economic sectors to create a stronger internal market and strengthening different manufacturing industries. Since coffee was the principal export product by that time, a great emphasis was put on the sector.

[104] "…coffee price (revenue) shocks have exerted an important influence on money growth, inflation, and real exchange rates, and the direction of these effects are in line with some of the predictions of

5.2.1.4. The ups and downs in the coffee industry and modernisation of the marketing strategies (1990 – 2011)

The market liberalisation during the 90s decade, fluctuation in international prices with a sustained downward trend, changing weather conditions having periods of drought (El Niño phenomenon) or excessive rainfall causing floods (La Niña phenomenon) and spreading of coffee rust[105], has caused a marked drop in coffee production. Also, the entrance of new competitors in the world marketplace with lower production costs, higher coffee production in Brazil, and the introduction of technological advances that has favoured a higher consumption of Robusta coffees, has resulted in a loss of competitiveness (Otis, 2013). With a production of 10.5 million sacks in 2000/2001, Vietnam surpassed Colombia taking the second production place in the world. In 2011, Vietnam doubled the Colombian production (International Coffee Organisation). However, the economic importance of the coffee sector remains prominent in the national landscape. More than 560 thousand families base their household income on coffee production and about one million people are involved in different phases of the production chain including activities such as processing, commercialisation, and exports.

The different stages of the coffee production chain can be seen in Figure 5.4. Small farmers with an average plantation of 4 hectares prevailed. The coffee plant cycle from the planting process until it is ready to sell takes on average 5 years. One of the distinctive characteristics of the Colombian coffee is that farmers, given the terrain conditions, handpick it, which makes very difficult the use of specialised machinery. Only the red coffee cherries are collected, which needs the judgement of the coffee growers and impact directly in the final quality of the coffee. The pulping process consists of the separation of the coffee bean from the skin and pulp; it is usually done right away after harvesting. The remainder of the pulp is removed through a

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traditional Dutch Disease type models…We find that in the time horizon of 5 years after the boom, real output has increased in response to the effects of the coffee boom. The finding that coffee booms can result in positive long-run output effects is an important finding since it contradicts the traditional conclusion of Dutch Disease type models which envision an adverse long-run effect on output." (Raju & Melo, 2003, p. 963)

[105] Coffee rust was first discovered in Latin America in Brazil in 1970. From that moment onwards, it spread throughout the region. It is a typical fungus that affects the leaves and the tree, causing defoliation and reduces yield. It is mostly spread by wind and rain water. It can be seen on the leaves as pale yellow spots breaking through its epidermis (Schieber, 1972).

fermentation treatment or through a *dry method.* The grains, still wrapped in a tough shell, are placed in water for 24 hours. This causes a mild fermentation that impacts on the coffee aroma. Once the grain is completely clean from pulp and shell, it is washed with clean water. The dry method consists in the removal of the remainder parchment skin and mucilage, once grains are completely dried (García Cáceres & Olaya Escobar, 2006). (See Figure 5.3).

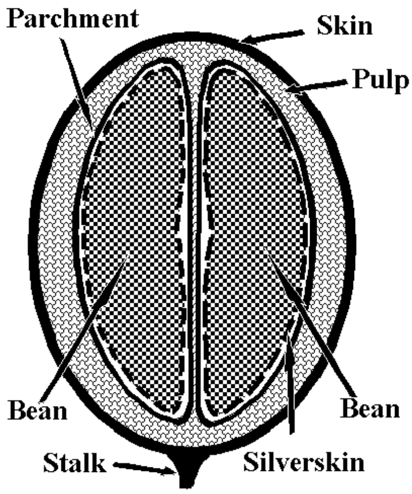

Figure 5.3. Cross-section of a coffee cherry

Source. Retrieved from http://pixgood.com/coffee-cherry-structure.html

The coffee grains are raked or turned by hand for improving the drying process which consist of a sun drying process in extensive terraces and when the parchment coffee is almost dry, it is put into special machines to dry it completely. The hulling process is done by specialised machines to remove remaining skin or pulp. When there is still skin on the coffee cherries, a polish process is done to improve the appearance and flavour of the grains. The best quality grains are packed into sacks to be transported to the nearest collection centre. The buyer makes a classification of the grains according to the aroma, colour, size, humidity, and texture. The best grains are sold for export, the remaining are sold in the domestic market (García Cáceres & Olaya Escobar, 2006). The planting, picking, and drying processes are done in-farm.

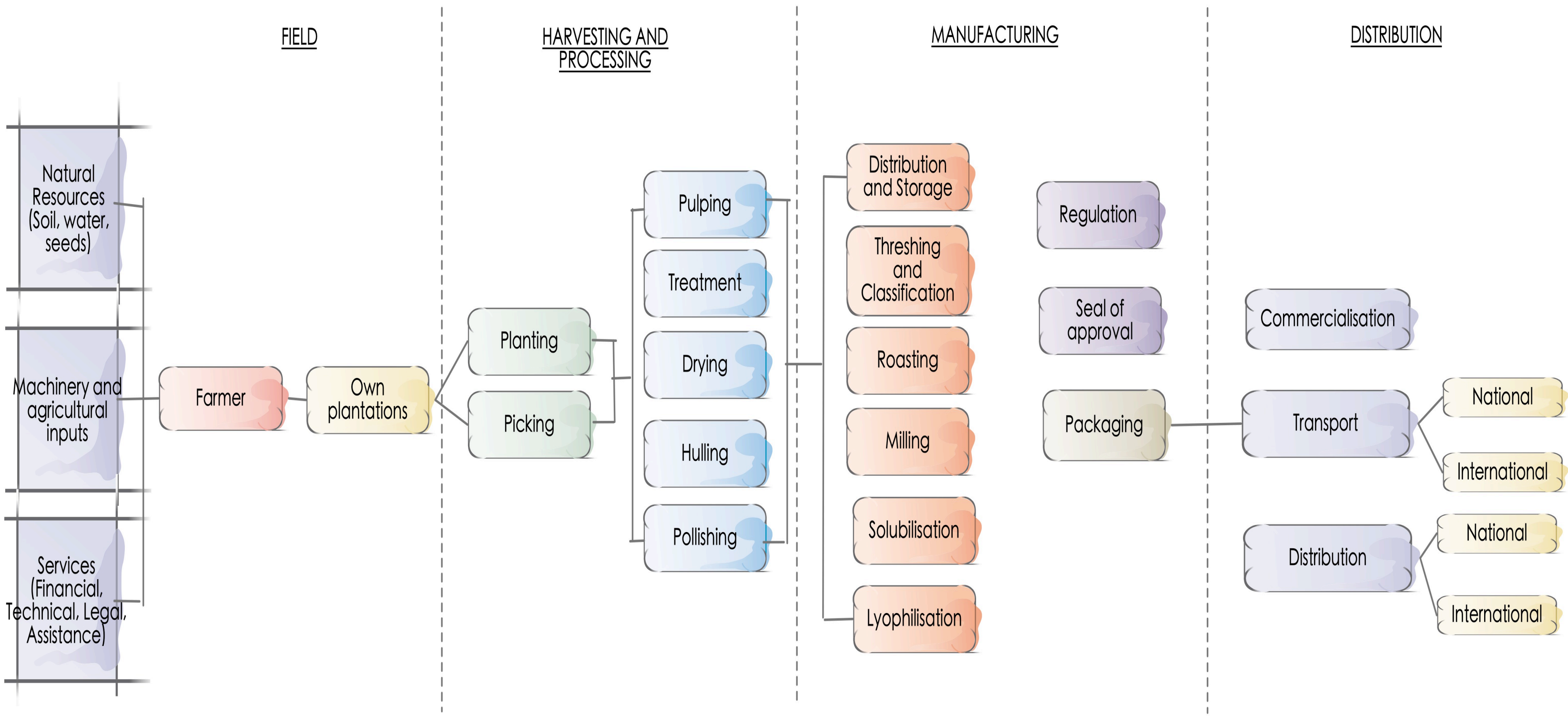

Figure 5.4. Coffee production chain structure

Source. Modified version of the coffee value chain presented in (García Cáceres & Olaya Escobar, 2006)

In the Colombian context, once intermediaries[106] have bought the parchment coffee grains from coffee growers, most of them local *campesinos*, the threshing and sorting process starts. The process consists of separating the parchment from the coffee grain and removing all impurities. The resulting product is green grain coffee; usually exported in this stage to the international market (only the grains with an olive green colour are selected for export). Before the grains are sold to international markets, the FNC test a sample of the grains to certify that it meets the quality specifications. This certification process is known as "Seal of approval"[107] to assure that the coffee meets standardised quality characteristics and it is a compulsory requirement for all exporters. There is also regulation to control the supply and demand of coffee in the marketplace and to stabilise prices. The coffee price in the countries where is consumed still responds to the speculative international fluctuations, so the internal price paid to the producer is fixed by sectoral support organisations[108] and the government (García Cáceres & Olaya Escobar, 2006).

Once the green coffee is classified and roasted, the milling process starts. It is one of the most important steps because the coffee grinding affects the final flavour and aroma. Then coffee is ready for packing. Also, coffee can be processed to be lyophilised or soluble. The former is made through a sublimation process at low temperatures, and the latter through a process known as spray-dry where the water is evaporated through the introduction of hot air (García Cáceres & Olaya Escobar, 2006). So the coffee can be exported as parchment coffee, green coffee, roasted coffee, milled coffee, decaffeinated coffee, liquid coffee or as instant coffee (lyophilised or soluble).

Most agricultural crops are very sensitive to climatic variation. In the case of coffee, the excess of rain raises the probability of coffee rust in the plantations. However, when the climate is very dry and there is predominance of high temperatures, there is

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[106] This can be private threshers or coffee grower cooperatives.

[107] The process is divided in two stages: a sample is weighed and rated, then another sample is picked from the same first sample sacks. The new sample is roasted, milled, and tasted in a fresh cup of coffee. Experts then give their score for aroma, acidity and uniformity. If experts are not satisfied with the quality of the coffee, the harvest is rejected for export. (García Cáceres & Olaya Escobar, 2006)

[108] National Coffee Growers Federation, Almacafé, coffee cooperatives, and *Fondo Nacional del Café*.

a higher probability of having coffee berry borer.[109] Coffee price is subject to different externalities that affect the production costs. Besides climatic variations, factors such as government incentives, phytosanitary problems[110], and fluctuations of prices are crucial for the coffee business. As coffee growers reported in a study conducted by Fedesarrollo: "With the rainy season 90% of the crop was lost during the past year, it also affected the phytosanitary control because the risk of diseases increased." (Perfetti, 2012, p. 59).

Labour represents the highest direct cost of growing coffee (around 40%), followed by harvesting costs (around 17%).

> "The agricultural component of the Chain (planting, harvesting, gathering, processing and drying of coffee), highly generates employment, while the purely industrial stages are capital intensive and require relatively less work…It is estimated that the occupation of the first link of the chain can reach about 500,000 direct jobs, while the industrial component thereof does not exceed 5,000." (Espinal, Martínez, & Acevedo, 2005, p. 5)

The distribution of the coffee lands is characterised by a predominance of small farms, but there are also few farms with 100 or more hectares. However, from 1970 onwards, there has been a shift towards smaller coffee production parcels and a larger number of coffee growers with a subsistence economy focus on growing food for feeding themselves and their families, besides their coffee production to sell in the domestic market. The cultivated coffee land area in 1970 was of 1.05 million hectares, while by 1997 this number had decreased to 869 thousand hectares. This is also seen in the average size of coffee farms, passing from 14.8 hectares to 5 hectares. Currently, most of Colombian coffee growers are small landholders (García, 2003) (See Table 5.1).

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[109] Coffee berry borer is the most damaging pest for coffee. In Colombia sixty per cent of coffee plantations remained untreated by 2006. It is a small beetle that attacks developing coffee berries from about eight weeks after flowering up to harvest time. Each berry is attacked by a single female (J. Jaramillo, Borgemeister, & Baker, 2006).

[110] Like risks arising from plant diseases, agrochemical residuals, presence of heavy metals or toxins.

	Percentage of surface area (ha)			Percentage of coffee area (ha)			Percentage of farms (ha)		
Size	1970	1993 - 1997	Change	1970	1993 - 1997	Change	1970	1993 - 1997	Change
0 - 5	8	17	125	17	43	144	53	80	50
5 - 10	8	14	64	14	18	26	17	10	-43
10 - 30	22	27	20	28	23	-18	19	8	-60
30 - 100	29	26	-10	25	13	-48	8	2	-71
> 100	33	16	-51	15	3	-78	2	0	-83
Total	100	100		100	100		100	100	

Table 5.1. Distribution of coffee land and farms by size.

Source. (Forero Álvarez, 2010, p. 99)

According to the FNC of 563 thousand Colombian coffee grower families, up to 96% have less than 5 hectares of coffee plantations. By 2000, seventy-eight per cent of the coffee growing area was planted and harvested by *campesinos*. Although the number of farms doubled during the period 1993-1997, the coffee area cultivated dropped by 18.6% compared to 1970. Looking at table 5.1, 80% of the coffee farms had a size less than 5 hectares during this same period (Forero Álvarez, 2010). Although crop diversification has been a livelihood strategy, many coffee growers are living in poverty conditions.[111] This has been worsened by the aging of plantations and weather problems that have increased the incidence of pests and diseases in coffee. As a result, the quality of life for farmers has deteriorated. Unemployment in coffee areas increased by 7.8% compared to 5.7% in the rest of the country. It is estimated that losses of coffee cultivation in 2001 had an economic impact equivalent to 257,000 jobs per year, of which 181,000 were direct jobs in the coffee sector (Fonseca, 2003).

> "These very fundamental changes reflect a profound restructuring of the coffee sector in the country to much smaller sizes of plantations: in 1970, the percentage of farms with less than one hectare coffee was 12.6% compared to 60.6% today, while the share of parcels larger than 20

[111] In the coffee zone the population bellow the poverty line increased between 1997 and 2000 by 6.7%. In the same way, the households bellow the poverty line increased 2.8%. "…the major limitation to family production is limited access to land. Paradoxically, their systems are productive and economically efficient, but because they are small they generate meager incomes that are insufficient to raise most small coffee growers above the poverty line with their farming income alone" (Forero Álvarez, 2010, p. 107)

> hectares was 16.5% compared to 0.5% today [2003].” (Fonseca, 2003, p. 5)

The sector keeps suffering because of both external and internal factors. In 2012 the coffee industry had one of the strongest crises. Coffee production began to decline rapidly since 2009 and was worsened by a rainy season that produced constant and heavy rains in the coffee zone. This resulted in the rapid spread of coffee rust in the coffee plantations, besides flooding and road disturbances, which also affected the transport of coffee to the market places. Brazil has kept high productions of coffee, having a record of 50.8 million bags to export in 2012. With steady decrease in levels of coffee consumption in the North American and European markets, there has been a surplus in coffee consuming countries. This has had a direct impact on the small coffee growers who are not making a profit, and actually losing money (Otis, 2013). Also, infrastructure problems represent a major burden for the agriculture sector, and particularly for the coffee growers. “Poor transportation networks create a major barrier to improved farm income and coffee farmer profitability. Poor sanitation and housing keep people impoverished and unable to successfully cultivate high-quality coffee at commercial production levels” (Mueller, Gómez, & Ricketts, 2013, p. viii). It is ironic how a sector that has represented a major economic activity for the country, has gone through a process of deterioration of the quality of life of the coffee growers. It could be an indicator for the FNC and the Colombian governments that more efforts to keep the sector competitive are needed, adopting different supporting strategies.

5.2.2. Demand

The coffee production in Colombia is concentrated in four regions: Central Western (includes Antioquia, Caldas, Quindío, Risaralda, Tolima and Valle departments); East (includes Boyacá, Cundinamarca, Norte de Santander and Santander departments); South (includes Cauca, Huila and Nariño departments); and North (César and Magdalena departments). The central-western region concentrates the 65.9% of the national coffee production (Fonseca, 2003).

Coffee is the largest cultivated area crop in the country. According to the Ministry of Agriculture and Rural Development (2011) 744.162 ha were planted in 2010, representing 19% of the total harvested area in the country, including temporary and permanent crops. The largest destination of the Colombian coffee exports is the United States, followed by Japan and Germany, as can be seen in Table 5.2.

COUNTRY	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
AMERICA												
USA	2,956	3,061	3,441	3,623	3,560	3,974	3,793	3,864	4,163	3,177	3,073	3,280
Canada	432	531	533	513	593	645	590	555	576	484	570	531
Argentina	28	27	7	11	10	7	7	8	8	7	5	7
EUROPE												
Germany	1,727	1,860	1,767	1,642	1,383	1,420	1,457	1,550	1,136	457	335	425
Belgium	485	741	486	531	543	664	615	776	710	519	571	569
Italy	228	234	257	255	285	409	392	410	392	141	108	122
UK	232	238	308	296	282	368	440	483	471	323	292	432
Sweden	223	271	265	247	266	262	296	291	266	188	130	115
Netherlands	238	260	214	268	208	166	218	220	131	62	52	29
Spain	228	191	256	249	217	228	277	338	282	196	209	250
Finland	110	184	180	134	187	166	229	220	224	95	117	132
France	306	320	242	193	159	136	159	186	158	186	158	109
Denmark	98	86	109	105	116	74	73	59	54	21	19	21
Poland	85	56	32	58	20	28	65	80	80	12	10	13
Portugal	13	19	20	21	20	20	23	27	40	10	4	7
Austria	17	18	17	15	15	4	1	1	0	0	0	0
Greece	13	13	18	13	17	16	15	16	22	12	5	3
Norway	70	103	126	136	161	130	139	153	116	101	115	89
Switzerland	19	44	35	19	12	33	5	1	0	0	0	1
OTHER COUNTRIES												
Japan	1,268	1,202	1,459	1,394	1,618	1,525	1,513	1,325	1,415	1,285	1,401	930
South Korea	122	104	101	134	149	170	167	205	233	218	267	287
Australia	24	28	32	36	39	42	48	54	58	45	55	58
Others	285	384	370	396	405	384	423	481	550	356	326	325
TOTAL	**9,206**	**9,974**	**10,274**	**10,289**	**10,263**	**10,871**	**10,945**	**11,301**	**11,085**	**7,894**	**7,822**	**7,734**

Table 5.2. Volume of Colombian coffee exports by destination country – Annual (Thousands of sacks of 60 kg of green coffee)

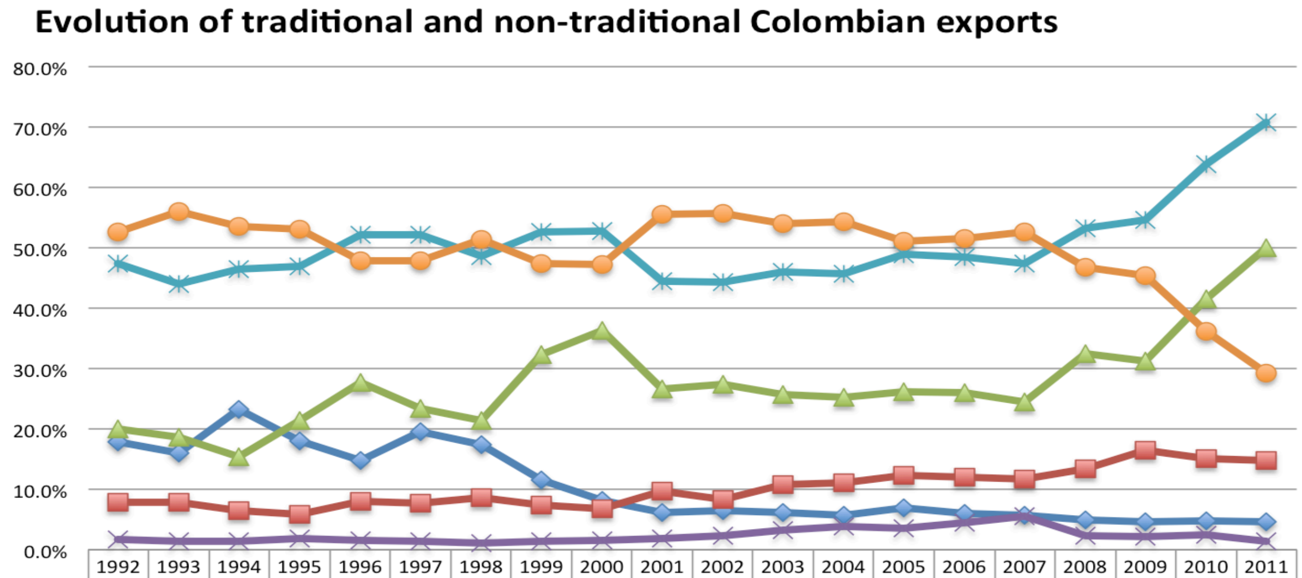
Source. Translated and modified by the author from Website Colombian Coffee Growers Association[112]

However, the contribution of coffee to the GDP has been declining over the years. In 1990 coffee accounted for 17.6% of the agriculture GDP and 2.8% of the national GDP. In 2001, the participation was of 12.9% and 1.8% respectively (Espinal et al., 2005). Also, there has been a rapid decline in the share of coffee in total national exports. Coffee went from being the most important export product in the country in 1989, to second in 1990 after oil and oil by-products, and third in 2001 after coal. This is partly due to the increasing demand of other traditional products in the

[112] Retrived from:
http://www.federaciondecafeteros.org/particulares/es/quienes_somos/119_estadisticas_historicas/ in October 01, 2014.

international markets, and an increase in exports of non-traditional[113] sectors (See Figure 5.5). This was also caused by the crisis that the coffee market suffered in 2001 when world production exceeded the world consumption leaving a surplus of around 10 million 60 kg bags. Consequently, the international price went below USD$50 for 46 kg (Flores, Bratescu, Martínez, Oviedo, & Acosta, 2002).

[113] Traditional export Colombian products are: oil and oil by-products, coffee, coal and ferronickel. Non traditional products are those that are not frequently exported. In this group are all exports different from the traditional ones.



	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Coffee	17.8%	16.0%	23.3%	18.0%	14.8%	19.6%	17.4%	11.6%	8.1%	6.2%	6.4%	6.2%	5.7%	6.9%	6.0%	5.7%	5.0%	4.7%	4.7%	4.6%
Coal	7.9%	7.9%	6.4%	5.8%	8.0%	7.7%	8.6%	7.4%	6.8%	9.7%	8.3%	10.8%	11.1%	12.3%	11.9%	11.7%	13.4%	16.5%	15.1%	14.8%
Oil and oil products	20.0%	18.6%	15.4%	21.4%	27.7%	23.4%	21.4%	32.3%	36.3%	26.6%	27.3%	25.8%	25.2%	26.2%	25.9%	24.4%	32.5%	31.3%	41.6%	49.9%
Ferronickel	1.8%	1.4%	1.4%	1.8%	1.6%	1.4%	1.1%	1.3%	1.6%	1.9%	2.3%	3.2%	3.8%	3.5%	4.5%	5.6%	2.3%	2.2%	2.4%	1.5%
Traditional exports	47.5%	43.9%	46.5%	47.0%	52.1%	52.1%	48.6%	52.6%	52.8%	44.5%	44.3%	45.9%	45.7%	48.9%	48.4%	47.4%	53.2%	54.7%	63.9%	70.7%
Non-Traditional exports	52.6%	56.1%	53.5%	53.0%	47.9%	47.9%	51.4%	47.4%	47.2%	55.5%	55.7%	54.1%	54.3%	51.1%	51.6%	52.6%	46.8%	45.3%	36.1%	29.3%

Figure 5.5. Evolution of traditional and non-traditional Colombian exports

Source. Based on DANE information.

An important market segment that has been developed from the early 21st century is that of specialty coffees. This refers to whole bean sales or to beverages sold in coffee shops. According to the coffee exporter's guide, specialty coffees can be classified as those with:

> [R]eliable and consistent grading procedures, strict compliance with contractual obligations and regular delivery will add value in the sense that the product will be preferred by primary buyers over those from less consistent origins. Certain growths of coffee, on the other hand, may be highly prized for their flavour characteristics and attract a suitable premium" (International Trade Centre, 2011, p. 38)

In order to compete in the international market and fulfil consumer requirements the FNC adopted three main strategies: First, the positioning of the 'Juan Valdez 100% Café de Colombia' as part of a broad marketing campaign to differentiate the Colombian coffee by having high quality standards. "The outcome was a terrific success and by 1980, 74 brands carried the *Juan Valdez* logo on their packages" (R. Arango et al., 2010, p. 4). Second, direct sales to consumers through *Juan Valdez* shops. The business model started in 2002 to generate added value to the Colombian coffee growers and the *Juan Valdez* brand. Up to 2014 there are two hundred *Juan Valdez* shops in Colombia and eighty-four shops around the world. Third, the FNC has built a strong linkage between the small coffee producers and world consumers seeking specialty coffees. In fact, most of the Colombian specialty coffees (organic, sustainable, fairly produced and commercialised, with special characteristics of acidity, aroma, and cleanliness in cup) are produced by small farms (Forero Álvarez, 2010, p. 103). Figure 5.6 shows the evolution and contrast between the volume and value of added-value coffee sales. It includes specialty coffees, freeze-dried coffee Buendía (Good Day)[114], and the Juan Valdez coffee shops sales.

[114] This is the coffee brand of the company Buencafé, owned by the FNC. It only produces freeze-dried coffee mainly for international markets. The sales distribution in 2011 was: East Europe (27%), Western Europe (26%), North America (22%), Asia-Pacific (13%), Colombia (8%), Central and South America (4%) (Colombian Coffee Growers Federation, 2012, p. 16).

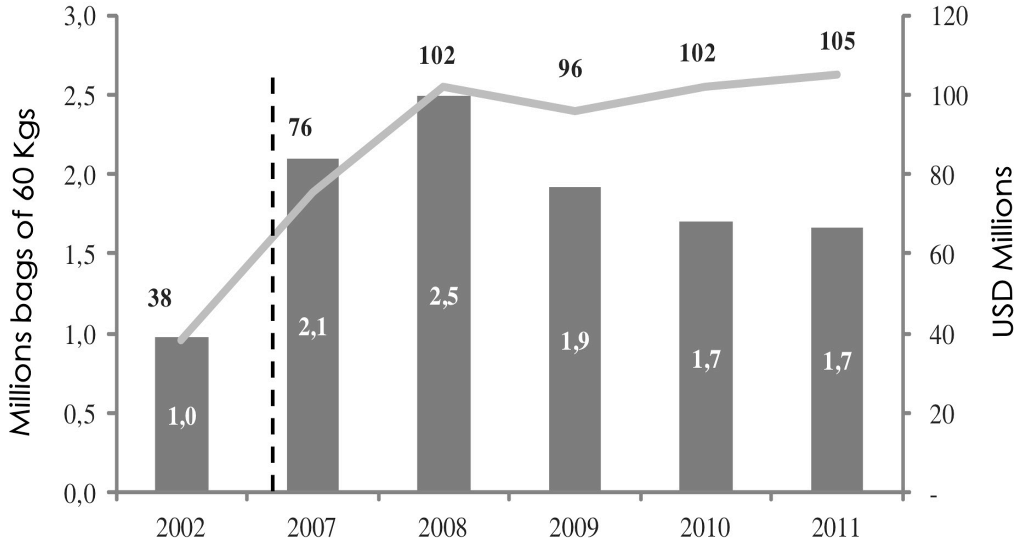


Figure 5.6. Volume and value of the added value coffee sales 2002, 2007 – 2011.

Source. (Colombian Coffee Growers Federation, 2012, p. 14)

The production of high value-added coffee has allowed higher profits for the coffee growers. In 2011 the price of these coffees was USD$4.9 higher per pound of coffee than the regular Colombian coffee, which represented for the 109 thousand of coffee growers growing these kind of coffees an additional USD$7.7m (Colombian Coffee Growers Federation, 2012).

Every firm that wants to export or sell coffee for the domestic market in any of its forms (green, toasted, soluble, freeze dried) has to be registered with the FNC. Only the Federation can certify the authenticity of the Colombian coffee and all the coffee exported from Colombia needs to have the Federation seal of approval. Also, every coffee exporter has to register its transactions with the Federation. In this sense, the Federation acts as a union but also as a competitor since it has its own companies selling all coffee by-products and the green coffee. The Federation represents its associates, but it is also part of the value chain.

As it has been seen in the different development stages of the coffee sector, the great fluctuation in prices and diffusion of pest and diseases has hindered the viability of coffee production. Although the Federation has implemented subsides and has sought fiscal incentives to protect the producers, the efforts has not always been successful and evenly distributed. The *Fondo Nacional del Café* collects private and public funds coming from the national budget. The coffee sector has had perks like this special fund and preferential subsidies that no other agriculture sector has experienced, and it is still experiencing serious financial problems. Referring to that, the *coffee mission*, convened by the national government in 2013, presents conclusions about the role of the FNC and the financial benefits given to the sector.

> In Colombia the coffee policy seems to have had inconsistent objectives, while at the same time sought to stabilize prices and to maximize producers' income. This dual purpose was contemplated from period to period, which has led to low savings in times of high prices and high tax costs when international prices are depressed awarding preferential grants. (Portafolio, 2014)

The expansion to other markets and higher volumes of coffee are the principal aim of the Federation as sectoral union and regulator of competitors. Focus now has centred on the growth of the specialty coffees market and alliances with commercial partners to be part of bigger coffee by-product markets (i.e. coffee beverages, dairy products with coffee) that represent higher profits for the sector in order to keep it viable in the mid and long terms.

5.2.3. Sectoral Organisations

The main organisation representing Colombian coffee growers is the Colombian Coffee Growers Federation. It was founded in 1927 to represent the sector nationally and internationally. Although it was created as a private initiative, it has had great support from public funds and it has had a strong influence on the sectoral policies for coffee. From its origin, the Federation has had close ties with the State, participating in the economic and social construction of the country, always protecting the interests of its members.

The FNC became a central actor after merging with a special coffee fund, '*El Fondo Nacional del Café'*. This fund was supported by the government and had a special account within the national budget. "The Fondo was technically an account in the Treasury which handled special taxes on bills for the export of coffee, and it was intended to finance the purchase and storing of coffee in order to meet the upper limits set upon exports by the pact." (Palacios, 1980, p. 223). It consists of a non-fiscal tax known as the *coffee contribution* paid exclusively by coffee growers, and public subsidies given by the state. It has two sub funds: one to invest in profitable business and enterprises owned by the FNC, and the other to stabilise the coffee profit reducing the effects of international price volatility. As explained by Luis Fernando Samper, Chief of Communications and marketing officer in the FNC (2012), the fund contains the royalties from the Juan Valdez trademark and the opening of every Juan Valdez shop. Also, every coffee producer has to pay six-dollar cents for every pound of coffee exported. With that money it is funded the extension service that provides technical assistance, partially Cenicafé, quality control processes, and promotion and advertising of Colombian coffee in the international market. However that money is not enough for funding all of these programs, so the Federation searches for other funding resources. Each Juan Valdez branch opened in Colombia or the world has to pay royalties for the use of the Juan Valdez trademark. This is other important source of resources:

> [R]oughly the proportion of resources that is leveraged is 7-1, that is, for every dollar contributed by the producers, we get 7 dollars from other sources. Trademark royalties are used to pay for the promotion of the Colombian coffee. We are always looking for ways to balance costs so the producer has the least possible direct cost." (Luis Fernando Samper, personal communication, January 15th, 2013)

During the fifties the FNC became stronger having wide international connections not only with the USA but also with Europe. The Federation invested in the first big national merchant fleet, getting better commercialization prices and trade channels. It also invested more funds to give technical assistance to small coffee growers, mainly in the regions of Boyacá, Cundinamarca, Tolima, and Antioquia. By the 1960s, coffee accounted by 70% of the total exports of the country (Palacios, 1980).

The Federation represents 563,000 families growing coffee along the country. It has a hierarchical structure and a special government system based on democratic elections every four years. This is a mechanism intended to provide democratic representation of the coffee growers needs within the FNC (See Figure 5.7).

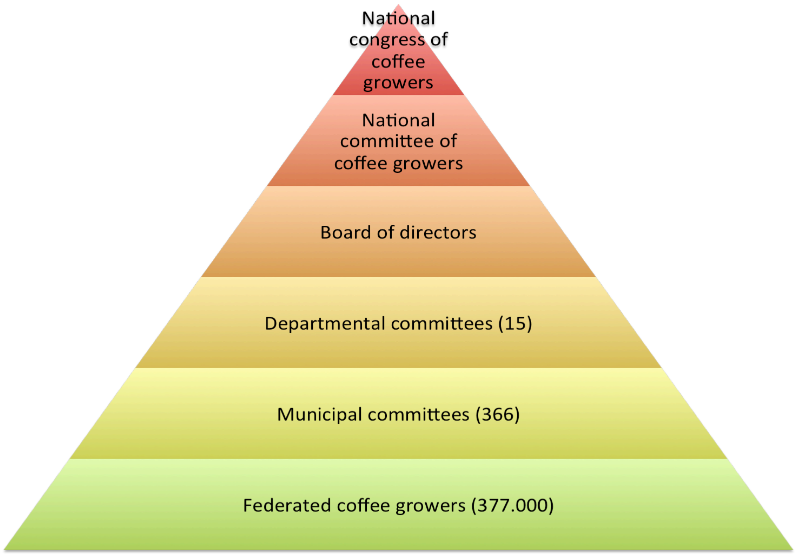


Figure 5.7. Coffee Growers Federation representative system

Source. Information gathered by the author.

The National Congress is the maximum authority of the Federation. Federated coffee growers elect it every 4 years in the coffee elections, as well as the representatives of the Departmental committees. The National Congress conveys at the end of November every year and gives the general guidelines and strategies to keep the competitiveness of the sector. The National Committee of Coffee Growers establishes the policies for the domestic coffee industry and is composed of policy-makers and delegates from the FNC's board, it also defines the distribution of the *National Coffee Fund* for special programs and projects. The Board of Directors has representatives from each of the 15 Departmental Committees and is approved by the National Congress. It coordinates and regulates national initiatives proposed by the National Congress and works for the departmental necessities of coffee growers. There are 15 Departmental Committees of Coffee Growers that represent the departments that produce more than 2% of the overall national production. The members of these committees are elected during the Coffee National Elections. These committees are a main linkage mechanism between the central FNC's government and the regional branches. There are 366 municipalities that possess at least 440 federated growers and produce at least 60,000 arrobas (about 690,120 Kgs) of parchment coffee. These municipal units have a Municipal Committee of Coffee Growers that can present special projects to the Departmental Committees for getting economic and technical support. Finally, the federated coffee growers are those who are permanent coffee growers in an area of at least half a hectare and with not less than 1500 planted coffee groves. These coffee growers are identified within a database in the FNC and have a special ID, *the intelligent coffee ID* that besides serving for identification purposes, has a magnetic band and an intelligent chip that can be used to receive payment for their crops (C. C. G. F. FNC, 2014a).

The presence of the FNC across the country and its long trajectory in the structural development of the sector has been instrumental for the execution of long-term strategies and coherent governance for the sector (Urrutia, 1983). The power and presence of the FNC has prevailed during the years and it controls the whole coffee production chain. Referring to the presence and power of the National Federation of Coffee Growers, Dr. Gabriel Cadena, Head of Cenicafé from 1988 to 2009, says:

> In Colombia there are not strong firms [coffee firms] that can compete with the Federation. The Federation is everything and does everything. It has presence in all coffee municipalities. It is the best company that has been created in Colombia and it is the most original one. (Gabriel Cadena, personal communication, January 15th, 2013)

However, there is criticism and doubt about the transparency of the Federation's board elections and decisions. "Critics of the Federation say that it has been governed by a closed group of large coffee growers and exporters who have steered some of its policies and administrative decisions in their favour." (Forero Álvarez, 2010, p. 97) Some companies of the Federation, such as the Great Colombian Merchant Fleet, accounted for large losses before it was liquidated. Although the FNC has made efforts to respond to international price fluctuations and to respond to climatic variations that have affected the overall national production, it seems to be insufficient given the continuous government subsides given to the sector and strong decline in coffee volumes because of the effects of diseases. Even having varieties resistant to coffee rust and coffee berry borer developed by Cenicafé is insufficient as less than forty per cent of the total coffee plantations have been planted with these breeds (Colombian Coffee Growers Federation, 2012). There are many factors that can influence the expansion and adoption of these breeds, but it could be concluded that the Federation has failed to some extent in the persuasion and incentives given to the coffee growers to change their coffee groves and their harvesting techniques to be more productive.

The FNC has a system of cooperatives to guarantee the purchase of coffee from producers. This system is supported by the *Fondo Nacional del Café* (FoNC). The relational purchase –how it is called by the FNC - provides stable prices to the coffee growers and offers future purchase guaranteed at pre-determined prices, which lowers the risk for the producers. During 2011 the international price transfer percentage to the producer was of 95%, and the price paid to the coffee growers was 4.6% higher than the base average price paid during that year for dry parchment coffee (Colombian Coffee Growers Federation, 2012). However, other countries like Brazil, Vietnam, Guatemala, India and Mexico that do not have this mechanism had higher price transfer percentages to the producers during 2012, which undermines the assumption that the purchase guarantee assures higher prices to the small farmers. Moreover, large producers get a higher price for their coffee than the small ones (Echavarría, 2014).

Figure 5.8 shows how the FoNC buys most of the coffee production negotiated by the cooperatives in order to offer better conditions to producers. Expocafé is the export company of the coffee producers' cooperatives.

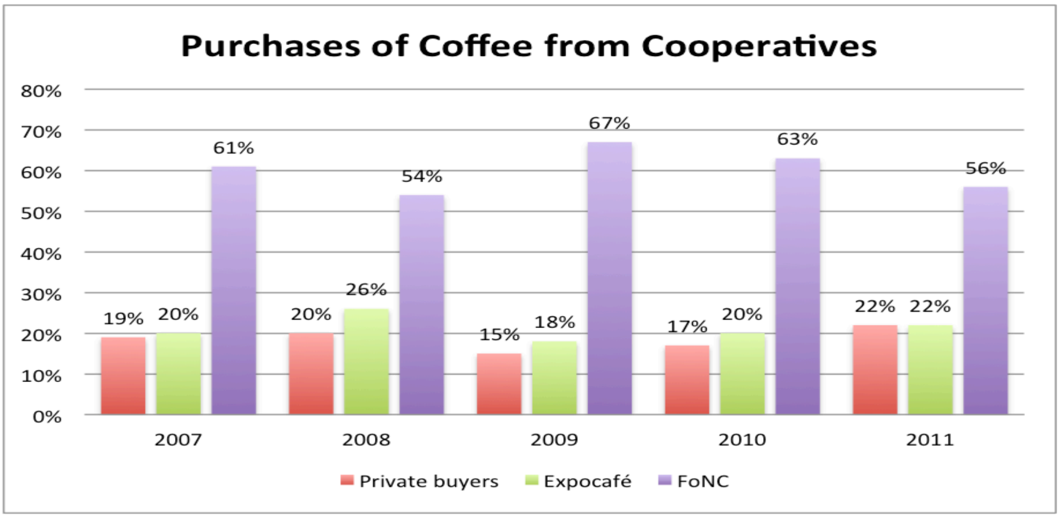


Figure 5.8. Distribution of coffee purchases from coffee cooperatives

Source. (Colombian Coffee Growers Federation, 2011, 2012)

These mechanisms have been designed by the Federation to protect the small producers. However, it has been argued that the active role of the Federation in the design of sectoral policies to regulate the sector and set prices, the commercialising role both for the domestic and international market, the administration of public and private funding sources through the FoNC, and the competition it exerts with private companies to export and produce final coffee by-products is not beneficial and have actually prevented the sector from being more competitive (Dinero, 2014).

Nevertheless, the role that the Federation has played to maintain sector viability cannot be denied. The FNC has been a main actor in promoting better production and business practices to have a fairer distribution of profit among the growers. However, it plays several different and in many ways antagonist roles. The Federation is a competitor with other companies, designs sectoral economic and social policies and regulates the market. It is a powerful organisation with power disputes between actors, it does not always represent the interests of the small growers and given its hierarchical structure and number of staff members, it responds slowly to the rapid changes of the market. It is also at the same time union and regulator, which make its role confusing.

5.2.3.1. Cenicafé

Eleven years after the National Federation of Coffee Growers was created, Cenicafé, the National Research Centre for Coffee, was founded (1938) to study on-farm production, harvest, grain quality, use of sub-products of the coffee production, raise productivity levels, and ultimately to have a sustainable exploitation of the coffee regions. The research centre was created and supported economically by the Federation. Cenicafé headquarters are in the municipality of Chinchiná, in Caldas department. Besides the main laboratories, Cenicafé has eight experimental bases distributed in the three mountain ranges that cross the country. They are strategically located so researchers can have access to most of the environmental areas where coffee is grown in the country (Cenicafé, 2014).

The first research projects in Cenicafé were related to characterisation of soils and weather. Thereafter efforts were focused on increasing the coffee plantations productivity. As a result, a formal research project on plant breeding was started in 1955. The first Arabica variety developed was *typical* variety, followed by *Bourbon* variety. The former did not have high productivity levels, whilst the latter - although more productive - was not widely adopted by the coffee growers because of the small size of the coffee grains. From 1960, Cenicafé developed more and better technologies for the management of coffee plantations both at agronomic level and at the harvesting process. In 1972 *Caturra* variety was developed and tested, its characteristics being: low-stature, high productivity, good grain quality, and excellent adaptation to the ecological conditions of the Colombian coffee zones. This advance resulted in a productivity increment of 58% ten years after the plantations were renovated with this specific breed. In 1982 when coffee rust arrived in the country, Cenicafé researchers already had a resistant breed to this disease that started to be developed 20 years previously, *Colombia* variety. Yet, the adoption process was not completely successful[115], which can be explained by the socio-economic structure of the coffee growers. On the one hand, they lived – and still live - in a subsistence economy basis, which meant that they could not afford the groves renewal. As was explained before, the time spam for a coffee plant to be productive is of three to five years. On the other hand, there was a lack of trust from the *campesinos* to the technicians in charge of the renewal process. Nonetheless, as a result of the good performance and resistance to coffee rust, in 1991 Colombia broke all previous production records registering a production of 18 million export bags of coffee. This production level has not been reached again (Cadena Gómez, 2005). In 2005 an improved coffee variety was developed and tested, *Castillo* variety. *Castillo* variety is coffee rust resistant, has a 17% higher productivity than *Caturra* and *Castillo* varieties, and 83% of the total green coffee has also a larger size and density. These advantages resulted in an improvement of the crop profitability and industrialisation (FNC, 2012). *Castillo* variety was developed by Cenicafé crossbreeding *Caturra* variety and the *Timor* hybrid. It has seven regional sub-breeds adapted to the specific climatic conditions. After the expansion of coffee rust and coffee berry borer started in 2009 and having the most devastating effects in coffee

[115] "Of all domestic production, which is about 12 million bags of 60 kg (720,000 Tons of green coffee), the main cultivated variety is Caturra (43%), followed by the Colombia variety (26%). The remainder are mostly high bearing varieties as Typica and Bourbon." (Puerta-Quintero, 2003, p. 2)

production in 2012, the FNC started an intensive program for the renovation of coffee plantations, renovating mostly *Caturra* coffee trees with the different *Castillo* varieties, raising the resistant plantations up to 54% of the total coffee grown in Colombia in 2012. The regional *Castillo* varieties were developed to adapt to the seven agro-climatic zones were coffee is grown in Colombia. Every regional breed was named after the experimental station where it was created[116] (Cortina Guerrero, Moncada Botero, & Herrera Pinilla, 2012).

Referring to the type of research conducted by Cenicafé, Dr. Gabriel Cadena says:

> We had time to do basic research, the one where immediate results are not expected and needs long term periods to be done. Cenicafé could do both, basic research on coffee genomics to develop disease and pest resistant varieties and plant physiology, and applied research on topics as ecological benefits and reduction of environmental pollution caused by coffee processing. Both modalities of research could be done simultaneously because while we were delivering results to farmers, we were doing basic science. (Gabriel Cadena, personal communication, January 15th, 2013)

Other important research program of the centre was an integrated pest management program (IPM) created primarily to control the diffusion of coffee borer beetle. The first strategy was to generate a biological pest control through the insertion of natural enemies in the plantations, accompanied by better collection practices of ripe coffee berries, leaving the use of pesticides as the last resort, so the secondary effects for both humans and environment would be minimised. Also important, is the water management project. The pulping and treatment processes consume high amounts of clean water and impact directly on the final quality of the grain. The main result of this project was to reduce the consumption of water to up to a tenth part of what it was initially (from 40 to 4 litres/kg) in the decontamination of solid (pulp) and liquid (fermented mucilage) waste. These advances have contributed to environmental sustainability and have had a considerable positive economic impact for the coffee growers (Zambrano Franco, Rodríguez Valencia, & López Posada, 2011).

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[116] These are: Naranjal, Paranguacito, Santa Bárbara, Pueblo Bello, El Rosario, La Trinidad and El Tambo.

After the breakdown of the International Coffee Agreement[117] in 1989, Cenicafé's mission was completely focused on lowering production costs; producing better coffee varieties resistant to pests and diseases; and having higher rates of productivity. The producers association knew that the only way to mitigate fluctuations in international market prices and maintain coffee production as a viable business for the thousands of families depending on it was being innovative. Cenicafé has developed cutting-edge research useful not only for the coffee sector, but for the agriculture sector as a whole.[118]

Given that Cenicafé was the first research centre in Colombia – it existed even before the creation of the Colombian Agriculture Institute (ICA) - it has had a long research tradition in the country and has always had the latest technologies and laboratories to develop basic and applied science related to the coffee plantations and its by-products. On this subject, Dr. Néstor Riaño, senior researcher in Cenicafé and coordinator of the research program of coffee production and climatic variability who has worked for Cenicafé for 20 years, remembers:

> The latest equipment and latest technology entered the country through the National Federation of Coffee Growers, even when many universities did not even know the technology. And that was basically because Cenicafé researchers and the laboratory for coffee chemistry, which was very important, had the financial resources and the vision to have the latest instruments and practices. This shows how from the very beginning the sector believed and invested in research as a main strategy. (Néstor Riaño, personal communication, January 9th, 2013)

[117] The International Coffee Agreement (ICA) is controlled by the International Coffee Organization (ICO). The ICO was created in 1963 after the signature of the first ICA in 1962. "The general goals of the first four International Coffee Agreements (1962, 1968, 1976, 1983) and therefore of the ICO during that time were thus: to achieve reasonable balance between the supply and demand of the various types of coffee (Arabica and Robusta), to contribute to the economic development of producer countries, to maintain reasonable coffee prices, to encourage coffee consumption throughout the world, and to foster cooperation on issues related to coffee production" (Boudon, 2006, p. 840). In 1989 when the 1983 ICA had to be renovated there was an "Indefinite suspension of quotas after the system breaks down under the pressure of competing demands from exporters for market shares under the new ICA then being negotiated. Backed by the United States, Central American states and Mexico press for a much bigger slice of the market at the expense of Brazil (which resists this) and of African producers" (International Trade Centre, 2011)

[118] The development of a coffee rust variety, Colombia variety and more recently an improved version of the Colombia variety, the Castillo variety represents by itself a radical innovation. Cenicafé was the first research centre in the world that developed such varieties.

One of the most important, and also criticised, projects developed by Cenicafé is the coffee genome. In 2003 a joint project led by Cenicafé with the participation of Cornell University, University of Maryland and the *Institute de Recherche pour le Développement* of France, was launched to study coffee, coffee berry borer and *Beauveria bassiana* fungus genome. The main objective of the project was to keep developing rust resistant coffee breeds. The permanent genetic improvement project has impacted directly productivity and profitability for coffee growers with the development of the breeds already described, all of them of the *coffea Arabica* family (Cadena Gómez, 2005). However, some have criticised it, given the great amount of financial resources required by the project and the slow pace for delivering results, including researchers within Cenicafé (personal communication, January 2013). The results have been conclusive:

> In the course of this work, there have been identified 95% of the coffee genes and described 90% of genes of the coffee rust, the coffee berry borer and the fungus Beauveria bassiana. Likewise, there is a molecular characterization of the Colombian Coffee collection or gene bank (80%) and there have been identified 70% of coffee berry borer and rust resistance genes, among other important results. This is certainly valuable information that is currently used in many disciplines and research projects within the Centre. (C. C. G. F. FNC, 2014b)

The model of the research centre has been successful for training human resources. Many researchers start their careers in Cenicafé by developing their undergraduate dissertation in the centre. The centre also has master and doctoral students doing research projects according to the research areas and strategic interests of the centre. A mixture of basic and applied research has been always present in the evolution and reason for being of the centre. Dr. Gabriel Cadena, current Principal of Universidad de Manizales, one of the most important public universities in Colombia, and ex director of Cenicafé says:

> During the 21 years that I was the director of Cenicafé more than 400 students were trained in Cenicafé doing their undergraduate, masters or PhD thesis. We gave them the possibility to join any of the existing projects and their respective directors. Then the student, after selecting a

> project, had a supervisor but he/she had to do the literature review, write the project, present the project to a research committee, and then be responsible for the execution of the project. Every year each student had to present a report, just the same as every researcher in the centre, and present the results of the project to the other researchers. Obviously this young researchers were extremely strengthened after being in the centre. (Gabriel Cadena, personal communication, January 15th, 2013)

Up to 2013 the centre has 159 researchers distributed as can be seen in figure 5.9.

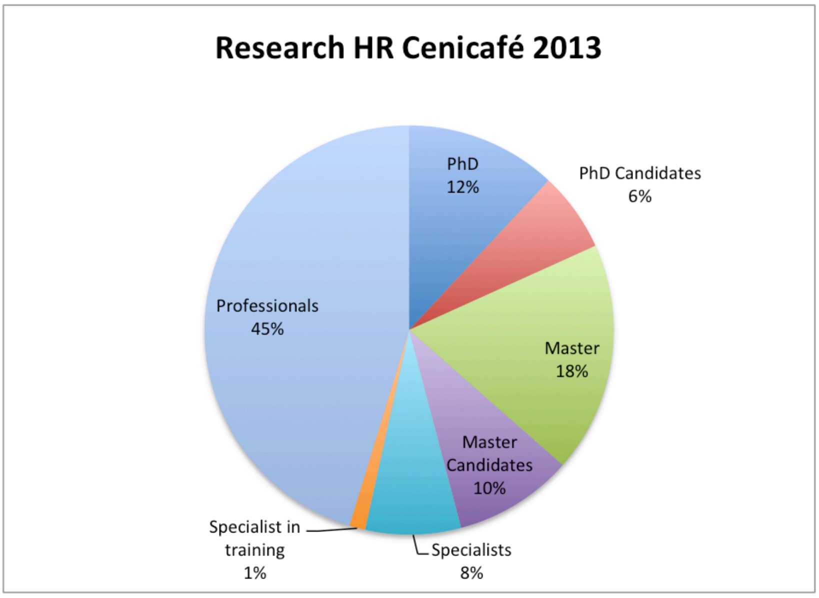

Figure 5.9. Research human resources composition Cenicafé 2013

Source. Data presented by Dr. Huver Posada, Researcher Cenicafé, in October 20 of 2013.

The centre has been the result of a long-term vision of the producers association from the start of the modern production of coffee in the first half of the 20th century. The development of varieties has been crucial for the sustainability of the sector and has preserved the coffee production as a profitable activity. A sustained training program for early career researchers mixed with a collaborative environment within the different areas of the centre and with other research centres has been a successful practice and model for other agriculture production chains. Even in the most difficult financial crisis for the sector, the research centre has been preserved as the main source of knowledge and innovation production.

5.2.4. Institutional Setting

We explained in section 4.5. how the distribution of land has hindered the productivity of the agriculture sector in the country, affecting also the growth and strength of the coffee sector over the years. As it is argued by Fernandez-Muñoz (Fernández-Muñoz, 2014) the lack of clarity about property rights during the colonial and post-colonial times had an impact on the way the coffee regions were structured and the success of some regions over others.[119] Also, the way labour was structured during colonial times has had an impact on the relationships amongst the actors in the production chain replicating unequal and exploitative economic and social institutions. However, non-exploitation systems of labour, with clear wages and fair trade have proved to bring higher economic benefits (Acemoglu & Robinson, 2012). Stable political and financial institutions in terms of regulation and surveillance, restriction of power from public servants and control over financial organisations is also important for the success of the different economic sectors. In the Colombian coffee lands, the west-central region has been more successful in terms of production, as was seen earlier in this section, in part because of the land distribution and a production system based on small land owners with enough labour to work in the coffee plantations (Murillo Lozano, 2010). In the early 20th century, colonization of vacant lands in the departments of Antioquia, Caldas, Quindío and Risaralda was made by two kind of social groups: independent miners in search for gold, and traders with enough money to start settlements around the regions. This new social order resulted in the appearance of new towns and settlements with an egalitarian land distribution based on small land units mainly dedicated to coffee production with clear trade and property rights. This historical process is known in Colombian history as the *Colonización Antioqueña* (López Toro, 2009). A tangible result of the impact of a positive institutional framework on the production and

[119] From 16th century when Spaniards started the colonization period until early 19th century when Colombia, as well as other colonial territories were independent from Spain, the distribution of land and property rights have followed in most of the Colombian regions the inherited colonial institutions. For the coffee regions, three structures of land distribution can be seen, one where the big *haciendas* predominated and were surrounded by small land parcels owned by *campesinos*; a second one where small families in need of land started a fierce fight to break the large extensions of land owned by one landlord, but without achieving formal property rights; and those regions where small growers and traders achieved to have legal property rights over the land, so large *haciendas* were less in number (Fernández-Muñoz, 2014, p. 220).

adoption of technological change can be seen in table 5.3. Municipalities that were part of *Colonización Antioqueña* experienced a higher mechanisation and introduction of modern techniques of farming when comparing per capita coffee plantations area.

Municipalities with Coffee Plantations	Coffee per capita area by municipality (1993/1997)	Coffee per capita area with mechanisation by municipality (1993/1997)
Colonización Antioqueña	0,152	0,121
Rest of coffee municipalities	0,086	0,052

Table 5.3. Comparison of coffee plantations in municipalities part of the colonización antioqueña and the rest of the country.

Source. (Fernández-Muñoz, 2014, p. 221)

Both the adoption of technological packages offered by the extension service of the Federation, and the economic and social structure of small pieces of land planted by independent *campesino* families has sustained the production levels of the sector. The coffee institutionality promoted by the Federation, and adopted to a greater extent by the coffee zone (Caldas, Risaralda and Quindío departments) of the country, has enabled increased productivity per hectare and in that way it has compensated, to some extent, for the constant price fluctuations affecting household income (Murillo Lozano, 2010).

The sector is characterised by a very formal and hierarchical structure represented by the National Federation of Coffee Growers (FNC). The National Coffee Fund (FoNC) is an important component of the Federation since it provides funding for research and also keeps the whole formal structure working. The main purposes of the fund are: to provide an income stabilisation for the coffee producers, especially for the small ones; to fund research and development for the sector; to deliver better life conditions and welfare for coffee producers; and to support the national and international marketing strategies to promote the consumption of *Café de Colombia* (Espinal et al., 2005). However, the Fund has suffered de-capitalisation as a result of continuous crisis in world coffee prices, adverse weather effects, an unfavourable exchange rate, and entry of new competitors. As Fonseca explains:

> During the nineties, the total assets of the Fund decreased by 67%, from $ 4.8 trillion to $1.6 trillion and assets shrank by 71% ($ 4.4 trillion to $ 1.3 trillion). This decline is mainly explained by the loss of major investments such as the Banco Cafetero, Corfioccidente and the settlement of the Grancolombiana Merchant Fleet, the declining of more than 70% of the inventories of coffee and deficits generated during 1991 -1993, 1995 and 2000-2001, besides low international prices. (Fonseca, 2003, p. 23)

Most of the institutions created by the FNC to support growers have focused on providing the technical, commercial, and social support to make the business profitable. The main mechanisms created have been: transfer of the final selling price to the producer; promotion of coffee value sales; support for insertion to new markets; and a program for domestic consumption (Colombian Coffee Growers Federation, 2012).

The price transfer to producers' strategy has different programs. It was shown in figure 5.8 how the FoNC plays a central role in the coffee producers' cooperatives sales. This is one of the mechanisms used by the Federation to transfer a higher final price to the first link of the production chain, the coffee growers. In 2011, there were 34 coffee growers cooperatives[120] with 540 purchase-points distributed in the different coffee regions. These cooperatives bought forty-one per cent of the total annual sales. The role of the cooperatives concerns the evaluation of the coffee quality and the final payment to the producers according to the coffee characteristics. For specialty coffees, the producers receive a second payment after the coffee cargo is sold to the final client, so the extra price is fairly distributed among the growers (Colombian Coffee Growers Federation, 2012). Also, the Federation has a coffee bonded warehouses company, Almacafé S.A. It provides logistics services to the Federation and other customers and products. Almacafé has expanded its services to determine the quality of parchment coffee according to Federation quality standards and customer requirements. It produces finished products so it offers services of

[120] The coffee cooperatives are private, non-profit organisations. They are governed by the solidarity sector and supervised by the superintendence of solidarity economy. They were created during the 1960s to mitigate the coffee price manipulation of individual buyers of coffee. The cooperatives operate with resources from the National Coffee Fund and own resources and buy parchment and green coffee for the FNC.

threshing, classification, roasting, and milling, along with the packaging, transport and distribution of green coffee or final products. Through Almacafé operation in 2010, threshing performance was substantially improved having higher volumes of green coffee from the industrial process of the parchment coffee, passing from a 73.2% to 76.9% yield, which represented higher profits for the sector that positively impacts the sums received by the *Fondo Nacional del Café* (Colombian Coffee Growers Federation, 2012). There is also a mechanism to manage risk, which includes financial instruments to share the price fluctuations and expected production levels with buyers. So the scheme allows producers to fix a price and volume of coffee up to 6 months ahead. During 2011 the final prices paid to the producers were 77% higher than the average price of coffee from 2006 to 2010 (Colombian Coffee Growers Federation, 2012).

In terms of monetary and agricultural policies, two changes have affected coffee production: the cutting of subsidies through credit—coinciding with a severe price increase in placement rates in the early 1990s—and the partial withdrawal of state bodies and resources previously devoted to rural development (Forero Álvarez, 2010, p. 96). However, the sector has had more benefits and subsides than other production chains and other main economic sectors, along with preferential export taxes, which has been highly criticised. Dr. Marcela Meléndez, part of the coffee mission called by the national government in 2013, noted that:

> The activity in the [coffee] industry is not developed in a flat terrain of competition: there is an agent that is both competitor, policy maker and regulator of the market, who does not face the same level of risk in its business decisions than their competitors, because it is covered by public funds (our taxes) and that does not face the same tax obligations as their competitors. (Meléndez, 2014)

The coffee institutionality, as it is called by the FNC, is going through a crisis that may culminate in a radical structural change. Although the sector has kept profits and expansion in the domestic and international markets, it is falling behind in its share of the Colombian economy and in the world coffee market. The strategy of selling specialty coffees is a good start to tackle the continuous falling of coffee prices, however the transition has not been quick enough and it represents less than one-fifth of national coffee production. The tension remains while some defend the model followed by the FNC as a way to generate greater social benefits for the small coffee growers and others who claim that unless a liberalisation of the coffee market happens in the short-term with incursion in the growth of different kind of coffees, the *robusta* ones, the sector will suffer a vast reduction affecting thousands of families that live from coffee production.

5.2.5. Knowledge and technology transfer, adoption, and validation model

The knowledge and technology transfer, adoption and validation process followed by 96% of the Colombia coffee growers (those associated to the FNC) has three fundamental pillars: Cenicafé, the extension service, and Fundación Manuel Mejía. For the purpose of knowledge and technology validation the FNC has a participative investigation program to link coffee growers, *extensionistas*[121], and researchers. The strategy is based in on-site visits to farms to validate new coffee varieties, hybrid materials of corn for packaging and as alternative crop business, new coffee harvesting tools, and new and better methods for drying coffee. The K&T model followed by the Federation can be seen in figure 5.10. It is important to highlight that 68% of coffee growers have only primary education, 19% have no formal education, 7% have secondary education and 2% higher education. Also, 61% of the coffee growers are between 31 and 60 years old, which means that young generations coming from families dedicated to the coffee business have decided to diversify their economic activity leaving their hometowns and breaking the traditional cycle of having same family coffee growers generations. Furthermore, it means that the extension services have been adapted to supply the needs and learning capabilities of the population according to their age, education level and socio-economic level (Colombian Coffee Growers Federation, 2006).

[121] "An extensionista encourages dynamic thinking to the farmer and his7her family. He/she links the gremial, technical-economic, and social aspects in the interest of a competitive and sustainable coffee sector." (Colombian Coffee Growers Federation, 2004)

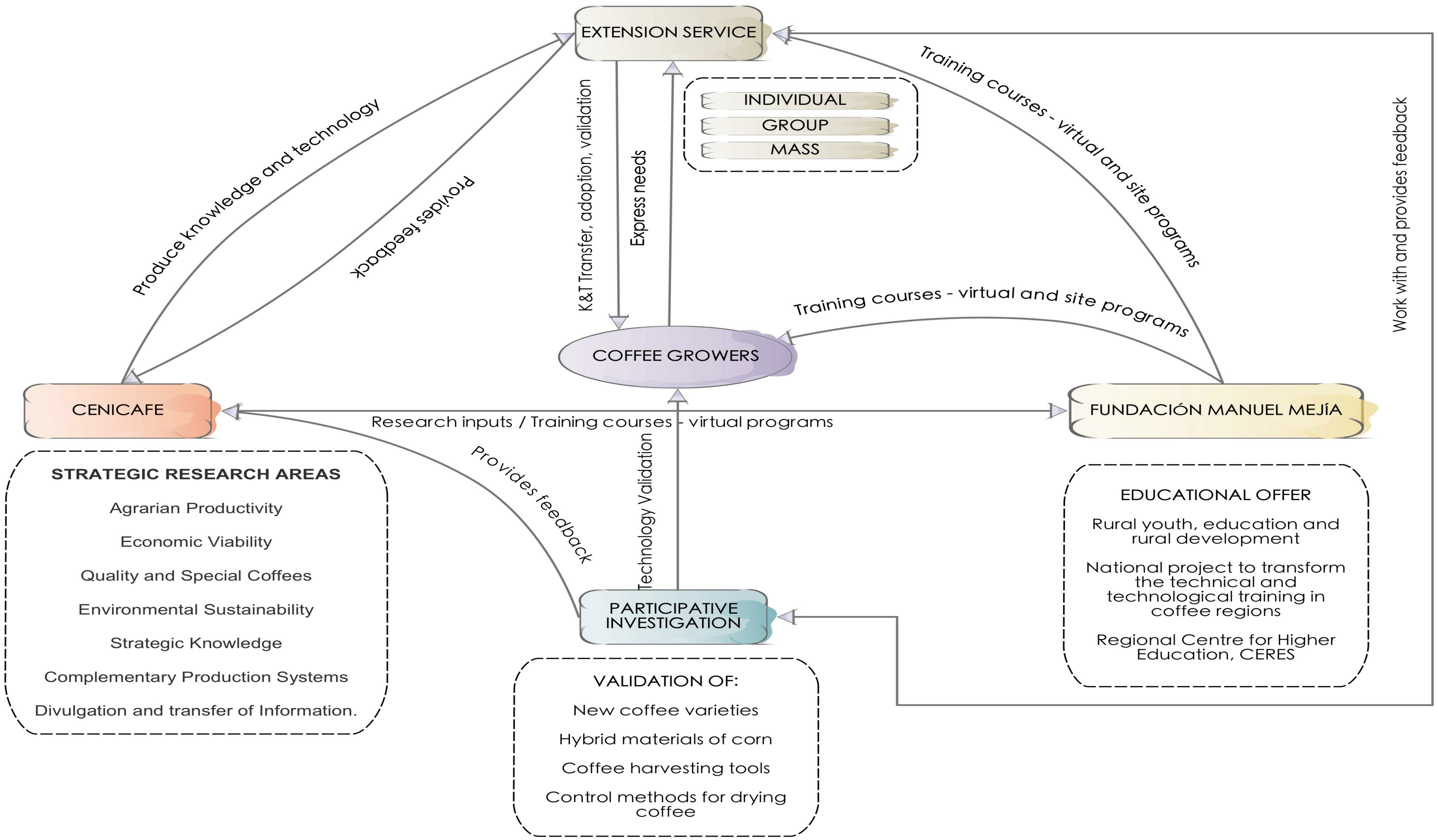

Figure 5.10. Knowledge and technology transfer, adoption and validation model for the coffee productive chain

Source. Made by the author with information gathered from different sources.

The Coffee Congress created the extension service in 1959 with the purpose of unifying training and technical assistance services. Up to 2012, there were 1,669 trained professionals providing support and training to small, medium and large coffee growers. Currently, the service also includes programs to transfer managerial skills and financial support to have access to different funding sources with preferential interest rates. The service has been created to be comprehensive in the context and environment of coffee producers. In that sense, the focus of the professional trainers or '*extensionistas*' is to provide financial advice, business management, and food security techniques along with the knowledge and technical transfer, adoption, and validation activities focus on the coffee plantations.

The extension service is delivered through three major methods: individual contact (personal visits to farms), group meetings (method demonstrations, coffee growers meetings, results demonstrations, technical tour, field day, contests, videos), or mass dissemination (exhibitions, newsletters and brochures, newspaper articles, dedicated radio and TV programs). The service is funded with the tax paid by the coffee growers themselves (*Fondo Nacional del Café*), public funds, and some national and international resources coming from NGOs and international organisations. This service transfer the technical and applied knowledge developed by Cenicafé. However, it is a two-way relationship, because *extensionistas* provide feedback to Cenicafé researchers about the adoption and validation of techniques and varieties developed by the research centre and report new needs found in the field through the communication with the coffee growers (Colombian Coffee Growers Federation, 2005). The main principle of the rural extension service is to provide training to the coffee grower and his/her family through efficient and proved techniques to raise the productivity and income level of producers.

Fundación Manuel Mejía is a private non-profit educational organisation founded in 1960 by the FNC and some of the companies owned by the Federation by that time. The foundation's purpose is to provide classroom and virtual training to coffee growers and staff of coffee agribusinesses. Growers have access to these programs as part of their benefits of being part of the FNC, so do not have to pay any extra cost for the training. The main methodology in the educational project is learning by doing. In that sense the foundation has an experimental farm to develop field practices and educational projects. After the coffee crisis of the 1990s, the foundation went through a restructuring process to become self-sustaining and to optimise resources by providing only focalised training according to specific needs. The recipients of the educational courses are: coffee growers and union leaders, technical and general staff of the FNC, Cenicafe staff, coffee cooperatives members, coffee growers' children, and *extensionistas*. It offers tailor-made programs to satisfy specific needs of companies, and standard programs focus on three projects that are developed in alliance with other educational institutions: Rural youth education and rural development[122]; a national project to transform the technical and technological training[123] in coffee regions, and a regional centre for higher education (CERES)[124]. It also offers distance education programs. Between 2004 and 2006 four programs under this modality were designed, one for food security for the coffee growers so they can produce food for their own consumption; solidarity economy to encourage associativity between producers; comprehensive management to produce quality coffee, which includes technical and managerial principles; and administrative and financial management of agricultural enterprises to manage the small coffee farms as productive enterprises. Also during this period virtual training courses were launched via 'Blackboard' a web-based learning management system (LMS). These courses are dedicated to *extensionistas*, Cenicafé researchers, and faculty of the foundation. Given the success of the virtual courses for technical staff of the FNC, a virtual classroom for coffee growers was designed mainly for giving further support to the technology transfer and adoption provided by the extension service (Fundación Manuel Mejía, 2008). The foundation has direct contact with Cenicafé and includes in its curriculums new knowledge developed by the research centre. This is one successful practice particular to the coffee production chain. The FNC has encouraged the training of specialised human resources according to sector needs and

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[122] It is a project to formulate and validate an educational model for rural population with specific pedagogical tools to develop basic and work skills for the rural youth and with the main aim of expanding school coverage (Fundación Manuel Mejía, 2008).

[123] The objective is to improve quality, coverage and pertinence of the technical and technological education in the coffee regions. It integrates secondary education with higher education to train youth according to coffee sector requirements (Fundación Manuel Mejía, 2008).

[124] It is an educational centre in the town of Chinchiná. It offers formal education to underserved communities, especially to those within the coffee sector activities.

particularities. The Foundation was a tangible effort to complete the knowledge creation, accumulation and transfer cycle. The methodology of all programs is based on learning by doing techniques since it is orientated to education for work, and to fulfil specific desirable skills needed for the sector. The training is based on practice and done within the producers' farms to see tangible results. This is undoubtedly a great success of the Federation and its organisations.

An aspect that can be found within the coffee production chain, that is transversal to all economic sectors in the country and has been mentioned before, is the difficulty of having research agreements between the productive sector represented by the FNC, coffee business companies and the national universities. Again, it is easier to have MoU with foreign universities, because processes are standardised and there are specialised technology transfer units for extension services. This hits directly at one of the biggest weaknesses identified by the MEAS team[125] in the assessment of the extension service of the FNC (Mueller et al., 2013). There are no strong links with universities, so the overall capacity to train trainers or *extensionistas* could be dramatically improved if there were more alliances with higher education institutions that have agriculture research groups.

The whole model is supported by the Coffee Information System (SICA – for its acronym in Spanish). It is a geo-referenced database with national coverage. It contains information on the coffee parcels with their geographic coordinates and altitude above sea level, and also information about coffee growers' socio-economic variables, farms, and production characteristics. The system is fed by the extension service and also provides services to the coffee growers themselves to have detailed information about their farms and to have direct contact with the extension technicians (Colombian Coffee Growers Federation, 2006). There is another service that has been implemented from 2012. The FNC established alliances with

[125] This was a service hired by the FNC to assess the extension service from January to May 2013. MEAS, Modernizing Extension and Advisory Services, is composed by researchers from the University of Illinois and the USAID. More information about the assessment can be found in: http://www.meas-extension.org/meas-offers/program-evaluation/national-coffee-growers-federation-fnc-colombia

technology companies[126], banks, and the Ministry of Information and Communication Technologies to provide tablets with special applications preloaded (management of the plantation, specific climatic information, site specific agriculture information, daily internal coffee price, latest news on the coffee market, technical information, amongst others) to support the whole coffee production chain. The main aim of this program is to provide timely and accurate information to *extensionistas*, coffee growers and people in the distribution and storage business. It also brings connectivity and Internet access to coffee growers in the whole coffee region (Luis Fernando Samper, personal communication, January 15th, 2013). However, the program is still under test and has not reached total coverage of the coffee actors. In this regard, external researchers have advised the FNC to keep up their effort to "increase and expand investments in communications and knowledge-sharing technology" (Mueller et al., 2013, p. viii).

Given the number of small coffee producers (more than 550,000), *campesinos* living on subsistence economy, the process of providing technical assistance and technology transfer methods is challenging and not sufficient with the high demand it presents. The service is good, but more *extensionistas* and technical personnel are needed to access all the coffee farms in the different regions of the country. This was one of the main aspects found in the evaluation of the extension services of the FNC (Mueller et al., 2013). But it is not enough to extend the service; it is also necessary to provide more financial support to these producers. Small coffee growers have scarce resources so planning in advance about financial decisions is problematic given their subsistence economy. This aspect is highlighted by César Echeverry, currently General Director of Supracafé, the most important company producing special coffees in Colombia, and who has been a coffee grower himself, representative at municipal, departmental, and national level of the FNC, and director of technological development of the Ministry of Agriculture and Rural Development of Colombia:

[126] The FNC signed up alliances with Samsung and Banco de Bogotá, among other organisations to access latest generation tablets at better prices and to provide special loans for the their acquisition by the coffee growers.

> "There is much room for improvement. We have 550,000 families who could not even appropriate technology that was available 30 or 40 years ago. This responds to levels of education, isolation, economic [and] subsistence problems. The *extensionista* can say to the *campesino*: 'if you use fertilisers you can raise the productivity'. They have known that for 30 or 40 years, but when the householder has to make a decision, he/she says: 'well, I buy the bulk of fertiliser or I buy food for my family'. The decision is obvious. Those are the kind of decisions that all *campesinos* have to make daily. So there is technological offer, but not enough instruments for technology adoption." (César Echeverry, General Director Supracafé, January 9th, 2012)

The process of technological change and extension to coffee growers has had some flaws, especially in gaining access to the most remote coffee farms in the coffee zone region. This had a major impact on the crisis in 2011, when the climatic conditions, the Niño phenomenon followed by La Niña, devastated more than half of the coffee production. This could have been prevented by the renewal of coffee plantations with varieties resistant to coffee rust, mostly when Cenicafé developed them in the mid-20th century. So we are facing a complex problem of the viability of the business given the poverty conditions of the coffee growers. In the coffee sector the challenge is not only to generate knowledge and technology to be transferred to the producers, but also the availability of subsides and preferential credit lines so coffee growers can effectively access to the knowledge and technology available. Resources can be available, but lack of structural conditions (transportation, roads, availability of basic public services as water, light, medical services, housing, education) can hinder completely the K&T transfer, adoption and validation model.

5.3. Sectoral Cases – Sugarcane

The sugarcane sub-sector is one of the most successful production chains within the agriculture sector. It is not only an up-and-coming sector within the Colombian context, but also important within the world market since Colombia has the highest productivity in production of sugar per cultivated hectare in the world. According to the International Sugar Association (ISA) in 2013 Colombia was the twelfth largest sugar producer in the world with a 1.42% of the world total sugar production. The most important producers of sugar in the world are Brazil, India, the EU, China, Thailand, the USA, Russia, Mexico, Pakistan, Australia, and Indonesia (Asocaña, 2014a). This responds to the proportion of number of hectares of sugar cane cultivated in each country. In 2007, there were 22 million of hectares cultivated in the world, of which 0.22 million were grown in Colombia (Colima, 1998).

The added value of agriculture as a percentage of GDP in Colombia has remained constant at around 6% from 2010 onwards[127]. The importance of the sugarcane sub-sector for the national economy is prominent. Sugar mills generate, directly and indirectly, more than 180,000 jobs, with an average wage 51% higher than the average industrial wage[128]. Also, 90% of tax revenues from more than 30 municipalities in the Colombian southwest depend upon the activity of the sector (Arbeláez et al., 2010).

It was highlighted in a study made by the Economic Commission for Latin American and the Caribbean that "[t]he Colombian sugar industry suggests having a balanced, incremental, consistent and integrated development in a particularly intense political, social and economic environment, which is configured as a conglomerate, making it an interesting case study." (Economic Comission for Latin America and the Caribbean ECLAC, 2002, p. 7). We will explore the characteristics of the sector and its success and failure factors both within the national and agriculture sector levels.

5.3.1. Industrial Setting, Technological Evolution, and Dynamic Complementarities

Sugarcane first arrived in Colombia around 1538 through Spanish colonization in the 16th century. Three sugar mills began their operations around 1560, near the Amaime River on the other side of Cauca River. By the end of 17th century many more sugar mills had been established and were successfully producing sugar. Plantations were

[127] The percentage share of agriculture has decreased by about two points from 2000. In the case of manufacturing, where the production of sugarcane derivatives is included, there has been a slower decrease, having 4.1% of the GDP in 2000 to 3.6% of the GDP in 2013. This lost of participation in the total GDP has been gained by sectors as mining, construction, and services. (Data retrieved from Agronet, the digital platform of the MADR: http://www.agronet.gov.co/www/htm3b/repparamnuke_2011.asp?cod=134.

[128] "The average monthly wage per worker of sugar mills was $2,6 million pesos [around £800], while the average salary of the manufacturing industries, according to the Annual Manufacturing Survey was $1,3 million pesos [around £400]" (Arbeláez et al., 2010, p. 37). That represents around.

not large, but planting and harvesting times were planned in advance. By 1721 there were already thirty-three sugar mills distributed in the Cauca River Valley. Besides the production of sugar, other sugarcane by-products as molasses and distilled liquors called ‘aguardientes’ were commercialized within the region. In the early 20th century the technology used for processing sugarcane was improved. Steam boilers operating with a central engine were introduced to replace the used animal traction mills for extraction of sugar. Farms were modernized and were transformed to mechanised sugar mills, had better roads, improved transportation methods and the introduction of specialised techniques and machines to get different sugarcane by-products, which allowed higher productivity.

> In 1901 the first imported mill using steam for cane milling and for getting centrifuged sugar was put into operation. With it the traditional methods hitherto used for the production of panela and sugar were left behind (Economic Comission for Latin America and the Caribbean ECLAC, 2002, p. 15)

However, sugar was still imported to the country. In 1927 an agricultural experimental station (EEA) was created in Palmira, a small town in Cauca Valley. New sugarcane varieties were cultivated and plant hybridization was tried. In 1929 an expert Puerto Rican scientist on sugarcane cultivation, Carlos Chandon, visited the region introducing different sugarcane breeds with a higher content of sucrose. Latterly, this visit would be known as the ‘Chandon Mission’. By 1940 there were sugar mills in different parts of the country, but these would gradually disappear because they could not compete with the ideal climatic and soil conditions for growing sugarcane in the Cauca Valley. However, as the production of sugar rose and became enough to satisfy the domestic market, sugar imports were phased out by 1948 (Ramos, 1995).

By the end of the 1950s there were 19 mills in the region, however due to economic and competence factors such as the cost of machinery versus sales participation in the domestic market and better infrastructure conditions as roads, electricity and water in some departments over others, the number dropped to 18 in 1978 and 16 in 1981. The area planted in number of hectares achieved sustained growth; passing from 18,625 ha in the early 1950s to 130,200 cultivated hectares by 1979. This coincides with two of the main developmental phases in the sugarcane sector: the first between 1901 and 1960 with the emergence and structuring of the sector, and the second from 1960 onwards during which the sector experienced a process of expansion and modernization. Other important factors affecting the development of the sugarcane industry were: the allocation of an export quota of 5,000 tonnes of sugar through the International Sugar Agreement between 1953 and 1959[129]; the Cuban Revolution in 1959 that transformed the sector into an exporter, mainly to the United States; the establishment of the sugarcane growers association, Asocaña, in 1959 as a result of the demand of sugar from international markets; and internal regulations on the production, storage, and handling of surplus in the domestic and foreign markets (Guardiola Mora, 1995).

The sugar cane lands are distributed within the same geographical region of the country, called "Valle del Cauca" or the Cauca Valley located in the south-west of Colombia and composed of three departments: Cauca, Valle, and Risaralda. Forty-seven municipalities within these three departments grow sugarcane. In this geographic area there are pronounced climatic differences in temperature and humidity between day and night, which is a needed condition for the concentration of sucrose in the sugarcane plant. Such climatic conditions allow for sugarcane harvesting and processing throughout the year, in sharp contrast to other sugarcane producing areas of the world where the cane harvest lasts between four and six months. As a result of these year-round harvesting conditions, the fixed costs of investment in factory, field equipment and working capital per ton of cane produced, are half or even a third part of those in the sugarcane areas of the world (Asocaña, 2014a). In terms of the commercialization of sugarcane derivatives:

> Of the total production of sugar, 43% goes to the export market and the remaining 57% to the domestic market; of this percentage, 53% is for direct human consumption and the other 47% is used as raw material in the process of adding value (Economic Comission for Latin America and the Caribbean ECLAC, 2002, p. 10).

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[129] The international sugar agreement was signed in London in 1953. Its main purpose was to ensure sugar supply to importing countries and markets for sugar exporting countries at equitable and stable prices.

Tables 5.4 and 5.5 show the average production of the main derivatives of sugar cane from 2000 until 2013. In the case of Ethanol, the statistics are presented from 2006 given that the first ethanol plants were opened at the end of 2005.

	Sugarcane (Tons)	Sugar (Tons)			Molasses (Tons)		
	Milled Sugar (tons)	Total Production	Domestic Sales	Total Exports	Production	Domestic Market	Exports
Average 2000 - 2013	21,104,791	2,269,909	1,365,906	898,669	381,898	311,598	48,930

Table 5.4. Average of sugarcane, sugar and molasses production from 2000 to 2013

Source. Data compiled from Asocaña Statistics.

	Alcohol Fuel (Thousands of litters)	
	Production	Sales to the domestic market*
Average 2006 – 2013	313,376	317,058

Table 5.5. Average of alcohol fuel production 2006 – 2013

* Sales includes the volume of ethanol with addition of about 2% of denaturing (gasoline)

Source. Data compiled from Asocaña Statistics.

According to Cenicaña's information (Cenicaña, 2014), the sugarcane planted area in Cauca Valley during 2013 was 225,560 ha. This land area is divided into small lots called 'suertes' (luck/fortune in English). Each *suerte* has an average area of 5 hectares. Of those hectares, 86% was harvested and used by the sugar mills and the remaining hectares were directly harvested by sugarcane growers. Concerning land property, 76% of the land is owned by more than 2,700 sugarcane growers and the remaining 24% belongs to the mills of the region: Tumaco, Incauca, Carmelita, Maria Luisa, Mayagüez, Pichichi, Providencia, Risaralda, Sancarlos, La Cabaña, Manuelita, Riopaila, Castilla (two plants) and Lucerna. Sugarcane growers provide the raw cane to the sugar mills through long-term supply contracts (generally between 5 and 10 years). This corresponds to the crop production cycle and the required investment for the planting and harvesting process (return on investment). Sugar mills are the main consumers of sugarcane in the region, having control directly or indirectly of virtually the whole sugar market in Cauca Valley. This aspect is highlighted in the sugarcane cluster study done by the Economic Commission for Latin America and the Caribbean:

> However, because of the type of contract between mills and growers (lease, joint accounts, suppliers administration), the mills retain control or direct management of 50% of the cultivated area." (Economic Comission for Latin America and the Caribbean ECLAC, 2002, p. 22)

There are fourteen sugar mills, five of which produce alcohol fuel. Traditionally, the main product produced by distilleries was sugar, however, the sugarcane derivatives industry within Colombia is now comprised of the following distribution of companies:

Food Beverage and Liquor Firms	40
Co-Gen Power Plants	2
Chemical Plants	3
Specialised Suppliers	50
Business Associations	88
Workers Co-Op	1

Table 5.6. Distribution of companies in the sugarcane industry

Source: (Cruz Aguilar, 2010)

Since 2006 there has also been the production of ethanol as a main biofuel for domestic consumption. Current installed capacity allows for the production of 1,050,000 litres of ethanol per day. In 2013, according to Asocaña statistics (Asocaña, 2014b), there were produced 387,859 thousand of litters by the biofuels plants in Cauca Valley. That represent nearly 102.5 millions of US gallons. According to the Renewable Fuels Association[130], in 2013 the USA, the main fuel ethanol producer had a production of 13,300 million of gallons, followed by Brazil with 6,267 millions of gallons. Colombia is not competing for international market sharing; the domestic market consumes the fuel ethanol production. Moreover, fuel

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[130] See: http://ethanolrfa.org/pages/World-Fuel-Ethanol-Production

ethanol producers are only allowed to export their product if the domestic demand is fully stocked[131]. The total production of alcohol fuel in Colombia is done exclusively in Cauca Valley through the bagasse processing (Unidad de Planeación Minero Energética, 2009). Also, there has been experimentation in using biomass to produce other sources of energy. Yet, sugar is the main product. In Colombia, four main types of sugar are sold: raw, white, special white (specially produced for the baking industry) and refined. Not all mills produce the four types, that way they have differential markets and specialities for other industry sectors.

A map of firms and non-firms organizations from the growing of the crop until the final commercialization of the finished products is presented in Figure 5.11.

[131] Resolution 180687 of 2003.

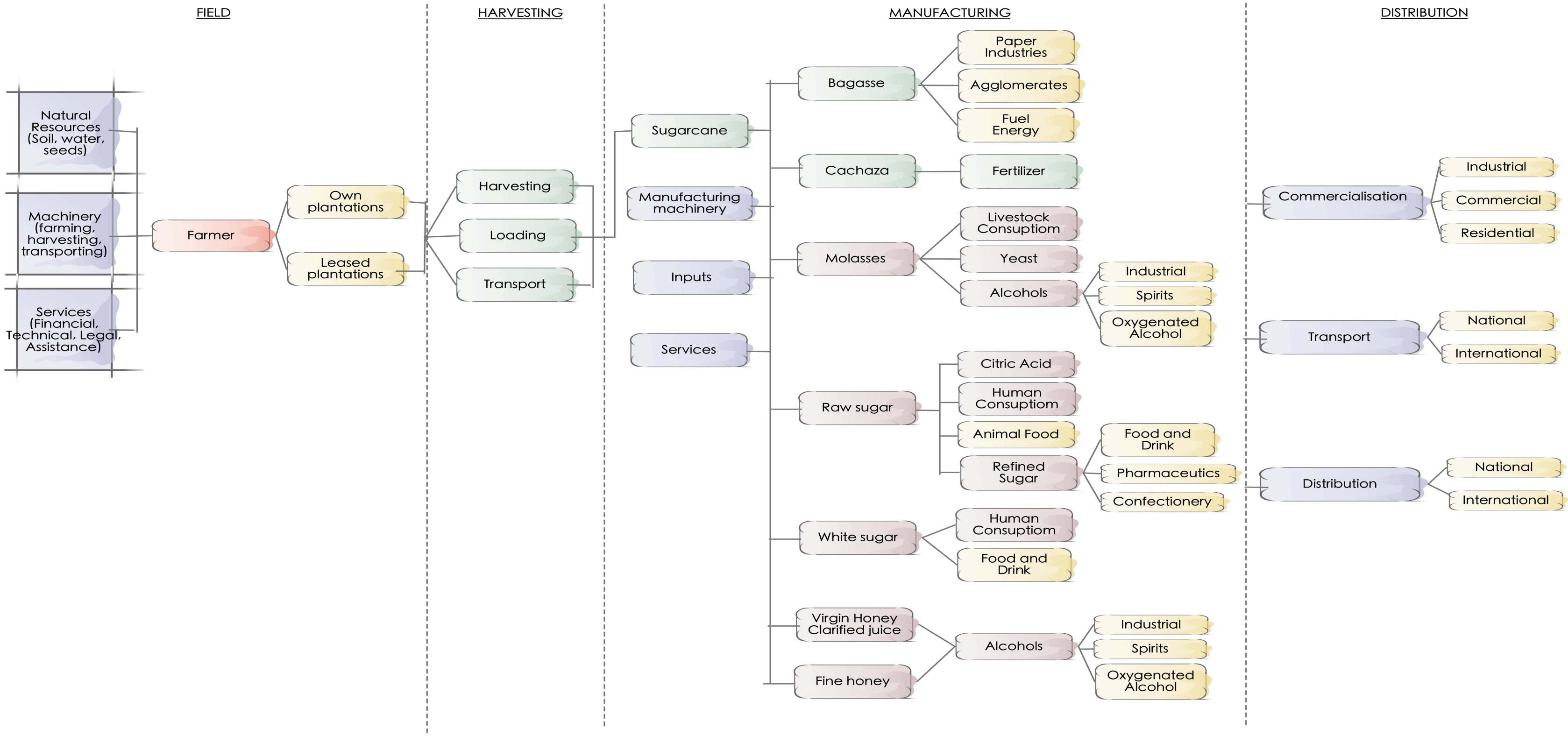

Figure 5.11. Sugarcane productive chain structure

Source. Figure based on (Economic Comission for Latin America and the Caribbean ECLAC, 2002, p. 11)

Cenicaña, the centre for research of sugarcane, has identified 156 relatively stable agro-ecological zones defined by biophysical factors in *Valle del Cauca* (Figure 5.12). For each of these agro-ecological zones Cenicaña has a complete characterization of weather (hydrological balance), and soil (humidity groups and homogeneous soil groups). These databases allow having a site-specific agriculture[132].

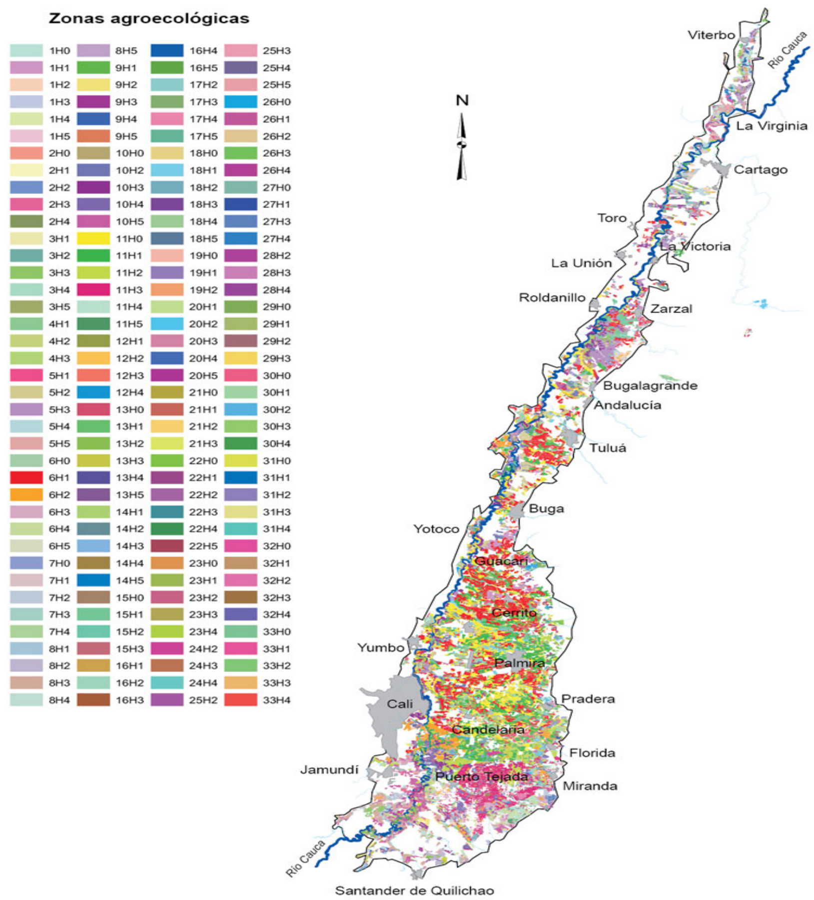

Figure 5.12. Agro-ecological zoning for the cultivation of sugarcane in the Cauca River Valley

Source. (Cenicaña, 2011)

Having structured and comprehensive information of the subsector is a differential aspect of the sugarcane production chain. Information is centralised in Cenicaña's databases, but databases are fed by different information sources like Asocaña, Tecnicaña, Corpoica, Ministry of Agriculture and Rural Development, the National

[132] Agriculture based on data about humidity, nutrients, soil composition for specific parcels. These data is usually processed by specialized software to determine precise procedures for particular crops.

Geographic Institute Agustín Codazzi, and the National Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). Cenicaña provides information, training, and technology services in several categories, listed in the following table:

Information category	Tool	Description
Commercial	Iso-productivity curves	Comparative analysis of the productivity of sugarcane breeds harvested in every agro-ecological zone. Users can see information for specific time periods, sugar mills, agro-ecological zone, age and number of crop cuttings.
	Statistical analysis	Experimental and commercial information used in the different intervention areas. It includes design of experiments, sampling design, spatial statistics, and data analysis.
	Economic analysis	In order to ensure the profitability of technology products generated in the research process, Cenicaña sets economic criteria for project evaluation, development of impact studies, and efficiency. It includes: costs, economic evaluation of research, analysis of business information, impact assessment, and efficiency studies.
Technology Transfer	Technology development model	Cenicaña builds communication technology transfer strategies embracing the principles of social marketing to meet the demands of producers with technological solutions. The model is based on a census of the producers that includes different socio-economic variables. To keep information up-to-date there are dynamic tracking studies using surveys and direct interviews with producers participating in the technology transfer groups.
Automated meteorological network (AMN)	AMN stations	Meteorological and climatological information of the entire region of Cauca Valley across 34 meteorological stations. Reports by hour, day and week. Wind-speed information, meteorological maps, and tracking of specific climate effects (El Niño and La Niña).
Hydrological Balance	In-house software developments	It is an automated application developed by Cenicaña to facilitate the calculation of the water balance in the soil and formulate the irrigation programming required for the cultivation of sugarcane. This tool is useful for saving water; therefore, its aim is to achieve a sustainable management of water resources.
Humidity	In-house software developments	It is an online system to determine the humidity group that better describes the soil humidity

		conditions of each 'suerte' within farms.
Maps server	Geographical Information System	The geographic database contains mapping with precise boundaries of the farms and lots harvested by 13 sugar mills.
Economic model for renewing sugarcane crops	Renova	Economic report on the additional net gain, valued at the time of the consultation, that would deliver a renovation project, compared to a non-renovation one.
Sugarcane fertilization	SEF – In-house software development	The Fertilization Expert System (SEF) is a tool that brings together the expert knowledge of the nutritional requirements of sugarcane in the Cauca River Valley, according to Cenicaña's research. The SEF provides fertilizer recommendations and amendments to cane production units with specifications for doses, times, sources and methods of application.

Table 5.7. Information services provided for the Cauca River Valley sugarcane sector.

Source. Compiled information by the author from Cenicaña's intranet and interviews.

The development, use, adaptation and validation of technologies for sectoral requirement and evolution have been progressive and have allowed producers to maximise production and revenues. Cenicaña has developed three research programs to support producers' needs: varieties, agronomics, and factory processes.[133] The varieties program focuses on seeds and breed selection, supporting the adoption of specific varieties for every agro-ecological zone. It also includes modern molecular techniques for disease detection. The agronomy program is intended to undertake research aimed at reducing production costs by developing the technology required to improve the productivity and quality of sugarcane. One of the main results of this research program is the reduction in water consumption for the sugarcane fields. This has been achieved by combining different irrigation techniques. Finally, the factory processes research program develops knowledge and technology for the optimization of industrial processes as energy consumption, integration of field and industrial operations of the sugar and alcohol production plants, automatic process control, and information management. Amongst the most significant results of this program are a 50% reduction of water consumption in plants, a lower percentage of sucrose in the sugarcane bagasse maximising the utilization of cane for sugar production, and

[133] Detailed information of Cenicaña's research programs can be found in: http://www.cenicana.org/investigacion/index.php

improvements to the processes of fermentation and production of ethanol (Cenicaña, 2014). As a result, there have been significant improvements in the harvesting technology. A shift from burning cane fields to cleaner production techniques has been a main issue from the 1990s onwards. Also, the introduction of mechanical harvesters and specialised machinery in the sugar mills has positively impacted on the manufacture of final products.

Application of improved harvesting techniques like alternate furrow irrigation, water balance, reduced tillage, application of ripeners and biological pest control are part of the most significant developments in the sector. Most technological advances are centred around the improvement of land adaptation; diseases and pest control; creation of new varieties according to site-specific agriculture requirements and intended use of the crop; fertilization with use of chemical and non-chemical products; crop irrigation techniques and equipment; cane maturation to have shorter harvest cycles; and cane harvesting process (Cock, Luna, & Isaacs, 1995).

Within the mills there have been significant improvements as well. The use of specialised electronic machinery, in-house laboratories for pest control, higher production of sucrose, replacement of steam turbines by hydraulic motors, and better processes in molasses production has allowed for growth in productivity. The other component of the sugarcane processing is the area related to biofuels. With the introduction of specific sugarcane varieties for alcohol generation and modern production plants, the business strategy has been expanded.

All of these improvements and the investment in research and development has resulted in the highest productivity in the sugarcane agroindustry worldwide (See Figure 5.13) in terms of tons of cane per hectare (TCH) and tons of sucrose per hectare (TSH). Productivity has doubled in the past 25 years; there is a 50% reduction in water use, and a sustained production of biofuels derived from sugarcane.

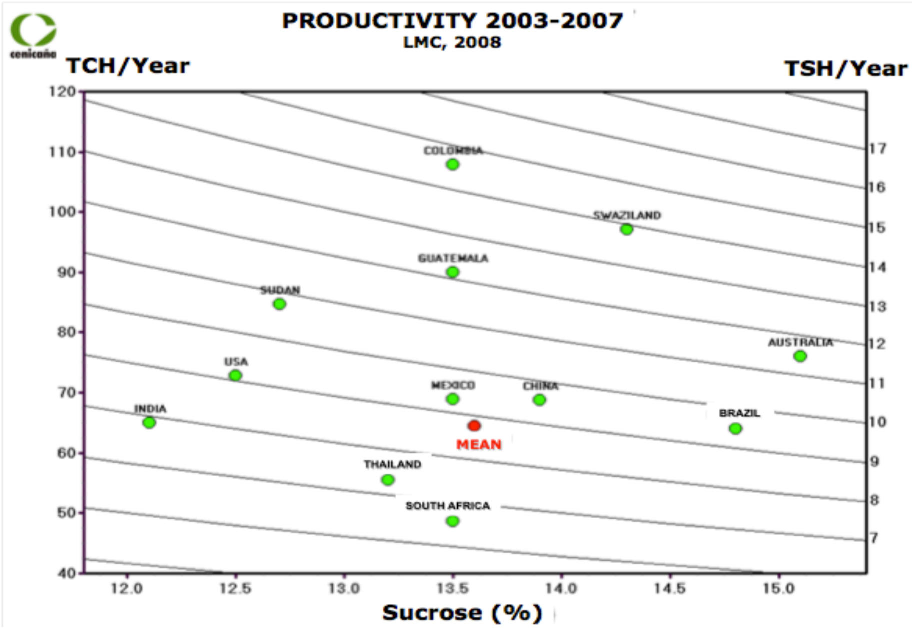

Figure 5.13. Sugarcane productivity in the world 2002-2007 by main sugar producers.

Source. (Cenicaña, 2011)

5.3.2. Interactions amongst Firms and Organizations: Type and Structure

Synergic and collaborative work is one distinguishing aspect of the sugarcane sector. No organization works in isolation from the others. The fact that sugar and biofuel production is concentrated in the same geographical area is an advantage, and has helped growers to organize themselves better, not only in terms of production and logistics, but also in the definition of sectorial strategic vision and a consequent research agenda. The peculiar organization of the sugarcane subsector could be characterised as a cluster[134], in the sense of horizontal and vertical cooperation. As it is explained by Schmitz (Schmitz, 2000), there is bilateral and multilateral cooperation at the vertical and horizontal levels (see table 5.8). In the sugarcane subsector there is bilateral cooperation between sugar mills to optimize financial and knowledge resources using joint organizations for international and domestic sugar commercialisation, Ciamsa and Dicsa respectively, and joint research programs with

[134] "…the existence of a cluster can only be acknowledged when the existence of intelligent communities is evident, and these communities have strategic capabilities to arrange and manage a shared vision; to guide changes and ensure the creation of knowledge-based competitive advantages; and there is a high command in the global value chain to which the cluster belongs." (Economic Comission for Latin America and the Caribbean ECLAC, 2002, p. 24)

Cenicaña's collaboration. Sugar mills operate also in block in front of the government to intervene in the definition of sectoral policies. Vertical bilateral collaboration can be seen between providers and clients in the form of joint alliances for specialised services, machinery acquisition, and consultancy processes. Multilateral horizontal cooperation is seen in the existence of different sectorial associations as Asocaña, Procaña and Tecnicaña [A description of these association is given below]. And finally, multilateral vertical cooperation can be seen in the links between the production chain and the agriculture sector, and also in the relationships between the associations with Colciencias, Corpoica, the Ministry of Agriculture and Rural Development, other National Agriculture Research Centres (CENIs), and different regional and national entities (Economic Comission for Latin America and the Caribbean ECLAC, 2002).

Cooperation	Bilateral	Multilateral
Horizontal	Sharing of some activities	Sectorial association
Vertical	Improvements in the relationships among producers (providers and clients)	Alliances between the chains of a local value chain

Table 5.8. Cooperation types.

Source. Adapted from (Schmitz, 2000).

The central actors in the productive chain are the sugar mills, and their operation is highly integrated with non-firm organization such as the producers associations, the growers, and R&D centres, particularly with Cenicaña.

> The cluster is characterized by a high degree of cooperation between participants. Formal and informal relationships exist so that sugar mills can unite forces to deal with suppliers, train their employees, use the same distribution channels, and share information. There is also a high degree of forward and backward cooperation between sugar mills, consumers and suppliers. Cooperation is generally seen through established contracts, for example in labour outsourcing, equipment repairs or consulting services.(Dueñas, Morales, Nannig, Noriega, & Ortiz, 2007, p. 26)

However, this shows as well the power that sugar mills have within the sector, which has caused unrest among some sugarcane producers who claim that Asocaña, the Association of Sugarcane Growers of Colombia, only represents the interests of the sugar mills and not of the small and medium sugarcane growers. Procaña, the Colombian Association of sugarcane producers and providers, represents the small and medium independent sugarcane growers, and through this association there have been several quarrels with the sugar mills. During 2007, the president of Procaña, Mr José Vicente Urrutia, said: "management of this entity [Sugar Price Stabilisation Fund –FEPA-], which is in the hands of Asocaña, has allowed the sugar mills the deed of the domestic sugar market and it has barred the assembly of new production plants in the country" (País, 2007). As a response, seven sugar mills instituted a formal complaint to the Colombian Superintendence of Industry and Commerce against Procaña and Azucari, the Association of Sugarcane Growers of Risaralda, by collective pricing in sugarcane with the direct involvement of these associations. The accusation is unfair competition and violation of the rules of free competition. The complaint was approved by the Superintendence and formal investigations were opened to Procaña and Azucari, and against their legal representatives in 2010[135].

Although there are horizontal and vertical cooperation between actors of the production chains, there are unconformities between sugarcane growers and mills and rigid supply and demand relationships between them causing a high interdependency.

> 13 sugar mills located in the geographic valley of the Cauca River, process 99.7% of the total production of sugar cane in the country, implying that the growers negotiate only 0.3% of its product with other market players such sugar trapiches [artisanal sugar mills] (Superintendencia de Industria y Comercio, 2010)

5.3.3. Demand

Demand for sugar (in its different forms) has been characterized by surplus and deficit mismatches with the world market. There was a high surplus of sugar in 2006

135 Resolution 7580 of 2010. Ministry of Commerce, Industry and Tourism. Superintendence of Industry and Commerce.

that affected the international prices, and from 2009 the sugar production has grown faster than consumption (See Figure 5.14). As a result, mills have accumulated large stocks of sugar:

> After a fourth consecutive season of large global surplus, world sugar prices weakened in late 2013. Market fundamentals provide little support to prices during the remaining months of the current season (1 October 2013 to 30 September 2014). World sugar production is now expected to grow less rapidly at the beginning of the outlook period, signalling the end of the surplus phase in the world sugar cycle. But any world sugar price recovery is likely to be muted in the short term by the accumulation of large global stocks in a number of countries since the beginning of the surplus phase in 2011. (OECD, 2014a)

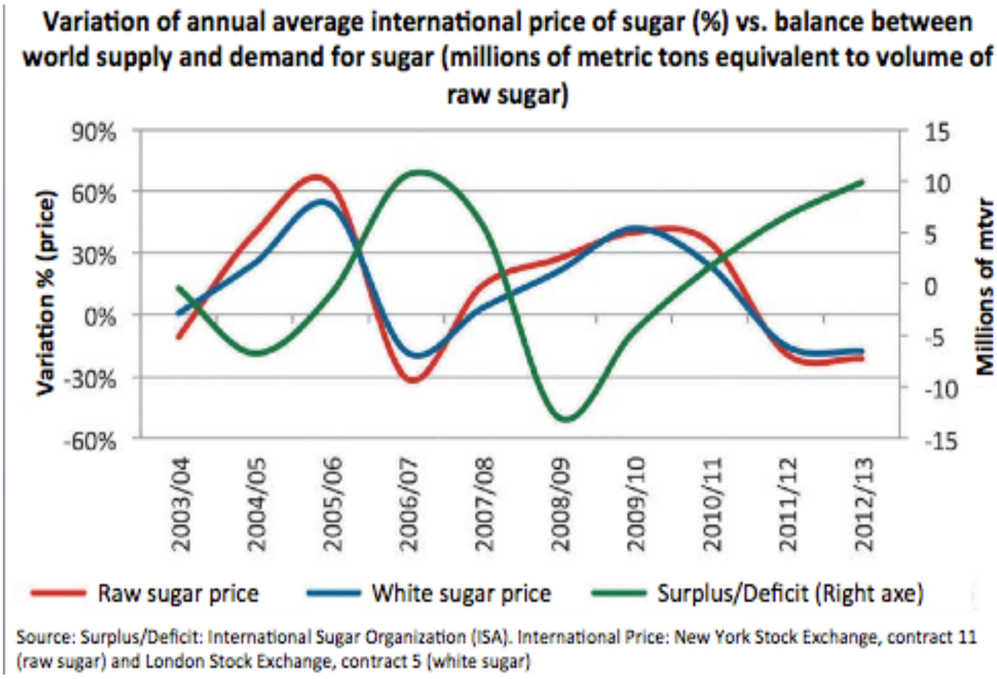

Figure 5.14. Relationship between sugar price and production in the world market.

Source. (Asocaña, 2014a)

The international sugar prices are defined in the stock markets of New York for raw sugar, and London for white sugar. There are other markets for different types of sugar and niches, but the prices are traded mostly in these two stock exchanges. The price volatility depends on the movements of supply and demand and the protectionist policies of producing countries (ISO, 2013).

The sugarcane market in Colombia is free, so exports and imports have no tariff barriers. With only 1.1% of the total world sugar production, Colombia is a price taker, so the price fluctuations directly affect not only the exports, but also the price in the domestic market. Additionally, there has been a sustained increase in the sugar imports volume, which has caused a sharp deterioration in financial revenues and margins of the mills, and therefore of cane growers (Asocaña, 2014a). However, Colombia, as part of the Andean Community[136] (AC) adopted in 1995 a comprehensive price band system known, as the Andean Price Band System (APBS), to control domestic price instability in some agriculture products, sugar (raw and white) included. It is basically a variable levy system where there are price floors and ceilings to buffer international price shocks. This has been beneficial in overcoming crises caused by strong price volatility, but the gains have been smaller than were expected. "For rice and sugar producers…the APBS has induced greater stability in real incomes and associated welfare gains, though these gains are relatively small" (Villoria & Lee, 2002, p. 11). Through the APBS the government controls the domestic price for sugar to protect the sugar mills production and stability. Sugar mills export part of their production (around 40%) to external markets but getting usually lower sugar prices than the domestic sugar price.

> [I]n 2002 the reference price for imported raw sugar fluctuated between 234 and 289 US$/ton, values corresponding to the floor and ceiling of the price band; while the international price (trading in New York, considered as the free market price) stood at 141.3 US$/ton. For white sugar, in the same year, the domestic wholesale price was 496 US$/ton while the international FOB price in the London market only reached US$203/ton (Prada Owen, 2004, p. 1)

Besides the APBS, a Stabilization Fund for Sugar Prices (FEPA – for its acronym in Spanish) was created in 2001. The intention was preventing future falls in the price of sugar, after the global sugar overproduction in 1999 that affected the domestic

[136] Group of 4 South American countries: Bolivia, Colombia, Ecuador, and Peru.

market. The FEPA controls the sugar offer, so the mills receiving a price above the price weighted transfer gains to those mills with prices below the weighted price through the FEPA. The purpose of the fund is to prevent the fall of the domestic sugar price. Since the domestic sugar price is higher than the international price, the FEPA offset the mills that have higher sales in the international market, with those that have a higher proportion of sales in the domestic market and therefore have higher profits. The FEPA has a weighted average price of all sugar sales, so those sugar mills that get higher prices than the FEPA price for sugar transfer the difference to the fund in order to compensate to those sugar mills that have prices bellow the FEPA price (Prada Owen, 2004). The way that the FEPA intervenes in the Colombian sugar market can be seen in Figure 5.15:

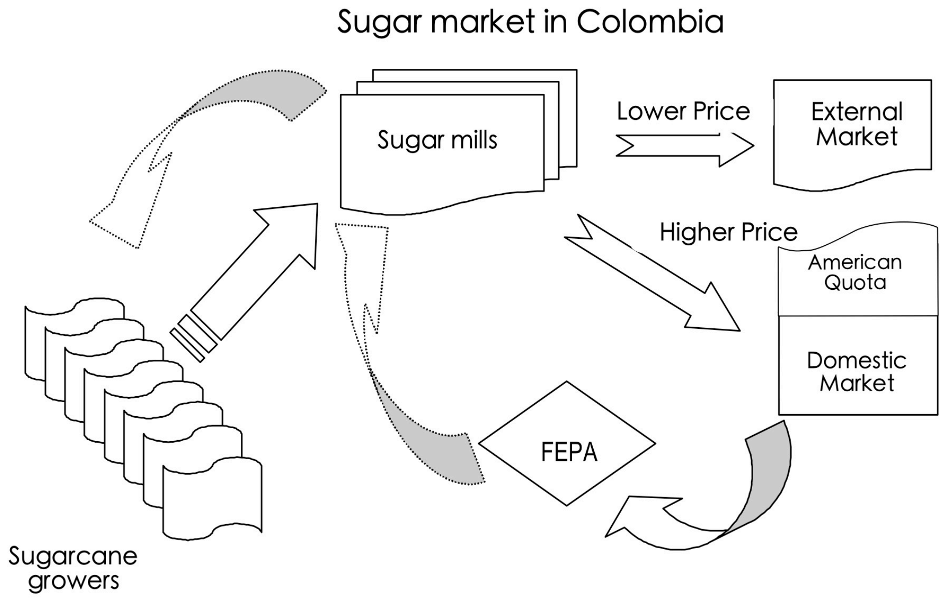

Figure 5.15. Role of FEPA in the Colombian sugar market

Source. Modified from (Prada Owen, 2004, p. 3)

The supply and demand dynamics for sugar in the domestic and international markets have caused a shift in the mills strategy towards the production of other products derived from the sugarcane. "The core business of the cluster has been migrating from sugar to sugar sub-products. Every sub-product in the cluster (sugar, bagasse, molasses and cachaza) occupies the same economic relevance and helps diversify the economic structure of the cluster." (Dueñas et al., 2007) The total production of ethanol produced by the mills in Cauca Valley is absorbed by the domestic market. In 2001, Law 693 regulated and approved the entry of alcohol fuels and other fuel sources, as alternatives for the composition of the country's energy basket. From 2008, gasoline composition has 10% of ethanol and the intended use should rise up to 85% of ethanol and 15% of fossil fuel (Unidad de Planeación Minero Energética, 2009). This has clearly opened a new business opportunity and dynamism for the sugarcane cluster. However, as it happens in the case of production of sugar, the guaranteed domestic market[137] for the fuel alcohol has prevented the distilleries to be innovative in their production and higher quality of ethanol produced. There is not a specialised demand that pushes the suppliers[138] (in the Colombian case the sugar mills of the Cauca region) to be more innovative in their products, either to have higher incentives to differentiate from their domestic competitors.

The final price paid to the sugarcane growers is set depending on the sucrose extracted from the plant in the case of sugar production or the litters of ethanol produced in the case of biofuels. Then, the final payment to the sugarcane growers is made according to fixed or variable participations of the crop yield. There are different forms of contracts between growers and mills. A description of the kinds of contract and payment modalities can be seen in table 5.9:

Type of Contract	Description	Payment
Purchase of production	Between grower and mill. The grower is responsible of the planation until the cut-off stage.	• Kilos of sugar per ton of cane produced • Percentage of sugar per ton of cane produced • Combination of the two.
Production Participation	Farm owner and mill agree beforehand a set participation on the sugar produced by ton of	Kilos of sugar per ton of cane produced.

[137] This aspect is highlighted by Mr Jorge Bendek, president of the National Federation of Biofuels of Colombia: "The biofuel market has been favourable. Everything that is produced is consumed. There are not negative variations that we need to worry about." (Retrieved from: http://www.fedebiocombustibles.com/v3/nota-web-id-1992.htm, December 10th, 2014)

[138] "Demand sophistication in Colombia is low. While most developed nations have fifteen types of sugar quality, Colombia produces only four types: raw, white, white special and refined. This is a result of the quality specifications demanded by sugar-based industries such as food and beverages. As competition in these markets intensifies, the specifications will increase and therefore the demand for sugar will be affected" (Dueñas et al., 2007, p. 29).

	sugarcane. The mill or a third party is responsible for the plantation	
Land tenure	The mill or a third party rent an extension of land and are responsible for the plantation.	• Kilos of sugar per monthly leased gross area. • Fixed monthly fee.
Plantation administration	The grower signs a contract up with the mil for the sugarcane plantation administration	Mill charges a percentage of the administrative costs.

Table 5.9. Contract modalities and payments between growers and sugar mills.

Source. Information gathered from the author by interviews and Finagro[139] information.

Different modalities of production, associations between growers and mills, and a balance between demand and supply have resulted in the development of sophistication from the start of the chain. Since the sugarcane produced has to meet high quality standards and meet a minimum production of sugar per ton of harvested sugarcane plant, the modernisation of the sector has evolved rapidly, so has the formal type of contracts between growers and sugar mills. However, the sugarcane by-products demanded by final industries like food, beverages and liquors are not sophisticated, so the sugar mills do not innovate either in their final products.

The production and commercialization process from the delivery of the sugarcane to the sugar mills, to the sale of processed derivatives to the domestic and international market can be seen in figure 5.16. The sugar mills pay Asocaña 0.65% of the sale price of the derivatives, regardless of the type of contract they have with the producers. This tax is deducted directly from the sugar mills to the farmers. In this way, the payment collection is easier and more organized, since there are more than 2700 growers in Cauca Valley (Alvaro Amaya, personal communication, April 24th, 2012).

[139] State agency for supporting the agriculture sector through projects funding. More information can be seen in: https://www.finagro.com.co

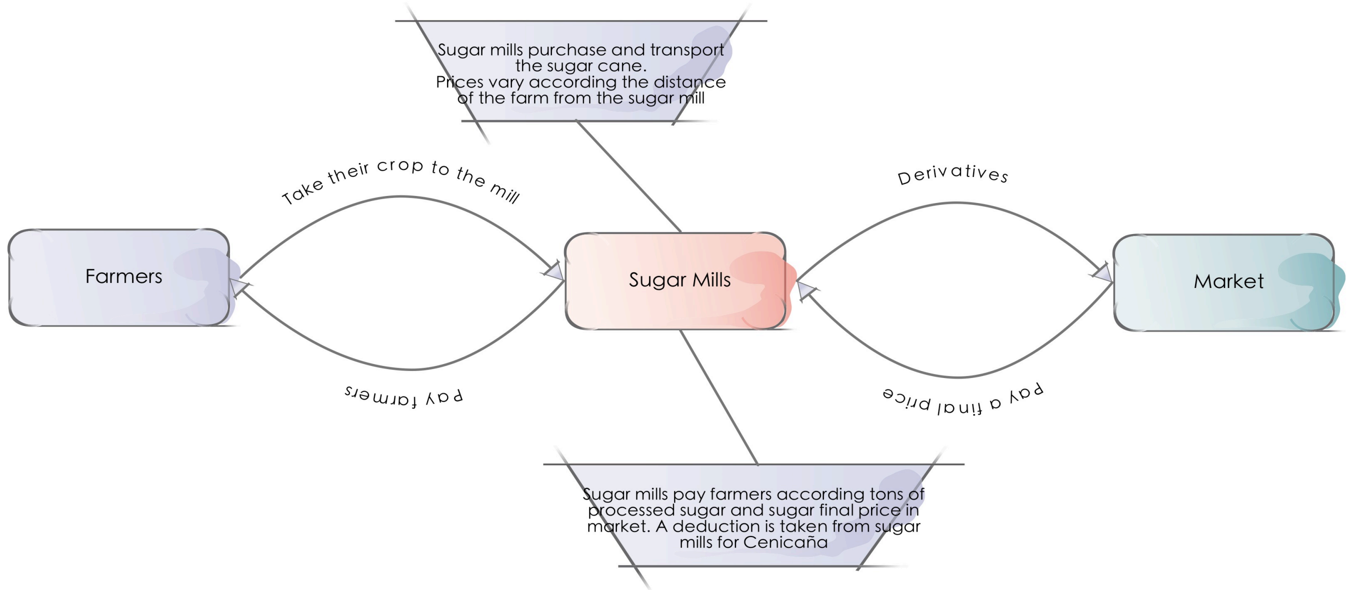

Figure 5.16. Pricing model from the raw plant to the final product and the profit return to sugar mills and farmers.

Source. Information gathered by the author

5.3.3.1. Panela as Another Sub-Product of Sugarcane

There is another product for domestic consumption derived from sugarcane, which is the panela. Panela is a product derived from unrefined whole cane sugar. It is a solid form of sucrose derived from the boiling and evaporation of sugarcane juice. It is used to sweeten food and drinks. The production of panela is concentrated in six departments distributed in different zones of the country. Panela producers are associated in Fedepanela, the National Federation of Panela Producers[140], and although there are certain collaborative links between them and Asocaña, the associations operate separately. Most of the panela production is made by local farmers with small land parcels. Until recently, the production of panela was absorbed mostly by the domestic market. Now Fedepanela is encouraging and supporting the technological upgrade of local companies to export different presentations of panela to the international market (solid, powder, liquid, cubes with flavours, etc.).

Panela producers have been unionized since 1976 and have received support from the Ministry of Agriculture and Rural Development and Corpoica. This derived product is not studied in this thesis since it represents a separated production chain within the agricultural classification of Colombia, and it is independent from the producers of sugar and energy. However, a deeper understanding of the relationship between the panela and sugar productive chains should be examined in more detailed.

Fluctuations in the sugar price and entrance of cheaper imported sugar also affected the panela sector. In terms of production, about 40% of producers buy sugarcane directly from the growers, and the remaining 60% grow it in their own lands. As it is explained by the agronomist and professor of Universidad Nacional de Colombia, Héctor Ramos: “when sugar prices are low in the international market, the cane price rises too, which generates that some panela producers go to the illegal market and

[140] More information about the Federation and the production of panela can be found in http://www.fedepanela.org.co

buy cheaper imported sugar to melt and produce panela" (Universidad Nacional de Colombia, 2014). Although whilst in terms of organizations, budgets, geographical distribution, target markets, and legal representation both productive chains are differentiated, they are closely related in terms of economic fluctuations and research necessities.

5.3.4. Sectoral organizations

Asocaña is the Association of Sugarcane Growers of Colombia. It was founded in 1959 and it integrates fourteen sugar mills and a small group of sugar cane growers in the Cauca Valley. Asocaña does not represent independent sugarcane growers. Its main role is to negotiate sectoral policies with the government, and other national and international organizations related with the sector. Besides Asocaña, the sugar industry has other organizational units for specialized tasks in the areas of research, training, and international marketing of sugar: Ciamsa, the international commercial trader of sugar and molasses created in 1961 as a commercial and international market branch of the sector that manages joint exports from the mills; and Dicsa, which is the national enterprise in charge of sales and distribution of the mills products for the domestic market; Tecnicaña, established in 1971, is the Colombian Association of Sugarcane Technicians, and it is in charge of training and technology transfer for technicians of the sector; Procaña, founded in 1973, which is the Colombian Association of sugarcane producers and providers, holds the representation of almost all natural or legal persons who grow sugarcane; and Cenicaña, created in 1977, is the sugarcane research centre, created and maintained with private funding from sugar mills and farmers.

5.3.4.1. Cenicaña

The main organization within the innovation system is Cenicaña. Through its operation there is knowledge creation and circulation, technology transfer, validation and appropriation processes in the productive chain.

Cenicaña is a private non-profit corporation created by Asocaña in 1977. Before the creation of the centre, the growers were doing the technological development process by themselves, but in order to avoid duplication of efforts and redundancy in technological solutions, the centre was created.

The initial trigger for the creation of the centre was the emergence of two major sugarcane plant diseases: sugarcane carbon, and sugarcane rust. These two diseases devastated entire sugarcane fields in South Africa and Barbados. With the imminent threat, a group of industry executives visited the main sugarcane production fields in the world. As a result, they understood that investment in R&D was essential, so Cenicaña was created following the South African model. South Africa's sugarcane research centre was sponsoring Cenicaña for ten years since its foundation. After 37 years of research, Cenicaña has developed 21 varieties of sugarcane with plant breeder's rights. Until mid-1970s most of the sugarcane breeds were foreign, now more than 70% of the varieties planted in the Cauca Valley are Colombian. Currently the centre receives royalties from countries such as Peru and Ecuador, and countries in Central America for using these varieties, which is another funding source for the centre.

Since sugarcane growers and sugar mills fund the research centre, their main aim has been to support the sector in bringing the latest technology and research. Commenting about the mission of the centre, Dr. Álvaro Amaya, executive director of Cenicaña says: "Creating value through research products is not enough. Our task is not completed until our products are in use" (Alvaro Amaya, personal communication, April 24th, 2012). That is why R&D priorities are defined in association with the producers. The centre proposes developments based on the state of knowledge in the area, bringing together producers needs and problems to generate real solutions. There is direct contact between users and the research centre through special committees[141]. However, it is important to mention that independent

[141] Cenicaña's board is comprised of sugar mills representative and growers who are Asocaña's donors. There are 3 main research programs in Cenicaña: Varieties program; Agronomy program; and Factory processes program. There is a Programs committee that defines the research priorities for every program. This committee has participation of the board and the research committees of each program where Cenicaña's researchers participate, as well as technical managers and sugarcane providers of the sugar mills. There are also technology transfer groups (TTG) that are composed by sugarcane growers, sugarcane mills, Cenicaña's researchers, and Tecnicaña technicians. Members of the group have similar interests and come together to exchange technological information. Finally, in every sugarcane mill there is a technological validation area where technologies are tested according

sugarcane growers –those who are not associated in Asocaña- are not part of the committees structure and do not get any benefit from the centre, since they do not contribute with the percentage of their sales for the funding of the centre. The independent sugarcane growers, associated in Procaña, represent 19.8% of the sugarcane planted area.

Cenicaña has three research programs: varieties, agronomics, and factory processes. Across these programs are committees and research support services for producers, researchers, and other specialists of the industry. The whole idea of having these three main research programs is to integrate geneticists, breeders, entomologists, plant pathologists, biotechnologists, and all necessary specialities to support different phases of a project, favouring transverse and cross-disciplinary research. This has allowed the centre to achieve comprehensive results for the industry[142]. This means that the research's aim is always attached to tangible and feasible impacts in the field. The executive director of Cenicaña repeatedly highlights this:

> For me it is vital that the researcher is close to who needs the solution. It is not only a matter of acquiring knowledge and making it available to a full extent. And here things are done rigorously, because they have to be done in that regard. But we must go further. We complete the whole cycle from investment to impact. (Alvaro Amaya, personal communication, April 24th, 2012).

In summary, there are three factors that may be directly attributed to the success of the centre's structural and functional dynamics:

1. Clearly defined beneiciaries. This provides a clear strategic line of priorities and outcomes.
2. Stable funding sources. Main funding sources come from the producers association Asocaña. Research has been a priority so funds are constant.

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to research results and products delivered by the research programs. Validation of technologies results is shared with all members of Asocaña.

[142] Results on quality and efficiency in resources management; better practices and use of technology to have environmental sustainable practices; higher productivity of sugar, ethanol and electricity depending on the purpose of the plantation per production unit; generation of new sugarcane varieties; site-specific agriculture compiled un specialized databases; innovative methodologies to transfer, adoption and validation of knowledge with the sugarcane growers and sugar mills (Cenicaña, 2012).

3. Good synergy between the producers and users of knowledge and technology. The transfer, adoption, and validation model is focussed on producers' needs, so many different mechanisms are used to improve communication between actors have been created.

A general relationship map between actors in terms of exchange of knowledge and technology (K&T) and the generation of innovative practices, products, or services, can be seen in Figure 5.17. In the case of the sugarcane subsector the research centre, Cenicaña, acts as a hub linking stakeholders interested in innovation for the subsector.

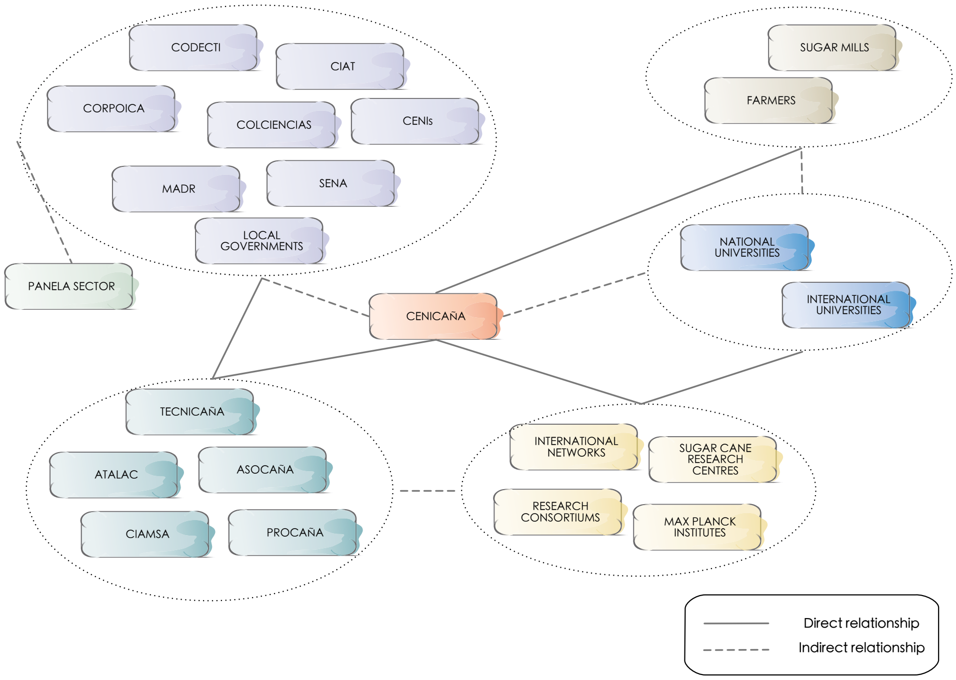


Figure 5.17. Relationships between actors in the sugarcane productive chain for innovation generation.

Source. Information gathered by the author.

The relationships between heterogeneous actors in the productive chain has resulted in the construction of a still emerging but strong knowledge base to boost firms' competitiveness in the domestic and international markets. This has been specifically relevant for the cohesiveness and innovation capabilities of the sector, and seems to be an essential characteristic of a sectoral innovation system, as Malerba expresses it:

> [I]nnovation and industry evolution are highly affected by the interaction of heterogeneous actors with different knowledge, competences and specialization, with relationships that may range from competitive to cooperative, from formal to informal, from market to non-market. (Malerba, 2006, p. 15)

Benefits of the multilateral vertical and horizontal relationship between actors can be seen in the performance of some indicators. In 2007, sugar mills made a direct contribution of 0.54% to the national GDP, and 0.86% to the industrial GDP. Additionally, for each Colombian peso of added value generated by the sugar mills, 3.9 Colombian pesos are generated in the national economy; for each peso of taxes paid by the sugar mills, tax production payments of 10.3 pesos are generated to the economy; and finally, for each job created by the mills, 28.4 jobs are created derived from their activities (Arbeláez et al., 2010, p. 1). This suggests a good and valuable contribution of the sector to the national economy and particularly to the agriculture GDP. The sugarcane sub-sectorial composition as a cluster has been beneficial for generating innovation in products and services and stronger industrial dynamics.

5.3.5. Institutional Setting

We described in section 4.3 (Policy implementation at the national level) the existence of national University-Enterprise-State committees (UEE) working regionally on different strategic sectors to link key actors from the academic, private and public sectors to work on special projects together. The department of the Cauca Valley has a UEE committee lead by the governor of the department and with the important participation of the Universidad del Valle, one of the most important universities in the country. Cenicaña is sometimes invited to these committees when topics related with agricultural development and the sugar and energy sectors are under discussion. However, the Cauca Valley UEE committee has the same problems of other regional committees. The lack of commitment from the business sector to participate in the meetings and low trust in the successful execution of joint projects; weak representation from public institutions expressed in the constant change of public servants attending to the meetings and their lack of decision-making power; and representatives from academic institutions that do not have any motivation from their HEIs to develop projects with the private sector, jeopardizes the medium and long-term decision-making process.

The development of Technology Transfer Offices (TTO) is a nascent process that requires further maturation. Few universities in Colombia have a TTO, so the link between universities and firms and non-firms within the NSSTI is weak. As Dr Alvaro Amaya, Executive director of Cenicaña, noted: “We interact with universities, and I give a great value to the university, but I would like to see universities engaging with research centres, and with the companies themselves, but that simply does not happen.” (Alvaro Amaya, personal communication, April 24th, 2012). Once again, the failures perceived and described in the National System of Innovation, are replicated at the sectoral level. Universities in Colombia are in a transition period to generate internal mechanisms and policies to ease research projects with firms and other research institutions and be able to perform successful knowledge transfer projects.

Asocaña has a strong influence on the definition of sectoral policies. As a result, the sector enjoys especial regulations as the creation of FEPA, the inclusion of sugar within the Andean Band Price System, and the guaranteed purchase of ethanol from the distilleries owned by the sugar mills.

> The Colombian sugar cane industry represents a market with high barriers to entry. Some of these barriers are: (i) the great influence that sugar mills have in defining industrial policy resulting from the market power that mills have over prices and suppliers. (ii) The economies of scale created by high fixed costs. (iii) The established quotas to distribute the market proportional to the production capacity of each mill. (iv) The oversupply of sugar in the internal and international markets. (Dueñas et al., 2007, p. 25)

However, the associations do not always work together or in a synchronized way. Asocaña and Procaña have had some disputes about the prevalence of sugar mill representation in sectoral decisions, lobby towards the Ministry of Agriculture and Rural Development, and public funding agencies. For example, in December of 2007 elections were held to establish the board of the FEPA. For this election, industry associations should be present to vote, but Procaña decided not to attend because, according to the president of the association, there were no guarantees for the sugarcane growers to defend their interests against those of the sugar mills. Thus, Procaña blamed Asocaña to maintain a monopoly within the cluster for the benefit of the sugar mills[143]. In terms of public sectoral policies, table 5.10 describes the most important policies that have affected the evolution and development of the sector:

Policy Category	Description
Infrastructure	1919 – 1922: Construction of the commercial dock of Buenaventura. 1926 – 1940: Construction of road infrastructure to connect the Cauca Valley with the centre of the country. 1992: Dock of Buenaventura privatization.
Research	1920: Experimental farm in Palmira. 1926: Chardon Mission. 1977: Creation of Cenicaña. 1990: Tax incentives through National law of S&T. 2000: Creation of NSSTI. 2009: Tax incentives through National law of STI.
Price policies	1990: Colombia, as part of the Andean Community, joins the Andean Price Band System. 2001: Creation of the Stabilization Fund for Sugar Prices.
Agriculture policies	2000: Creation of the Agro-industrial National System of Science and Technology. 2001: Introduction of alcohol fuels to the energy sector. 2003: Creation of agriculture productive chains.

Table 5.10. Formal institutional setting affecting the sugarcane industry

Source. Made by the author.

As mentioned before, collaboration between actors is a key feature of the cluster either backwards (between the growers and the mills) and forward (between mills and industries in demand of sugarcane by-products). As Alberto Otoya, Strategic

[143] More information about this dispute can be found in:
http://historico.elpais.com.co/paisonline/calionline/notas/Diciembre052007/caliazucar.html

Projects Manager of Manuelita sugarcane mill highlighted, procedures to weigh sugarcane crops when they are delivered to the sugar mills, and the amount or percentage of sugar or ethanol produced from the cut-cane is a regulated and transparent process to growers at all stages of the chain from harvesting until distribution (Alberto Otoya, personal communication, February 18th, 2012).

It can be argued that sugarcane in the Cauca Valley has been an outlier within the agriculture sector because of the privileged geographical location, strong growers associations –even counting the differences between Asocaña and Procaña-, a long-term view from the producers based on S&T as main variables for the viability and sustainability of the sector, and the diversification of sugarcane by-products to open new market channels. The director of Corpoica, Dr. Juan Lucas Restrepo, said referring to the sugarcane sector in the Cauca Valley: "It is a self-sufficient sector in terms of resources, with few major firms that absorb the whole production of the cluster, highly associated, and with a great influence in the sectoral exports and imports policies" (Juan Lucas Restrepo, personal communication, May 3rd, 2012).

5.3.6. Knowledge and Technology Transfer: Adoption, and Validation Model

Knowledge and technology transfer, adoption and validation processes have been at the heart of the sugarcane industry. As it was described in the previous section, Cenicaña was created as an initiative of the association of sugarcane growers to solve extant problems and, as far as possible, to anticipate and manage risk. Then the focus of the research centre is to provide updated and relevant knowledge and technologies to its users. One differential aspect of the sugarcane production chain has been the emphasis put on knowledge as the base of competitiveness from an early stage of the modern production of sugar in Colombia. Production and implementation of new techniques and technologies to improve practices in field, harvesting, manufacturing, and distribution have increased efficiency and productivity in the sector, bringing higher profits to both growers and sugar mills. Cenicaña, acting jointly with the other sugarcane associations, performs constant technological monitoring and evaluation, so it can deliver better solutions to its clients (the growers and the sugar mills). Technological surveillance has been a non-stop process in the Colombian sugarcane industry: “The development of new technologies has been a key aspect for the advancement of the sugar industry. It has enhanced the productivity, and has helped to fight against diseases as roast and coal of the sugarcane.” (Cock et al., 1995, p. 24)

The K&T transfer, adoption, and validation model is outlined in figure 5.18. R&D processes are centralized in Cenicaña, but the centre receives feedback from its contributors to develop the research agenda and set priorities. For gathering producers’ demands there are committees composed of Cenicaña’s researchers, Tecnicaña’s technicians, technicians and engineers from the sugar mills, and farmers who are the sugar mills suppliers[144]. According to Cenicaña’s Technology Transfer Chief, Camilo Isaacs, for transferring K&T there are Technology Transfer Groups (TTG) operating in different agro-ecological zones. These groups organise field trips to the most innovative farmers’ plantations. The farmer presents how he/she uses a particular technology for having better productivity results. Then the sugar mill presents its advances on the specific topic under discussion, and finally Cenicaña and Tecnicaña introduce the new technique, technology, or variety that can be used to achieve particular production goals. Upon completion of these field trips, round tables are set to discuss and hold Q&A sessions with participants, and also for understanding other needs they may have.

From 2013 onwards, the technical cooperation and transfer technology service of Cenicaña implemented a new Program for Technical Assistance (PTA). The aim of this program is to educate and provide guidance for trainers. Researchers from Cenicaña provide training to technicians and engineers working in the sugar mills. Cenicaña leads a process of identification of knowledge and technological needs in order to design and provide training programs focused on real sectoral necessities. There are specific methodological guidelines for the training courses, so they can be replicated for different groups of growers across the region. As of June 2014, one hundred and twenty technicians at different levels have been trained in three specific new technologies to increase productivity in plantations (Camilo Isaacs, personal communication, August 5th, 2014).

[144] Basic information about the technical cooperation and technology transfer service, can be found in: http://www.cenicana.org/investigacion/sctt/index.php. We had access to protected information in the website for a period of time granted by Cenicaña.

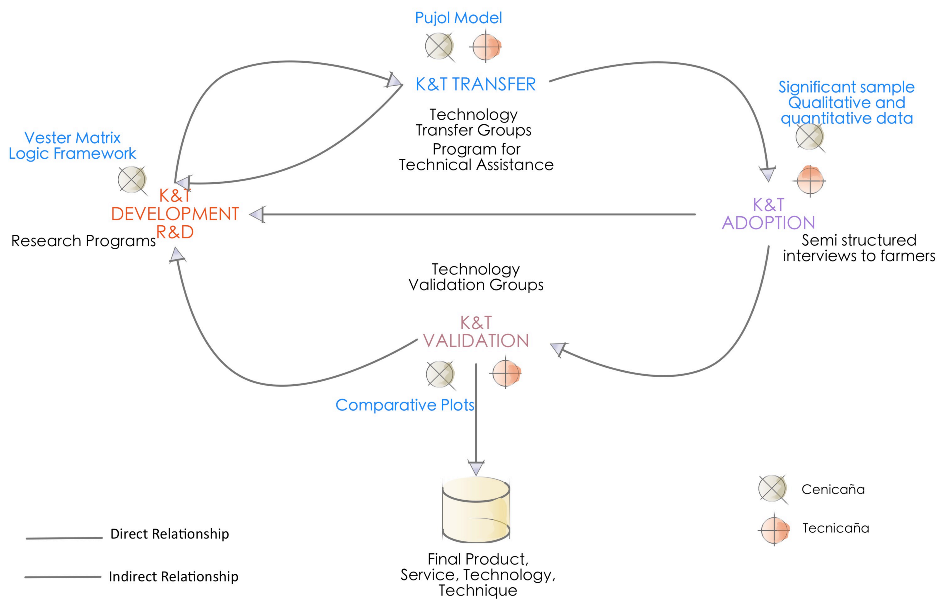


Figure 5.18. Knowledge and technology transfer in the sugarcane sector.

Source. Information gathered by the author.

Members of Cenicaña, sugar mills, and growers' representatives compose the research programs committees. Through these committees, research agendas are defined. The main tool used to determine the K&T transfer strategies and programs is the "Puyol model for innovation". It consists of: 1. Determining the characteristics of the technology that will be transferred; 2. Determining the psychological and socio-cultural characteristics of the producers; 3. Determining the installed infrastructure of the farm. Then these three variables are compared and different profiles and types of transfer strategies are implemented (Puyol, Estebáñez, & Méndez, 1995).

Making the model participative has proved to be beneficial for the cluster, since it reduces the mismatch between K&T demand and supply. It also eases the technology transfer process. A success factor of the model is the differentiation of target publics. Cenicaña has robust databases containing all sorts of information not only about geographical, technical, and biological data. All producers are registered, and every record not only contains information about size of the farm, production levels, and land characterization, but also information about socio-economic factors as schooling level, average income, composition of families, and others.

In this way, the TTGs are carefully defined. Cenicaña classifies producers in three different categories after applying the Puyol model: innovators and early adopters; late adapters; and stragglers. Then, Cenicaña structures TTGs mixing the three types of growers, so learning and feedback processes have a higher impact on those who need to catch up with new technologies and techniques. There is also an on-going program to identify the growers and producers attitudes towards adoption of K&T. The intention is to understand psychological and sociological characteristics, risk aversion or proclivity, traditionalism and possible fears growers and industrials have. The integration of more social and psychological characteristics allows directing better products and strategies to the targeted groups. As stated by the Chief of the service of technical assistance and technology transfer of Cenicaña, Camilo Isaacs:

> You can try to transfer new knowledge and technology, or try to transmit better practices with the current knowledge and technology, but if they [growers] do not have an open attitude and a willingness to listen, it is impossible to start any technology transfer process. We want to go further by increasing the adoption levels. They are not bad, but we want to reach the ceilings. Each technology has its ceiling of adoption level and we want to target that. (Camilo Isaacs, personal communication, February 18th, 2012).

Cenicaña has a specific market oriented model for technological development that integrates the research and transfer of technology actions so there can be synergy between the industry expectations and the research centre. The main purpose is to maintain a cycle of continuous improvement (Figure 5.19).

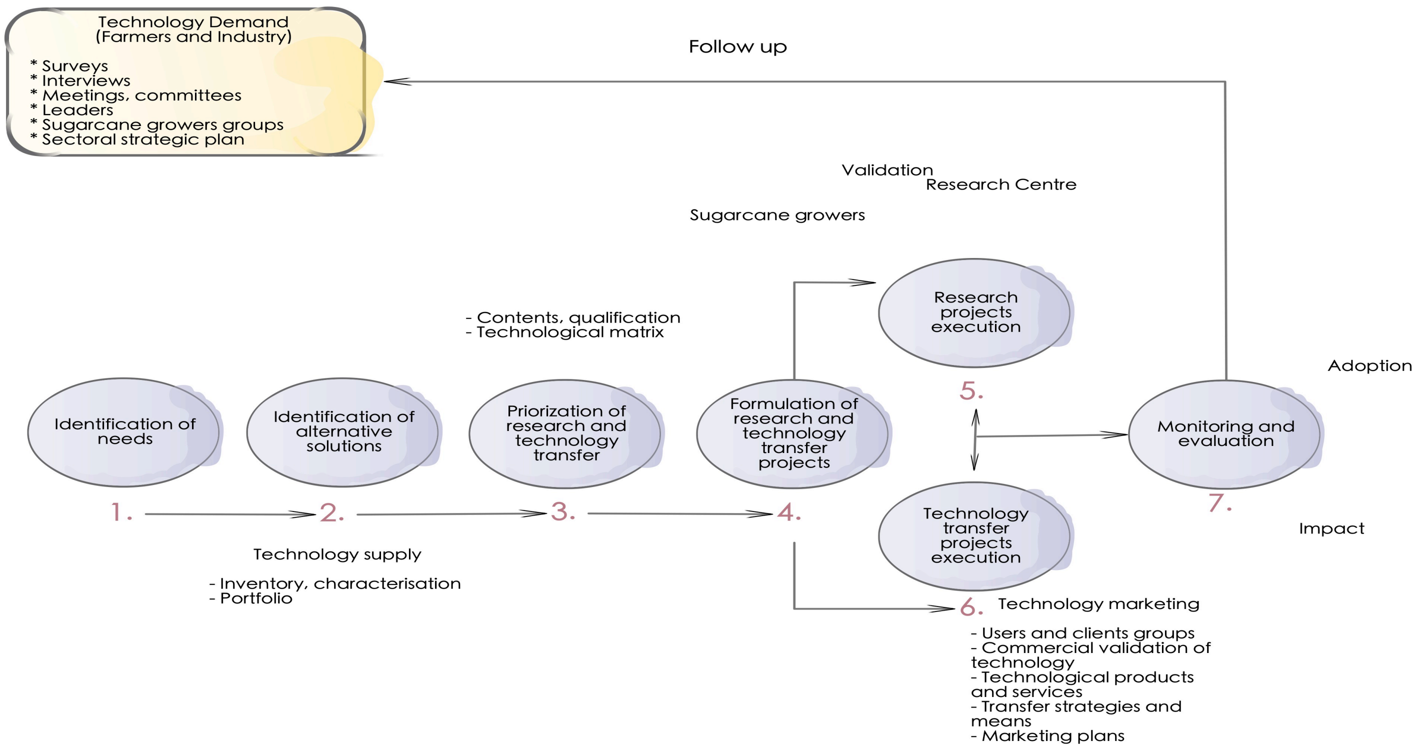


Figure 5.19. Technological development model market-oriented followed by Cenicaña.

Source. Cenicaña. Translated to English by the author.

This K&T transfer, adoption, and validation model was adapted from the experiences of Chile and Argentina[145]. Although the model is very focused on the producers' needs, researchers have the autonomy to present research projects on different topics, as long as there are feasible and have applicable results for the producers. The centre does the whole R&D cycle, from production of basic science, through the generation of applied knowledge, to appropriation by growers and sugar mills, and finally to the validation of new technology and knowledge with the final users. It is not a linear and sequential process; there is always intervention of Cenicaña's researchers, representatives of sugar mills and feedback from sugarcane growers in different stages of the knowledge and technology generation. It is important to maximise the research centre resources so results are focalised on products to help growers to have higher productivity, less use of water, biological pest control, more efficient harvest and transport techniques and even managerial skills centred on the sugar and ethanol production (Camilo Isaacs, personal communication, February 18th, 2012).

Concrete results can be traced and seen in action after successful R&D projects. As it is highlighted by Fernando Villegas, head of the agricultural mechanization research group in Cenicaña:

> Thanks to research done in the centre [Cenicaña] we apply today 50% less irrigation water without affecting crop production. We use less fertilizer for nutrition, achieving greater efficiency of the products we apply. We maintain crop health using mostly biological controls. As soon as a new pest appears, immediately we start looking for natural enemies. Rarely a chemical is applied to control an insect pest (Fernando Villegas, personal communication, May 18th, 2012).

Training of human resources necessary for meeting field and sugar mill requirements is a main part of the K&T cycle. Tecnicaña, for example, is closely related to Cenicaña. Tecnicaña's main services are to disseminate, promote, share and transfer knowledge and technical research in different areas of the sugar industry. Cenicaña

[145] In 2002 a group from Cenicaña went to Chile and Argentina to see how they managed their process of technology transfer in different agricultural subsectors. As a result of that visit, the technology transfer groups were created in Cenicaña, bringing together producers and researchers. In the Chilean and Argentinian cases these were self-managing groups leaded by the most advanced farmer. In the Cenicaña's model, the groups are managed by the technical assistance and technology transfer service.

transfers the latest knowledge and technology to this association and they train the professionals of the sector. Besides the close relationship between Asocaña, Cenicaña, and Tecnicaña, there is a special agreement between them and SENA to develop training programs for trainers. These programs keep running parallel to the new program for technical assistance.

Cooperative relationships with national and international partners have been fundamental for understanding sugarcane genetics and producing varieties with higher levels of sucrose and resistant to diseases and technological solutions adapted to the particular geographic conditions of Cauca Valley. In order to share knowledge on biotechnology, a consortium was created between five important sugarcane producer countries: Australia, South Africa, Brazil, United States and Colombia. The chief of Biotechnology in Cenicaña, Dr. Jerhson López, explains that the intention on participating in this consortium is to bring together efforts to produce research results maximizing physical and intellectual resources. Research project expenses are paid between members of the consortium according to the benefits each centre receives and the expected impact on the sugar, biofuel, or energy produced. Additionally, training of researchers and technicians in new techniques are essential, so there can be diffusion of results to the producers. Knowledge and technology is always available to the members of the association (Jerhson López, personal communication, February 18th, 2012).

Summarising, we found a well-organised system for the production of knowledge and technological solutions for the different actors within the sub-sectoral innovation system. Cenicaña has remained as a fundamental hub for bringing together the growers and sugar mills necessities with cutting edge S&T production so the sector is updated and remains competitive to meet domestic and international market demands. It has also opened the possibility to develop new business opportunities, as in the case of ethanol, so what was waste in the early stages of the industrial development, it is now an important source of clean energy.

5.4. Sectoral Cases – Fresh-Cut Flowers

The cut flowers sector is in many senses *sui generis* in the Colombian agriculture sector. It is a non-traditional agriculture sector that emerged as an initiative of a group of private investors who saw a business opportunity in the potential development of fresh-cut flowers plantations in Colombia for the international market. Given good land areas and climatic conditions, technology and expertise was imported from Holland in the 1960s. During the 1980s the sector experienced an important growth mostly supported through governmental incentives such as tax exceptions, direct subsidies and special credit lines. The success of the sector was aided during the 1990s by large companies that bought many small and medium flowers companies and then introduced modern packaging and transportation techniques (Madrid & Lovell, 2007). However, the sector composition is mixed in terms of firms' size. The production chain is controlled by SME's and large companies that own the flower farms and in some cases the brokerage firms in order to avoid intermediaries in the merchandising and distribution links of the chain. These companies hire low-skilled local labour surrounding the flower plantations.

After twenty years, the sector experienced important growth as a result of a period of maturation in cultivation and harvesting techniques and a supportive institutional setting. The cut flowers, foliage, young plants, and trees trade is known as floriculture. It has evolved over time from being a good, grown by consumers themselves, to a dynamic and expanding market worldwide (Czinkota & Ronkainen, 2013).

Colombia is the second largest exporter of fresh-cut flowers and flower buds after the Netherlands with exports of over one billion of US dollars in 2009. For the same year, the total world export of fresh cut flowers was US$6,466,810 billion according to the International Trade Centre (ITC) (Czinkota & Ronkainen, 2013). The flower industry is recognised as one of the most successful and dynamic sectors in Colombia, being the principal exporter of fresh flowers to the United States and the world-leading exporter of carnations. The flower industry is the second largest foreign exchange revenues generator in the agriculture sector, after coffee (Reina, Acosta, & Oviedo, 2008). It is also highly relevant for the social development of the country since it is the agriculture production chain that generates the highest employment rate with an average of sixteen employed persons per hectare. The second agriculture sub-sector in terms of employment is coffee with an average of 0.8 persons per hectare (Castellanos Domínguez, Fonseca Rodríguez, & Buriticá Ospina, 2010). This production chain represents the highest agriculture non-traditional exports in Colombia and generates nearly 200,000 jobs (both direct and indirect) which represents up to 4.5% of agricultural employment (Arbeláez, Meléndez, & León, 2012). The sector is a major source of exports and jobs in the Colombian economy, but has also been surrounded by deep structural crises that have put its stability at risk in the mid- and long-term.

5.4.1. Industrial Setting, technological evolution, and dynamic complementarities

5.4.1.1. Fresh Flowers Industry in the world

When the flower trade started in the 17th century, the main producers and consumers were centralised in Europe, Germany, France and Japan being the leading countries in the flowers market (Czinkota & Ronkainen, 2013). It was in the Netherlands where the first greenhouses were developed to commercialise cut flowers. Tulips were imported from Turkey to the Netherlands during the 16th century, which opened the interest and consumption of exotic flower bulbs in this country. The development of this market segment in the Netherlands has been done through the domestication and adaptation of foreign flower bulbs during the last five hundred years (Benschop, Kamenetsky, Le Nard, Okubo, & De Hertogh, 2010). Then, following the European model, David Landreth Company opened a store offering flowers' seeds in 1784 in the United States. There was an emergent and growing market that represented a good business opportunity (McDonald & Kwong, 2005). However, the major expansion of the floral industry took place during the 20th century. The Netherlands continued to be the major producer and exporter of flower bulbs, even when new competitors entered the marketplace during the second half of the 20th century. Given the need for fresh soils and better climatic conditions; lower production costs, especially in labour; and the flexibility to produce flowers customised to market demand, the floral industry has been in a process of diversification. "…globalization and increased competition have led to the development of new bulb and flower production centres. For example, floricultural production in Latin America, Africa, and Asia is increasing rapidly." (Benschop et al., 2010, p. 10).

> During the 1980s there was a modification in the cut flowers market. Holland, main producer and marketer in the world, increased its investments in other countries through different strategies, for example: knowledge transfer through training to producers and private firms providing seeds, fertilizers, etc. (Castellanos Domínguez et al., 2010, p. 24)

The commercial products offered as part of the floriculture can be seen in figure 5.20. Colombia has specialised its commerce on fresh-cut flowers and foliage, either loose or as finished bouquets. The Colombian flowers market is customer-driven so production depends on international demand tendencies. The business niche that will be analysed in this section is the traditional fresh-cut flower since it represents higher sales and revenues for the chain.

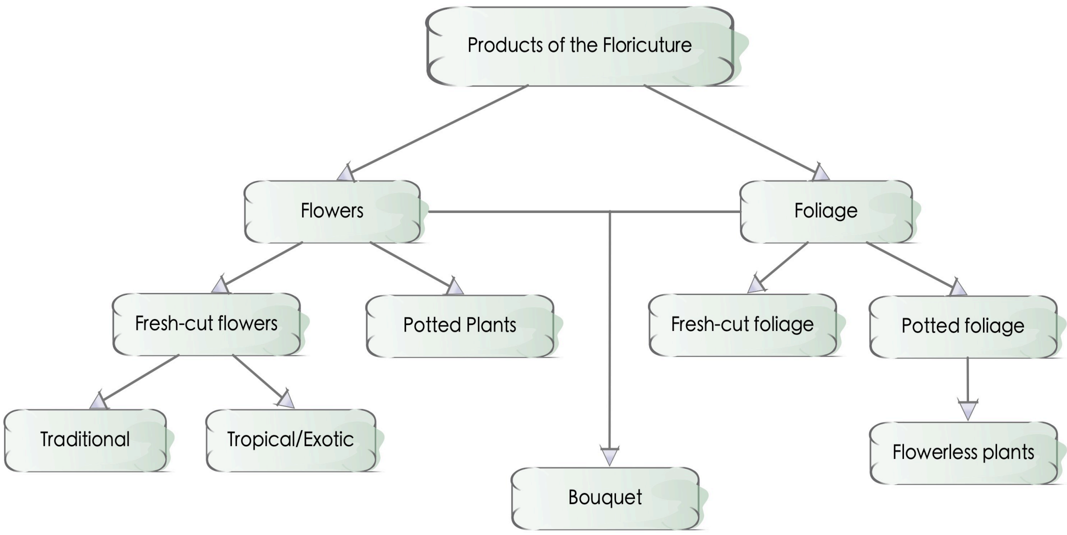


Figure 5.20.General scheme of the commercial products of the floriculture business

Source. Based on (Castellanos Domínguez et al., 2010, p. 18)

The evolution of the flower market composed of flowering, foliage, fresh-cut flowers, finished bouquets and greens has experienced an important growth, as can be seen in figure 5.21. Between 2002 and 2007 the sector grew 34%, and maintained the position of Colombia as the second exporter of flowers in the world, after the

Netherlands (Reina et al., 2008). From 2003 to 2008 the tendency on flower exporters, in terms of millions of dollars exported, continued to favour the Netherlands (53%) and Colombia (16%) as the main exporters, followed by Ecuador (7%), Kenya (7%), Ethiopia (2%) and Italy (1%). Roses and carnations are the flowers with higher demand in the market, the Netherlands being the lead exporter for the former and Colombia for the latter. The Netherlands holds the first position in market exports not only because of its flower production, but also because it is the biggest re-export centre in the global market, mainly importing flowers from Kenya, Israel and Ecuador. It is in Holland where the flowers and foliage European market set prices through an auctions system (Castellanos Domínguez et al., 2010).

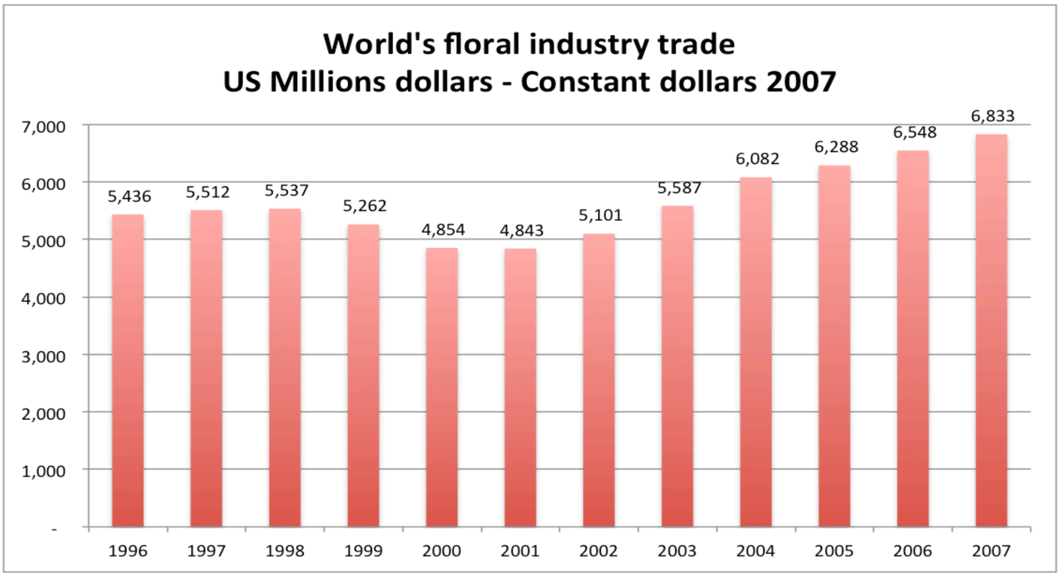


Figure 5.21. World exports of fresh-cut flowers production

Source. Based on (Reina et al., 2008, p. 3)

5.4.1.2. Colombian Fresh Flowers Production Chain

The floriculture business in Colombia emerged as a business opportunity spotted by a young researcher, David Cheever, who wrote his floriculture bachelor's degree dissertation about the potential that Colombia had for growing flowers that could be exported to the U.S. market. Since the climatic and soil conditions, and cost of labour were not optimum[146] in the aforementioned market, his innovative proposal found an

[146] Short days, with low light intensity and bad conditions during the wintertime made flower production very expensive. Also, labour is more expensive and soil conditions are not as good as the fertile soils and stable temperature of tropical countries.

audience in Colombian and American investors interested in developing the business opportunity. Even including transportation costs, growing flowers in Colombia was 31% cheaper than do it in the United States:

> [T]he discovery process in Colombian flower exports began in the mid-1960s when floriculturists and businesses (American and Colombian) identified the potential for this activity, thinking exclusively of external markets, with the United States as the core target (Arbeláez et al., 2012, p. 77).

From the very beginning the core market was North America, so Cheever, together with two investors from USA, founded Floramérica in 1969 which would dominate Colombian exports as early as one year later. The company introduced innovation in three areas (production technology, distribution channels, changes and adaptation to the product to satisfy the U.S. demand and training for the labour force). Domestic companies set up during the same period like 'Flores la Conchita', 'Flores Colombianas' and 'Flores de los Andes', rapidly copied these techniques to improve their production. Floramérica created a brokerage firm, Sunburst Farms, to avoid intermediaries in the value chain for commercialising the flowers coming from Colombia (Arbeláez et al., 2012).

The prevailing sales and distribution channels during the 1990s were intermediated by an exporter who had the responsibility to deliver the boxes of flowers to the buyer, typically a wholesaler, who then sold to a retailer, who in turn distributed to florists. In 1998, Floramérica and Sunburst were bought by Dole (a multinational food corporation from the U.S.), which also acquired other small Colombian firms, becoming the largest flower company in the country. The multinational bought around 25% of the flower farms and controlled about 20% of the Colombian flower exports. In order to counter the market control of Dole, many small Colombian firms merged to gain negotiating power with the wholesalers (Salom Serna & Sepúlveda Calderón, 2012).

Colombia has maintained its position as the second exporter of fresh-cut flowers and flower buds for bouquets or ornamental purposes with a 16.1% share of the market (Czinkota & Ronkainen, 2013). In 2009, ornamental plants and floriculture products represented 3.21% of the total Colombian exports according to the Colombian National Administrative Department of Statistics (DANE)[147]. Flower plantations are mainly concentrated in the department of Cundinamarca, in the region known as the Savannah of Bogotá (approximately 79% of the total hectares) and Antioquia (approximately 17%). The remaining 4% is distributed in Cauca Valley, the Coffee Region and Nariño (DANE, 2010). During the expansion of the world floral trade, between 2002 and 2007, Colombia increased its floral industry exports by 1.4 times (Reina et al., 2008). The flower production chain is considered a successful case since it grew by 144% during the 1990s when the general growth for the overall agriculture sector was 63% during the same period. The evolution of flower exports in Colombia, normalised at 2007 US Dollars, can be seen in figure 5.22.

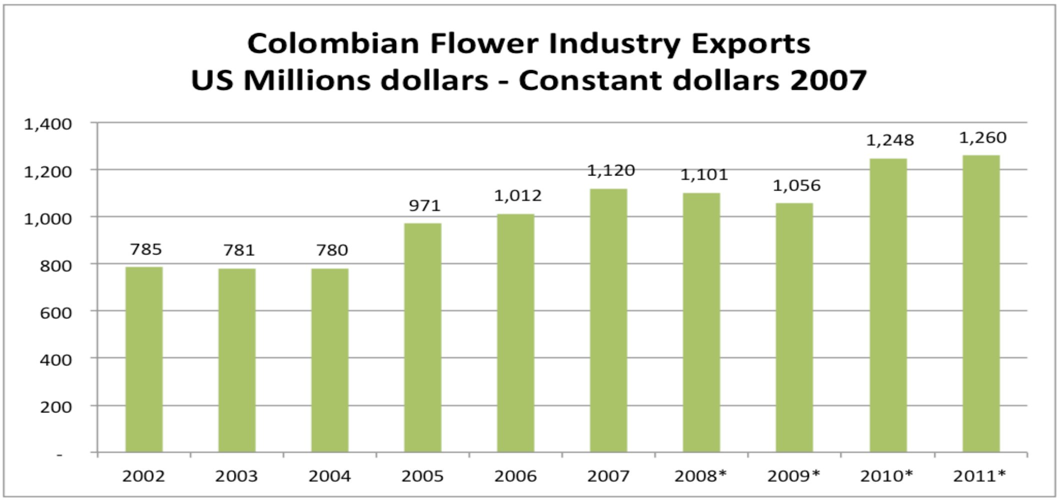


Figure 5.22. Colombian floral industry exports 2002 – 2011.

Source. Data from 2002 – 2007 from (Reina et al., 2008, p. 5). Data from 2008 – 2011 retrieved from DANE statistics: *Colombia, exportaciones según capítulos del arancel 2008 -2004*[148].

Up to 2008 the hectares cultivated for cut flower production amounted to 8,352, experiencing a constant growth in terms of area cultivated and tons of flowers per hectare (see Figure 5.23).

[147] Calculations made by the author based on DANE information: http://www.dane.gov.co/index.php/comercio-y-servicios/comercio-exterior/exportaciones. Retrieved in 07/01/15.
[148] Retrieved from: http://www.dane.gov.co/index.php/comercio-y-servicios/comercio-exterior/exportaciones, in 07/01/15.

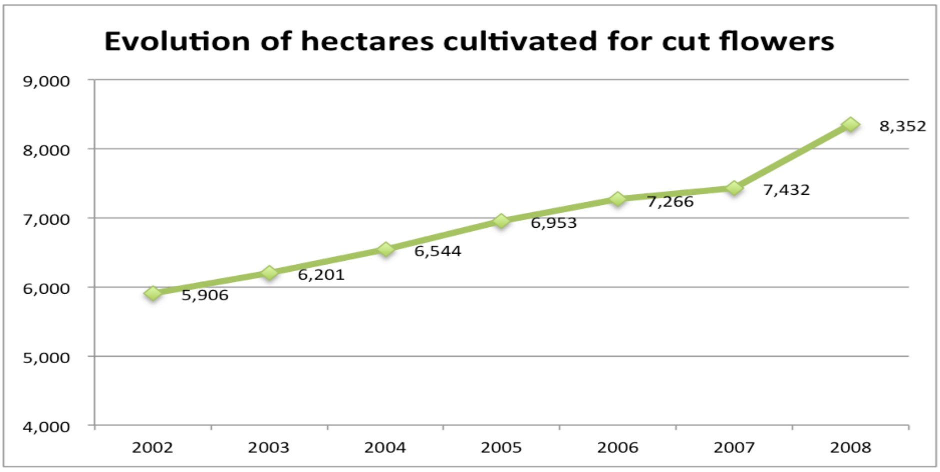


Figure 5.23. Cut flowers area evolution in Colombia

Source. Adapted from (Castellanos Domínguez et al., 2010, p. 43)

From 1962 when the first plantations were established in the Savannah of Bogota until the end of the 1970s the sector was preparing to compete with the international flower business leaders. Once the production levels were stabilised and the producers absorbed the knowledge required to produce more technologically intensive flowers like roses, exports increased. Over the years the exports have grown, ranging at 119 per cent year-over-year increase during the 1970s and then at a slower pace during the 2000s (Arbeláez et al., 2012). This tendency can be seen in figure 5.24.

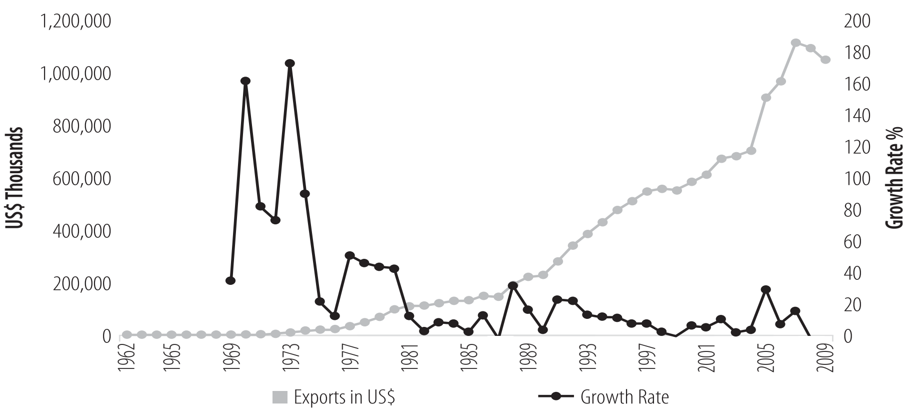


Figure 5.24. Colombian Flower exports from 1962 to 2009

Source. (Arbeláez et al., 2012, p. 70)

The fresh-cut flowers production chain stages and processes can be seen in figure 5.25:

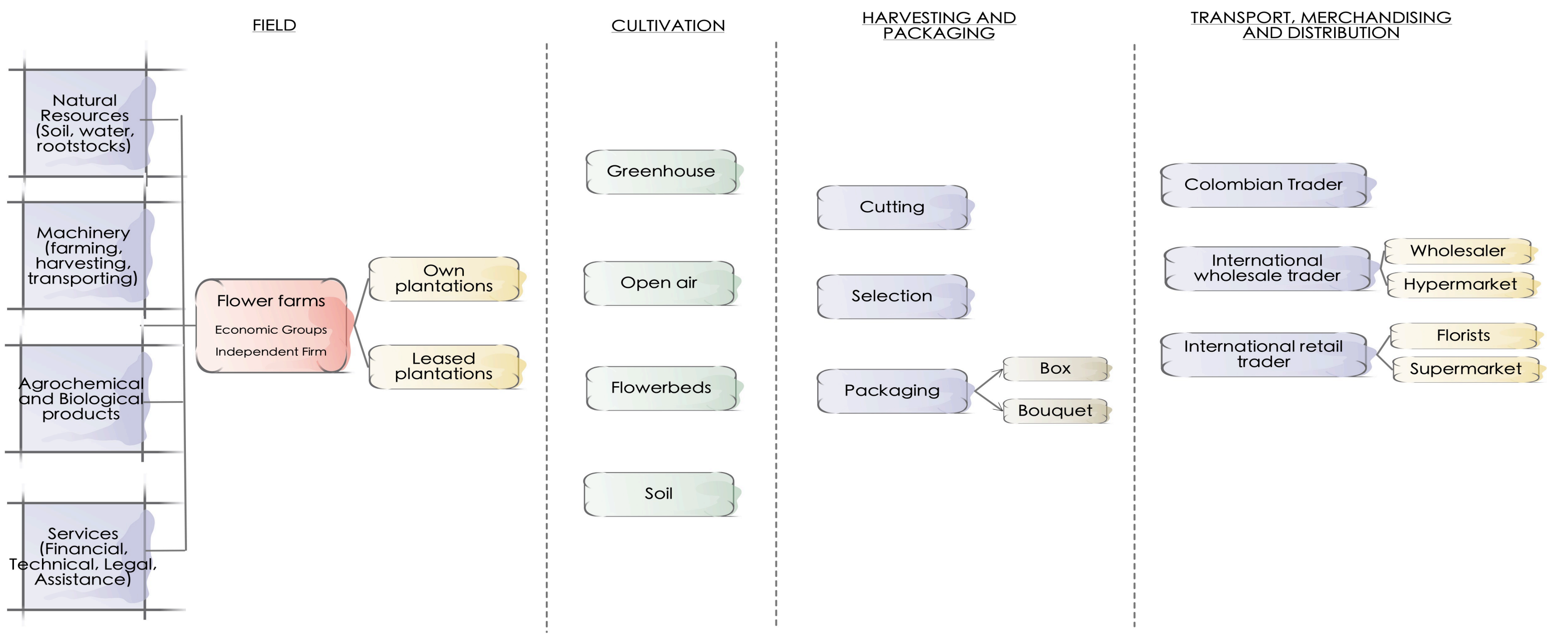


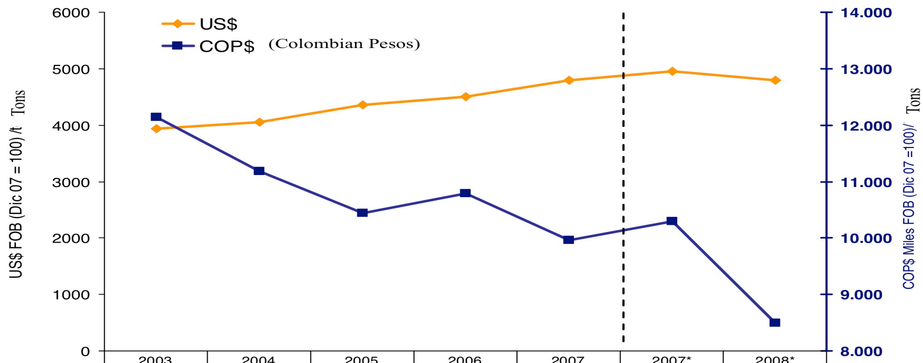
Figure 5.25. Fresh-cut flowers production chain structure

Source. Made by the author based on interviews and (Castellanos Domínguez et al., 2010; Salom Serna & Sepúlveda Calderón, 2012)

The main products offered by Colombian floriculture are fresh-cut flowers and foliage. Flower plantations have two modalities: greenhouse and open air. Most of the farms producing flowers have their plantations under greenhouse, leaving the open-air technique mostly for growing alstroemerias. The composition of Colombian flower exports up to 2008 was: 29.69% roses, 12.74% carnations, 6.72% mini carnations, 7.53% chrysanthemums, 32.48% bouquets (that includes a mixture of the exported varieties and foliage) and 10.83% of other kind of flowers, including tropical flowers (Castellanos Domínguez et al., 2010, p. 44).

5.4.1.3. Competitiveness of the sector

The appreciation of the Colombian peso has represented a major threat for the flower production chain. Even when the exports have increased, the profit in local currency has declined as it is shown in figure 5.26. If it is taken into account that one of the higher direct costs for fresh flowers production is labour (30.2% of the total costs) and wages are paid in Colombian pesos, then higher production with lower revenues generates a strong impact on the economic viability of the industry. There is a marked contrast between the 43% export growth in millions of dollars between 2002 and 2007, and its equivalent in Colombian pesos, which was only 6%. Additionally, during the same period, the total costs of the sector (including operational, sales, services, management and taxes) increased by 38% (Reina et al., 2008; Tenjo G, Montes U, & Martínez T, 2006).



	2003	2004	2005	2006	2007	2007*	2008*
US$	3.943	4.059	4.352	4.506	4.791	4.954	4.792
COP$ (Right axe)	12.144	11.188	10.446	10.788	9.956	10.289	8.499
TRM**	2.878	2.628	2.321	2.359	2.078	2.094	1.831

Figure 5.26. Evolution of prices in US Dollars and Colombian Pesos per fresh-cut flowers ton exported

Source. (Reina et al., 2008, p. 10)

To cope with precarious income levels, firms have increased their debt, causing overruns. Short-term loans increased 2.1 times between 2002 and 2007. This indicates that liquidity levels have deteriorated over time. In 2007 short-term debt reached 54% of the total financial liabilities. Additionally, financial costs rose because of an increase in loan interests. Also, the fresh-cut flowers market price has not had a substantial increment, compared with other agricultural commodities. Products like corn and bananas doubled their prices between 2006 and 2008. Summing up, the revaluation of the Colombian Peso in a sector with growing direct and indirect costs paid in local currency but with exports paid in US Dollars has caused an economic deterioration of the firms, lower profits and the necessity of higher indebtedness levels to keep the business alive. This has raised the vulnerability of the fresh-cut flowers production chain (Reina et al., 2008).

The flower production chain can be characterised as an export oriented, customer-driven business, composed by SMEs and a few large companies exporting directly to their customers who are mostly based in the USA market. Up to 2012 there were around 600 firms, most of them producers and direct exporters. From those, 55% were small and 30% medium. Despite the large number of firms participating in the industry, nearly 60% of the total exports were concentrated in the largest firms (DANE, 2010). "In 1974, 9 per cent of total firms (the largest firms) accounted for 60 per cent of total exports, while in 2000, the same 9 per cent of firms accounted for 45 per cent of total exports" (Arbeláez et al., 2012, p. 74).

The main source of competitiveness among the Colombian flower firms is the creation of value in the supply chain, particularly in the last stage concerned with the trading, transportation and distribution of the final product. Innovation in trading channels has been a major concern for the industry; so new models are constantly implemented in order to obtain higher profits. Producers know that the closer they can get to the final consumer, the higher the revenues they can obtain. According to Salom and Sepúlveda, the flowers production chain in Colombia has gone through three stages with regard to distribution channels. In a first stage, between 1990 and 1998, Colombian firms used indirect channels. Firms controlled their distribution to

Miami's airport, where the flowers were sold to a wholesaler, who would sale them to a retailer and from there, to the final consumers, usually florists. Then, from 1999 to 2001, the industry dynamics changed with the entry of two big competitors, Dole and USA Floral. Flower volumes increased; there was more associativity between Colombian firms to compete with these two multinationals that were controlling up to 20% of the exports and up to 40% of the Colombian flower distribution in the USA. With the increase in flower supply and a greater number of intermediaries in the distribution channels, the prices dropped, which made USA Floral disappear in 2001 and caused Dole's sale of the business because it was not profitable. The last stage has taken place since 2002, when importers and wholesalers have looked for other strategies to survive in the market. Two models have been followed according to the size of the firms, determined by the volume they can export. 80% of the sales are made by 20% of the companies. These companies have handled their own export processes and from 2004 they started to sell directly to large supermarkets, mostly to Wal-Mart Stores, Kroger Co, and Costco Wholesale Corp., which represent up to 40% of the USA market. In this way, they can control the logistics from the very beginning until the end of the distribution network. Small and medium companies that do not have the volume required to sell directly to retailers have followed a FOB[149] sales model using wholesalers (Salom Serna & Sepúlveda Calderón, 2012).

As it was recalled before, the appreciation of the Colombian peso has represented a huge imbalance between sales and the final profit captured by the producers. This aspect is particularly critical for the sub-sector since sales are not representative enough to offset losses caused by exchange rates. Other factors that impact the chain's performance are the highly technology dependence from the Netherlands that prevents the development of local breeds to offer differential products to the marketplace; and sales cycles determined by festivities and seasons, which makes the firms very dependent of the market fluctuations (See figure 5.27).

[149] 'Free On Board' is an agreement model for international shipping that specifies responsibility for the goods in transit, insurance costs, and freight charges. With an FOB agreement, seller and buyer agree on a designated point of delivery for the goods, so from that point onwards, the seller is released of responsibility for products.

Figure 5.27. Main characteristics of the Colombian fresh-cut flowers production

Source. Made by the author based on (Tenjo G et al., 2006, p. 7)

Summing up, the main factors that bring competitiveness to the Colombian flower industries are: high value added to the flowers per hectare in terms of cultivation techniques, less use of water, cutting and packaging techniques, and most importantly, innovation in the trade and distribution of flowers to the customers that can be wholesalers, retailers or supermarkets.

5.4.1.4. Social and environmental sustainable development

In contrast with major producers like the Netherlands and Israel, the composition of the flowers sub-sector in Colombia is characterised by relatively few owners (about 300 national and foreign companies) and 111,000 wage labourers. Of those workers, 60% are women, mostly head of the household. The flower farms were an option for rural under skilled female workers to have a higher wage than being domestic maids or having freelance jobs in other crop cultivations. During the 1990s there were high rates of unemployment and high rates of informal jobs, conditions that added to a higher mobilisation of labour to an emergent industry. Women were hired mostly as lower rank supervisors, and for planting, cutting and packaging duties. However, many of these women were hired with salaries under the legal minimum wage and exceeding the legal working hours without receiving further compensation. These cases were reported by several NGOs and academics (Korovkin & Sanmiguel-Valderrama, 2007; Meier, 1999). Thus, it can be argued that the concentration of the local population in the flowers industry and the destination of the land for a non-food agricultural product has put the already poor population in an even more vulnerable scenario of food security and unstable labour conditions.

> At the household level, the competitive strategies of the Colombian cut flower agro-industry and the neoliberal policies of the national government have adverse implications for domestic poverty alleviation and the vulnerability of households, including their capacity to maintain unremitting food security. While state regulation and the flexibilization of employment practices in the cut flower agro-industry have succeeded in making it internationally competitive and a model of success in export-led growth, these gains have not 'trickled down' to the individuals upon whom this so-called success is built (Patel-Campillo, 2010, p. 290).

There has been a great controversy about the labour conditions of the field workers of the flowers industry. By the end of the 20th century and the first years of the 21st century, some NGOs, academics and activists, drew attention to the work conditions, stability and wages received by the employees in the Colombian flower companies. "In Colombia, the product is produced under exploitative conditions and the benefits of increasing revenues for the companies do not reach to the workers" (Madrid Berroterán, 2003, p. 3).

As a response to national and international pressure to have sustainable development practices, both environmental and social, Asocolflores - the Colombian Association of Flower Exporters - developed a strategy to certify the Colombian flowers produced under fair trade conditions. "Florverde® is a comprehensive strategy aimed at optimizing the use of resources, with projected long term and permanent dynamics to improve the competitiveness of the Colombian flower industry in the concept of sustainable development." (Asocolflores, 2010, p. 1). In 2002 Asocolflores signed up an agreement with SGP[150] to demonstrate that the Florverde® certification was compliant with national and international standards, so it could be recognised in international markets. Afterwards, during 2004 and 2007, there was an equivalence between Florverde® and GLOBALGAP (The Global Partnership for Good Agricultural Practices) and also a recognition that the standard was fulfilling the Ethical Trading Initiative (ETI) in terms of labour fair conditions. When the standard started it had 28 companies certified. In 2008 there were 132 companies participating that represented 2,843 hectares and employed 43,000 workers (Asocolflores, 2010). During 2011 Florverde® was renamed as Florverde Sustainable Flowers® after a comprehensive review. As a certification scheme, the standard was separated from the producers' guild in 2012, so there is more transparency to assess the implementation of good practices in farms. The latest version of Florverde has regulations and standards in fifteen different dimensions seen in table 5.11:

<table>
<tr><th>Dimension</th><th>Category</th><th>Number of requirements</th></tr>
<tr><td rowspan="4">Management System</td><td>Managerial responsibility</td><td>5</td></tr>
<tr><td>In-house inspection and auditing</td><td>1</td></tr>
<tr><td>Customer service for non-conformities, complaints and claims</td><td>3</td></tr>
<tr><td>Total</td><td>9</td></tr>
<tr><td rowspan="8">Employment Rights</td><td>Child Labour</td><td>2</td></tr>
<tr><td>Volunteer work</td><td>4</td></tr>
<tr><td>Discrimination</td><td>2</td></tr>
<tr><td>Freedom of association and freedom to join employee unions</td><td>1</td></tr>
<tr><td>Remuneration and Salary</td><td>7</td></tr>
<tr><td>Working hours</td><td>3</td></tr>
<tr><td>Outsourcing</td><td>5</td></tr>
<tr><td>Total</td><td>24</td></tr>
<tr><td>Employee Education and Training</td><td>Employee Education and Training</td><td>4</td></tr>
<tr><td>Employee welfare</td><td>Employee welfare</td><td>5</td></tr>
<tr><td rowspan="2">On-the-job health and safety management</td><td>Health and safety program</td><td>2</td></tr>
<tr><td>Committee on the advancement of industrial health and safety</td><td>1</td></tr>
</table>

[150] Sustainable Green Printing Partnership is a non-profit organisation that builds in economic, societal and environmental pillars to provide certifications to raw material manufacturers, converters, printers, fishing facilities, trade associations, and print buyers. The pursuit is to guarantee a more sustainable supply chain.

	Company employees responsible for industrial health and safety	1
	On-the-job health and safety management	22
	Total	**26**
Rational use of water resources	Rational use of water resources	8
	Irrigation water quality	4
	Total	**12**
Fertilization and soil/substrate management	Use of substrates	3
	Soil management	3
	Monitoring of nutritional needs	2
	Fertilizer application programs and records	2
	Safe handling of fertilizers	7
	Total	**17**
Integrated Pest Management (IPM)	Pest-Free Plants	2
	Pesticide selection	9
	Pesticide programs and records and other control strategies in place	3
	Minimizing chemical pesticide risk	7
	Proper pesticide installations, equipment and handling	10
	Total	**31**
Waste Management	Prevention and minimization	7
	Reutilization and recycling	3
	Treatment and final disposal	9
	Total	**19**
Farm, landscaping and biodiversity management	Background and farm management	6
	Biodiversity and conservation	7
	Total	**13**
Energy efficiency and equipment and machinery maintenance	Energy efficiency and equipment and machinery maintenance	**6**
Origin of plant material	Origin of plant material	**9**
Post-harvest product handling	Post-harvest handling	6
	Post-harvest water quality	3
	Total	**9**
Traceability and record keeping	Traceability and record keeping	**4**
Status and use of the Florverde Sustainable Flowers Conformity Trade	Status and use of the Florverde Sustainable Flowers Conformity Trade	**2**
Total of Requirements		190

Table 5.11. Florverde Sustainable Flowers® Standard

Source. Table based on (Asocolflores, 2013)

The standard has been strengthened given the criticism it had when it was first launched in 1996, because it was mostly focused on improving the profitability of the firms through the use of cleaner practices but little was done concerning the workers welfare. Also, the independence of the standard from Asocolflores was crucial for bringing independent third parties to assess compliance with the standard. Another critical issue is that the construction of the standard did not take into account the input and feedback from the field workers, which make them feel excluded and dominated by a new source of power (Talcott, 2003; Wright & Madrid, 2007).

5.4.2. Demand

Fresh-cut flowers are a special trade product in many senses. First of all, it is a luxury good and as such it does not represent a staple commodity. It has a high demand elasticity, which means that as income increases in the domestic economy, its demand also increases (Castellanos Domínguez et al., 2010). Second of all, being extremely perishable and taking into account that its value relies on its freshness and outer beauty, handling and transportation are very important aspects within the production chain. Thus, for the cut flower chain, logistics is a main aspect for the business (Czinkota & Ronkainen, 2013). "Good logistics, in addition to marketing, consumer-oriented production and outstanding management, have produced significant growth in Colombian flower exports" (Eyerdam, 2009).

The distinctive features of cut flowers as a product remain in the social and cultural meaning that they have for the consumers according to their cultural setting. "Flowers are 'cultural' as well as 'natural' products. Cut flowers are not just 'another' commodity produced by international capital (such as shoes, clothes) for mass consumption, they are constructed as a 'natural' commodity, they are loaded with cultural meanings and they are often given as gifts, producing and reproducing social relationships between giver and receiver" (Madrid Berroterán, 2003, p. 1).

The consumption pattern of flowers is seasonal, influenced by festivities such as San Valentine Day, Mother's Day, Women's Day, St Patrick's Day and Christmas. During these periods, the demand for fresh-cut flowers and bouquets increases, so flower farms adjust their production to these specific dates of the year. Also, important consumers such as Germany, the United Kingdom and the Netherlands have a higher demand from the external market during the winter season, when their flower production is low. One of the major challenges for the industry is achieving a reconversion of the product to be consumed during the whole year with reasonably stable demand. The consumption of fresh-cut flowers has increased considerably from the late 20th century and into the 21st century. This corresponds to an increasing population with purchasing power that can buy luxury goods. The European Union consumes more than 50% of the flowers market and includes many countries such as Sweden, Norway, Holland, Germany and the United Kingdom with high per capita flower consumption (Castellanos Domínguez et al., 2010).

The main consumers of fresh-cut flowers in the world are Western Europe, North America and Japan. In 2008, Germany, the United Kingdom, the USA, the Netherlands, France, Russia, Japan and Italy in that order, were the main importers of fresh-cut flowers in the world. Worldwide, the European Union (EU) is the leading flowers and foliage importer with imports of up to USD 5,000 million in 2008 (Castellanos Domínguez et al., 2010). In Europe, the prices are set according to an auction system established in the Netherlands. This country is the first producer and exporter of fresh-cut flowers in the world. Around 6,000 small families grow flowers in farms of 1 to 2 hectares size. In order to change the tendency of the industry from being customer-driven in prices, growers organised themselves and set up a grower-led cooperative auctions to maintain economic leverage over buyers (Patel-Campillo, 2011).

> The Dutch cut-flower cluster consists of breeders, small growers, a grower-led cooperative auction, traders, buyers, and logistic firms, among others, located near the grower-led cooperative auctions of FloraHolland in Naaldwijk and the Aalsmeer Flower Auction (VBA) in Aalsmeer. (Patel-Campillo, 2011, p. 2520)

The Colombian case is different, since growers have not organised themselves to act as a block for the international customers. The main export destination market for Colombian flowers, the USA, is led by individual bargaining between firms and customers, who can be wholesalers, retailers or supermarkets. In this case, customers have total control over the producers and given the wide offer market with slight differences in the final product, the growers are at a disadvantage. This market dynamic, coupled with the Colombian peso appreciation that started in 2003 has placed growing pressure on the sub-sector.[151] The Colombian flower sector composition in terms of direct and indirect associated costs has grown the financial stress of the firms. Taking into account that the main production costs are labour, raw materials (mainly agrochemicals and plastics) and land – all of them with costs in Colombian pesos -, it can be understood that the sector has lost liquidity and raised its debt levels (Reina et al., 2008).

> The performance of the floriculture activity in Colombia is extremely sensitive to the behaviour of the exchange rate, to the extent that all of its income from abroad is denominated in USD and more than eighty per cent of its costs are in Colombian pesos. According to Asocolflores estimations, a period of sustained appreciation reduces the sector's competitiveness on world markets, make its products more expensive in foreign exchange and reduce the income of the companies in local currency.(Reina et al., 2008, p. iii)

Colombia supplies around 51% of the total demand of the US market, which for 2006 represented USD 1,117 millions. Roses are the main product in this market with 33% of the total imports, followed by carnations and mini carnations with 8%, chrysanthemums with 7.6%, alstroemeria 5.7%, foliage 9,2%, and other tropical and garden species with 36.5% (See figure 5.28). The price is set by the clients, with high levels of competition between providers, which hinders the negotiation power of the producers (Castellanos Domínguez et al., 2010, p. 38). There has been a growing tendency to sell directly to large supermarket chains in the USA, which has changed the way the products are offered, shifting from cut flowers packed in boxes, to finished bouquets, ready for the final customer. This product represents higher profits for the Colombian firms (Tenjo G et al., 2006).

[151] In February 2003, one USD dollar had a price of $2,968 Colombian Pesos. That was the highest value that the USD dollar had before a process of continuous revaluation of the Colombian Peso up to 2014. The dollar dropped by 40% during these years for various reasons: growth in exports, mainly from the oil and mining sectors, higher Foreign Direct Investment product of better national macroeconomic conditions and control of the internal conflict, and the economic crises suffered by the USA during 1998 and 1999, and the world financial crisis started in 2008.

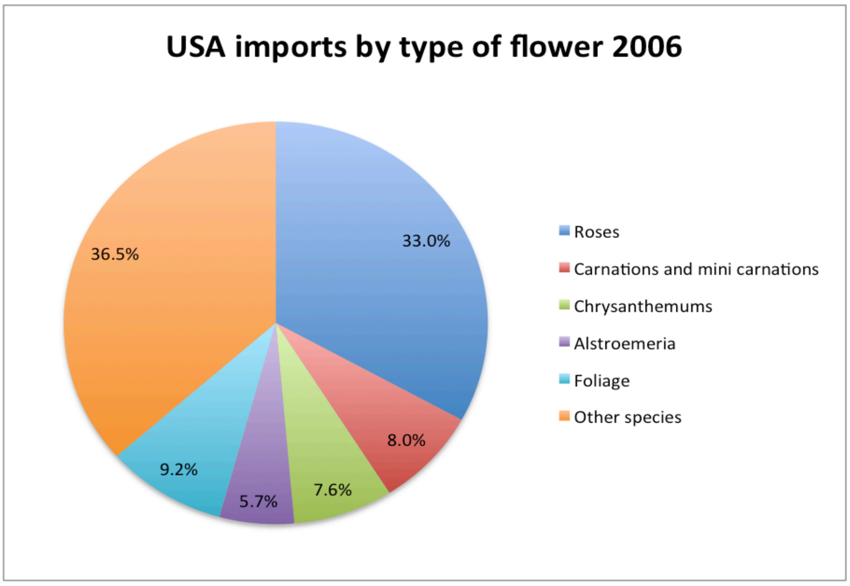


Figure 5.28. USA imports by type of flower, 2006.

Source. Made by the author, based on (Castellanos Domínguez et al., 2010, p. 38)

However, from 2004 other markets have become increasingly important. Russia and Japan have grown 275% and 117% respectively from 2000 to 2006. The main customers for Colombian flowers during the period 2001-2007 can be seen in table 5.12. The tendency has not changed dramatically in the latest years:

Country	Position		Market share		Growth (%)
	2001	2007	2001	2007	2001- 2007
USA	1	1	79%	80.50%	62%
Russia	5	2	2%	3.63%	275%
UK	2	3	5%	3.62%	20%
Japan	7	4	1%	2.51%	117%
Canada	3	5	2%	1.77%	49%
Spain	4	6	2%	1.70%	46%
Holland	6	7	1%	1.39%	50%
Germany	8	8	1%	0.78%	95%
Subtotal top 8			**94%**	**99%**	**65%**
World			**100%**	**100%**	**58%**

Table 5.12. Colombian flower imports by main destination markets

Source. Adapted from (Castellanos Domínguez et al., 2010, p. 47)

The fresh-cut flowers production chain is customer driven and adapts its practices, production, logistics and technology to the requirements of the clients. Since its inception the chain has replicated the Dutch model of production, importing practices, technology, and seeds. Colombia is a follower, not a pioneer, in the flower global production chain. It is easy to understand why the Dutch model for the production and merchandising of flowers is successful. There is important support from the government for the development of the sector, both in terms of standards and organisations such as the KCB (Kwaliteits Controle Bureau) and Naktuinbouw (Netherlands Inspection Service for Horticulture) that ensure compliance with EU quality standards, and collaboration from the Ministry of Agriculture, Nature and Food Quality for research in every part of the value chain of the industry. Besides the governmental support, the producers work jointly as a block and have direct collaboration with Wageningen University, the VHL University of Applied Sciences, and specialised research centres (Castellanos Domínguez et al., 2010). This has allowed the Dutch flower industry to be at the forefront of innovation in the development of new breeds with specific characteristics and in everything concerning the logistics of the chain.

5.4.3. Sectoral Organisations

Asocolflores is the Colombian Association of Flower Exporters and represents nearly 75% of the producers. It was created in 1973 to support the nascent flowers industry in the country. The association has focused its action on the creation of effective mechanisms for promoting and supporting logistics, research, and marketing to penetrate international target markets for Colombian floriculture. In order to be part of the association, flower producers have to pay a membership fee in accordance with their annual production. Up to 2009, there were 272 companies as part of Asocolflores, most of them located in the Savannah of Bogota. Since 95% of the flowers production is exported, the association has focused its attention on representing the industry internationally, so it is a member of the most important flower associations in the world to keep Colombian firms updated with customer expectations and the latest innovation in the sector. The lobby function is very important for the associates (Asocolflores, 2010).

The association has a participatory government system where all the associates have the right to nominate members for chairs of the board. However, the number and importance of chairs is determined by the amount of the hectares cultivated by the firm. Thus, small producers are unlikely to have a significant position and support within the board. As Fabiola Valcárcel, scientific advisor for the flowers sector with 25 years of experience working with large and medium flower companies expresses:

> The hierarchy in Asocolflores is determined by the area, by the size of the company. If you are a large company, then you can have a chair in Ceniflores. How big are you? Then you can be the president of the board. If you are a small producer you can only be a member of the board. So it is said that the system is pluralistic and democratic because there is representation of all producers, but these have 10 chairs, these have 3, and these have 1. Small producers do not have real participation in the decisions of the association. (Fabiola Valcárcel, personal communication, January 16th, 2013)

After the financial crisis that the sector suffered because of the revaluation of the Colombian peso and the negotiation power held by the customers over the Colombian flower exports, Asocolflores lost important members who had paid high membership fees. From 2010 onwards the association lost influence with the government and the main international clients. Since there is not an auction system for setting the price of flowers in the USA, prices are set mostly by customers that have higher negotiation power, since there are many providers offering the same product. Competition between flower companies is based on transportation and distribution logistics, volume, and price. In this sense, Asocolflores has been losing its bargaining power to represent the entire sector and achieve better negotiation conditions. Firms are also very wary of their customers, so do not reveal who they are, and do not let anyone approach them because the competence is fierce and most of the companies depend on the loyalty of their customers. These factors added to the financial stress that firms have faced have caused the voluntary departure of several associates. Flower growers from the Savannah of Bogotá and Antioquia, started to call Asocolflores, *the club*, in the sense of a social club, since they could not perceive the benefits of being part of the association (Head of a large Colombian flower company, personal communication, September 7, 2013; Fabiola Valcárcel, personal communication, January 16th, 2013).

Besides Asocolflores, there are other small associations such as the Association of west central flower growers, Colfloras; the Colombian federation of tropical exotic flower and foliage producers, Fedecolflorex; *Corporación parque de las Heliconias*; Tulúa Association; *Flora Tropical* and the Association of Sevilla (Valle) producers. These are all small flower growers associations focused on the production of exotic flowers and foliage for bouquets. These associations work separately and all together do not exceed 480 planted hectares (See table 5.13).

Department	Number of Producers	Total hectares	Heliconias	Foliage	Other flowers
Cauca Valley	141	289.4	270.6	14.8	4
Risaralda	56	83	33.5	45.06	4.5
Caldas	6	36.4	16.9	14.71	4.8
Quindío	56	62	44.9	17.08	0
Total Region	**259**	**470.8**	**365.9**	**91.65**	**13.3**
% Over the total hectares			**77.7%**	**19.5%**	**2.8%**

Table 5.13. Distribution of flowers plantations in the Colombian west central region

Source. Adapted from (Díaz M, 2006)

The largest association of the aforementioned is Colfloras. It was created in 2001 to provide technical assistance, research, training and help in the commercialization of flower producers in the coffee zone and north part of the Cauca Valley Department. The association had initially 23 members that traded around 47 flowers and foliage species with more than 123 varieties (Ocampo García & Osorio Franco, 2007). These flower growers concentrate their production in exotic varieties, such as the Heliconia flowers and a wide range of foliage for bouquets. Up to 2007 there was an important growth of this business branch having more than 120 hectares cultivated, 150 flower producers as part of Colflora and exports above USD$1.5 million. The main destinations for exports are USA, Spain, UK and Italy (DNP, 2007).

5.4.3.1. Ceniflores

Ceniflores is the youngest agricultural research centre in the country. It was founded in 2004 as the research centre associated to Asocolflores. Before the creation of Ceniflores, Asocolflores had a technical division in operation since 1976, which was the predecessor of the centre. This technical division was created as part of the growing need of flower growers to have solutions for recurrent diseases and pests in the plantations. From the beginning, this technical division was supported by research groups based in universities and by international experts that were hired according to specific problems that Colombian floriculture had at the moment (Edison Valencia, personal communication, December 15, 2012). Most of the diseases found in the plantations came with the rootstocks imported from international breeders. In the 1960s the Colombian Institute of Agriculture (ICA) did not have standardised procedures for imported biological material, so in a joint effort with Asocolflores, regulation and standards started to be defined. During this first stage, the flower farms received technical support of specialists from Israel, since there were no local capabilities to deal with common phytosanitary problems (Arbeláez et al., 2012). The learning curve began to develop, but always with a heavy dependence on external knowledge and technology.

Ceniflores provides services to Asocolflores associates and works as a virtual Technology Development Centre (CDT), which means that the centre does not perform research directly and does not have physical capacity installed. Ceniflores acts as knowledge broker or bridge institution between the firms' needs and research organisations. In this sense, the centre has important alliances with local universities, international research groups and other agriculture research centres (Edison Valencia, personal communication, December 15th, 2012). There are three research programs developed by the centre: technological upgrade, crop protection and soil and substrates. Each program has several research lines that are developed with the support of Colombian universities that provide the human and physical resources to perform the investigations. The key partners are *Universidad Nacional*, *Universidad Militar Nueva Granada, Universidad Jorge Tadeo Lozano*, and *Universidad de la Sabana*. These mainly support the farms located in the Savannah of Bogota and Cundinamarca department. For the Antioquia region, there is collaboration with *Universidad de Antioquia*.

Ceniflores is funded partially by Asocolflores, but one of the major motivations for migrating to a research centre was having access to different funding sources. Asocolflores decided in 2004 to strengthen the technical service, but did not want to invest more financial resources to create a research centre, so given the possibility within the Ministry of Agriculture and Rural Development to have virtual research centres to support production chains, this was a feasible strategy. In words of Valcárcel:

> I was part of the technical committee before the creation of Ceniflores. I was there when Ceniflores was founded and then this committee became Ceniflores' board. We changed the title, but we just kept doing the same as we did before. What we did was to formalise our status to obtain state resources…We were always struggling to develop in-house research, but Asocolflores' board always held the position of not even having a microscope of its own. They always wanted to have partners with the infrastructure and training to do research and deliver results. And that is what they have done. (Fabiola Valcárcel, personal communication, January 16th, 2013)

Before the creation of Ceniflores, most of the technical and logistic problems were solved directly by the firms. This responded partially to the secrecy and lack of trust between firms in the sub-sector, but also because of the lack of a central organisation to collect producers' needs and to create common sectorial solutions. Then, large and medium companies had their own research groups or technical departments to investigate particular problems with the crops. However, the main interest of the firms' administrators was to maximise profits and research to face common pest management and productivity problems. Thus, it was imperative to create a stronger instance within Asocolflores to support producers' needs, and this is how Ceniflores was born. This is how the decision of having a virtual research centre was approved. Referring to this process, Dr. Fernando Cantor, Dean of the School of Basic and Applied Sciences of *Universidad Militar Nueva Granada*, says:

> They decided to form a virtual research centre, which meant that they had only one office to make alliances with research centres and universities. Each one would receive support depending on its participation to support the needs of the sector. We were invited to those early meetings. All actors were defining the priority of the industry research agenda, and that was when the trouble started. Everyone was trying to impose their own necessities, and then there was use of all sort of influences below the table. Finally they [Asocolflores] defined an agenda, and that agenda is focused on traditional themes like transport, roads, the airports, the planes, and little on the technical part [pest control management, crops and

> soils studies, substrates, etc]. (Fernando Cantor, personal communication, January 22nd, 2013)

From the constitution of Ceniflores until 2013, the centre has not standardised procedures to collect research needs from the sector, transfer knowledge to all Asocolflores' associates, or have regular mechanisms for K&T appropriation and validation with producers. This has caused discontent between the firms because they feel they are not represented within the system and their needs are not satisfied. This situation has encouraged secrecy and isolated efforts from producers to find solution to common problems by themselves. In this aspect, the role of Ceniflores could be improved to have a higher impact with its research products. As mentioned before, Asocolflores has lost representativeness of the sector because the associates do not perceive direct benefits to remain part of the association. There are complaints about the role of Ceniflores and the impact of the research projects funded by the centre. As noted by the general manager of a flowers company in the department of Antioquia:

> I am no longer affiliated with Asocolflores. That represents to my company 200 million pesos a year [USD$100,000 approx.]. I cannot pay 200 million to not receive anything. I paid it someday, but I left. They don't accompany us, they don't visit us, they don't consult us about what they are doing there. Then we do our own research. I cannot pay that sum to be part of a club. (General Manager medium flower firm, personal communication, January 18th, 2013)

5.4.4. Institutional Setting

The flowers production chain, as a sub-sector within the agriculture sector, is regulated by the agro-industrial institutional framework. However, there are some environmental regulations that have had an important impact on the sector, particularly with respect to environmental standards. The main normativity impacting the chain can be seen in table 5.14:

Regulation	Description
Decree 1843 of 1991	Legal regulations for the use and manipulation of pesticides
Law 101 of 1993	General law of agricultural and fishery development
Law 306 of 1996	Creation of the agricultural solidarity fund
Resolution 1068 of 1996	Agricultural inputs handbook creation

Resolution 1023 of 1997	Regulates the distribution, marketing and sales of agricultural inputs
Law 373 of 1997	Sets the program for the efficient use and conservation of water
Resolution 1367 of 2000	Authorization procedures for import and export of biological diversity specimens
Law 822 of 2003	Regulates the production and commercialization of generic agrochemicals

Table 5.14. Main legal institutional framework regulating the flowers production – chain.

Source. Based on (Castellanos Domínguez et al., 2010, p. 92)

In terms of the macro external conditions regulating the international market and benefiting the Colombian fresh-cut flowers sub-sector, there are some important international agreements with the main customers of Colombian floriculture. The Andean Trade Promotion and Drug Eradication Act (APTDEA) is an agreement signed between the United States of America and Colombia, Ecuador, Peru and Bolivia to allow free trade for 6,500 products (including flowers) to enter the United States. Before the agreement was in force, the average import duty for flowers was 6%. This gives Colombia a preferential place against its competitors in this market. As already noted, the European Union countries are one of the most important consumers of Colombian flowers. Being the second region (overall) with the highest import levels, the Generalised System of Preferences for trading with certain developing economies, where Colombia is included, has meant an important incentive and expansion of this market for the Colombian firms. The aim of the preferences is to promote sustainable social, economic and environmental development, in addition to promoting good governance and fighting against drugs. Concerning the Russian market (which had an extraordinary growth of 275% between 2001 and 2007), there is a correlation between the Colombian flowers exports to this country and the enacted Resolution 414 of 2000, where a list of products coming from developing countries have preferential tariff conditions. This agreement is known as the Russian Generalised System of Preferences. Thanks to this agreement, Colombian flowers have a zero entrance tariff to the Russian Federation. Finally, the program known as *Plan Vallejo* allows Colombian firms to import raw materials or supplies used in the production of export goods with total or partial tax exemption from customs duties (Castellanos Domínguez et al., 2010).

These commercial agreements have positively impacted the growth of the sector and have allowed the survival of many flowers firms that depend almost exclusively on the international market.

In 2007 the Program for Rural Development with equity (DRE – for its acronym in Spanish) was created. The aim of this program has been to improve the competitiveness and productivity of the agriculture sector promoting at the same time a sustained social development. For that purpose, the central government, through the Ministry of Agriculture and Rural Development, assigns 500 thousand millions of pesos (approximately US$ 25 million) annually to support small and medium rural producers. One of the instruments of this program is the Incentive for Rural Capitalisation (ICR – for its acronym in Spanish). Through this incentive, producers can obtain up to 40% of an investment for renovation of plantations; land improvements and irrigation systems; crop biotechnology development; production infrastructure; or even machinery and specialised equipment for agriculture production.[152] The fresh-cut flowers sub-sector has used this incentive along with the *sanitary incentive* and the *program for the revenues protection for exporting producers*. The former was given from 2006 to 2010 to exporters of flowers and foliage, plantains, bananas and palm for supporting the sanitary control and management of plagues and diseases according to a set budget for every year. All producers registered in the Colombian Institute of Agriculture (ICA), with a Certification for integrated pest management (IPM) given by ICA and with exports equal or superior to USD$1,000 could claim this incentive. In 2008 the MADR gave 104,000 million of pesos (approximately USD$52 million) to the flowers and foliage sub-sector to promote appropriate sanitary conditions in the plantations. The latter consists of an economic support to counterbalance fluctuations in the exchange rate through the acquisition of coverage mechanisms like European put options[153] (Ministerio de Agricultura y Desarrollo Rural, 2009; Reina et al., 2008).

[152] More information about this program can be found at: https://www.minagricultura.gov.co/ministerio/programas-y-proyectos/Paginas/Programa-Desarrollo-Rural-con-Equidad-DRE.aspx

[153] An option contract in which the holder has the right, but not the obligation, to sell some underlying asset at an agreed-upon price on or before the expiration date of the contract, regardless of the prevailing market price of the underlying asset. One buys a put option if one believes the price for the

Between 2005 and 2009 the flowers sector received 664,258 million of pesos (approximately USD$3,300 million) in incentives from the Colombian government. Besides the IRC, sanitary incentive and the program for the revenues protection for exporting producers, one of the most important incentives given to the Colombian flower industry during 2005 and 2006 was the *incentive for exchange hedging* (ICC, for its acronym in Spanish). Given the persistent decline of the US dollar because of Colombian peso appreciation from the end of 2003, and steadily during 2004, the government decided to support agriculture producers with high exports and low production inputs imports, a subsidy of 200 pesos for each dollar that enters the financial system from their international sales, up to the FOB value of the total production exported in 2004 (DNP, 2004). During 2005 fresh-cut flowers producers received 86,080 million of pesos (approximately USD$43 million) and 3,546 million of pesos (approximately USD$1.7 million) during 2006. This incentive was suspended and changed from 2007 onwards for the revenues protection program with resources coming from the MADR and managed by FINAGRO. This program differentiates the benefits according the producer company size and has a daily, weekly and monthly maximum limit to cover for medium and large producers. Flower growers have also benefited from special credit lines.[154] Only during 2007 and 2008, the industry received 270,417 million of pesos (approximately USD$143 million) through: a preferential credit line for flowers, a special credit line for exporters, a special credit line for the rainy season, and a special program *Agro Ingreso Seguro* (AIS) (Castellanos Domínguez et al., 2010).

This inventory of fiscal and research incentives shows that the sector has not been neglected by the central government. On the contrary, it has received more perks than many agricultural production chains. However, subsidies and special credit lines have not been enough for the firms. This raises doubts about the efficiency of the

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underlying asset will fall by the end of the contract. If the price does fall, the holder may buy and resell the underlying asset for a profit. If the price does not fall, the option expires and the holder's loss is limited to the price of buying the contract (Farlex Financial Dictionary, Retrieved from: http://financial-dictionary.thefreedictionary.com/European+put+option, February 11, 2015).

[154] In 2006, Banco Agrario, state financial institution for supporting the agriculture sector, provided subsides of up to 90% of raw material for flower firms. Also, a special line for exporters supported by the Ministry of Agriculture gave credits for a value of $46,630 millions of Colombian pesos in 2006. More special credit lines have been available from Banco Agrario, Finagro, Bancoldex and the Ministry of Agriculture.

sector and its viability without government intervention. The question remains about what can make the chain more competitive and what strategies can be used to reduce the labour dependency of the population working in the flower farms, mainly in the Savannah of Bogotá and several municipalities in the department of Cundinamarca. Contraction of the sector appears to be the tendency. Strategic alliances and merger of firms to be more competitive is one pathway that has been in development during the sectoral crisis (Reina et al., 2008; Salom Serna & Sepúlveda Calderón, 2012; Tenjo G et al., 2006). However, less is said about the need of the sector to develop research capabilities in order to lessen the high dependency on international breeders coming mainly from the Netherlands. Competition solely through mass production, small incremental innovations, and price reductions will not bring much higher profits for the sector. Cheap labour, lower cost of land and revaluation of the US dollar are not sufficient conditions to keep the sub-sector competitive. Referring to this topic Hernán Jaramillo, dean of School of Economics of *Universidad del Rosario* and former sub-director of Colciencias and Corpoica, says:

> It is inconceivable to pay ROI per exported flower. Why? Because it was a sector that always lived protected from everything. Subsidised credit. Part of the special government program *Agro Ingreso Seguro*. Subsidy for the exchange rate revaluation. Then, do you think that a flower grower will make a risk loan for innovation? Never! Then there is a dynamic inconsistency of public policy. If you want a sector to be more dynamic, do not subsidise it. (Hernán Jaramillo, personal communication, May 23rd, 2012)

There are doubts about the viability of the sector without State aids. Having the sector highly protected has caused market imperfections that have kept an artificial balance between supply and demand. It has also hindered a proactive attitude from firms to look for innovative strategies to continue being competitive in the international market reducing direct and indirect costs and being innovative in the products offered. After all, this is not the only industrial sector with high export reliance, which means that the public subsidies and preferential treatment cannot be the main source for keeping the sector alive. We believe that it is necessary to protect sectors in their infancy, especially those perceived as strategic at the national level, but excessive protection can hinder competitiveness instead of encourage it.

5.4.5. Knowledge and technology transfer, adoption, and validation processes

Domestic research for the flowers sector is still scarce and has not had a long-trajectory of development. As it was explained in the first section, the sector was developed by a group of private investors that imported knowledge and technology from the United States and the Netherlands to develop the sector in Colombia, given good climatic and soil conditions, land availability, cheap labour, and a relaxed regulatory framework. It was with the generation of new regulations and customer requirements that internal capabilities started to build-up, mainly within the firms controlling the production. Most of the research developed in the industry is done by transnational firms and imported by those companies, the producers associations or directly by the producers. The knowledge and technology generation by local actors is mainly concerned with trials of technologies developed abroad.

> There are few national and multinational companies doing research [in flowers] in Colombia. Floramérica, a producer and exporter of Colombian flowers, began its research program in 1982. Hoechst, a German multinational, started its research activities in Colombia on agrochemicals and seeds in 1985. Hoechst merged with Schering in 1997 to form Agrevo. Cargill, an American multinational, began testing sorghum hybrids locally in 1987 but their research activities in Colombia were taken over by Monsanto in 1998. (N. M. Beintema, L. J. Romano, & P. G. Pardey, 2000, p. 13)

The breeding of new flower varieties is focused on two main aspects: the external appearance dominated by colour and size; and the resistance to diseases, which also impacts the longevity of the plant. The R&D process for these developments is performed by foreign countries. This represents a huge weakness for the sector (Castellanos Domínguez et al., 2010).

> Even though Colombia is positioned as the largest exporter of carnations in the world, yet the progress made in the development of new improved varieties of carnations is almost nil. The plant material is imported from leading countries in developing biotechnology and breeding techniques such as Italy, Israel and the Netherlands. (Castellanos Domínguez et al., 2010, p. 83)

The Colombian fresh flower industry has remained a follower in developing knowledge and technology for the sector. There is a total dependency on leading flower-breed research countries for the production of specific flower varieties. Since there has not been a local development of new varieties, customers' preferences are fulfilled by imported varieties grown in Colombian territory but without any strategic differentiation in the final product.

> Although successful in mass production—more than 80% of the Colombian exports consist of roses, carnations, and pompons (Asocolflores, 1998)—other countries, with the Netherlands in a leading position, control the research and development as well as the promotion of new trends in the consumer markets. (Meier, 1999, p. 276)

To compete, the chain approach has been to mobilise towards mass production and adaptation to customer requirements. However, the producers are powerless in terms of radical innovation in their products. There is no research towards the development of original, new flower varieties to offer in the marketplace. The improved production processes within the chain have achieved better quality standards of the flower and longer vase life, which are important aspects for the final customer, but since there is not a radical new product to offer the market, the firms keep paying royalties for the use of specific varieties and are subject to the world market prices. In the U.S. case, they are subject to the price paid by the customer and in the European case they are subject to the prices of Dutch auctions. About this topic Dr. Fernando Chaparro, former director of Colciencias and Corpoica, says:

> It is myopia of certain business leaders in specific production chains. For example, one very successful case is flowers. A success story, impressive, but with an Achilles heel, producers did not invest in basic research, contrary to the Dutch case. And Holland, without the genetic resources that we do have, is selling seeds of sophisticated flowers to us. I don't mean the flowers that are sold here [Colombia] for mother's day, no, I mean sophisticated flowers that have certain characteristics according to specific market specifications. The Dutch master the industry. The flower market in Amsterdam keeps on giving the worldwide standard. (Fernando Chaparro, personal communication, May 22nd, 2012)

Some farms have their own laboratory for the production of fertilizers and pesticides based on botanical or biological alternatives, however most of the companies rely on agrochemicals for their plantations care, leaving to their technical staff the role of identifying the mixture and quantity of chemical products needed. These agrochemical products are provided by a group of companies that import most of these products, either chemical or biological, from countries such as the USA, Germany and China. This has turned into a problem for the agriculture sector in general, since 46.6% of the agrochemical products are classified as extremely hazardous (Level 1A) or highly hazardous (Level 1B)[155]. The flowers sub-sector is one of the sectors that consumes more of these kinds of products (Castellanos Domínguez et al., 2010).

Since the business was created in Colombia, in the sense that it was not a traditional agriculture crop and it was not commercialised before the 1960s, the evolution in terms of construction, application and validation of knowledge was promoted by the producers themselves. They started to face problems in the production chain that were solved in so far as the industry was growing. Phytosanitary problems like lack of nutrients in the soil for flowers cultivation; plant diseases and quality of water were just some of the difficulties that the growers had to cope with. Floramérica, mentioned before, was a pioneer in the flowers industry in Colombia and as such, it was the first company that had a research area dedicated to find feasible solutions for the oncoming problems. Knowledge diffused rapidly among companies, which started to copy the techniques used by Floramérica.

> On one occasion, the United Kingdom stopped admitting flowers from Floramérica because worms were found in the shipment boxes, a direct consequence of the contaminated water in which the flowers were packed. To solve this problem, Cheever and other exporters learned about dry packing. Flores de la Sabana started employing this method, and knowledge of its use spread rapidly (Arbeláez et al., 2012, p. 81).

[155] The World Health Organisation has defined a toxicological classification of pesticides to distinguish between the more and the less hazardous forms based on acute risk to human health (that is the risk of single or multiple exposures over a relatively short period of time). There are five groups: 1A-extremely hazardous; 1B-highly hazardous; 2-moderately hazardous; 3-slightly hazardous; 4-Normaly not hazardous.

So the starting model for knowledge and technology transfer was that of imitation. Turnover among farms, knowledge diffused by agrochemical providers for the treatment of diseases and higher productivity in-field, and the advice given by international experts directly to the firms, were the major sources of innovation in the early stages of the industry development. This tendency has prevailed over the years. Now the flower firms are better organised and have changed their distribution channels so they can get first-hand requirements from the customers. However, international breeders keep as the R&D leaders in the flower industry. Colombian firms import rootstocks according their customer requirements and pay royalties for the commercial use of the varieties exported (Edison Valencia, personal communication, December 15, 2012). Colombian firms are followers also in the consumption tendencies of the final customers that absorb the trends from European countries. Breeders and agrochemical companies provide the cuttings and technical assistance (TA) about the best practices for growing each variety. These transnational companies have a bidirectional relationship with Colombian and international research groups to transmit growers' needs to the research centres and to provide support to local research initiatives. The knowledge and technology generation and transfer pattern followed by the production chain can be seen in figure 5.29:

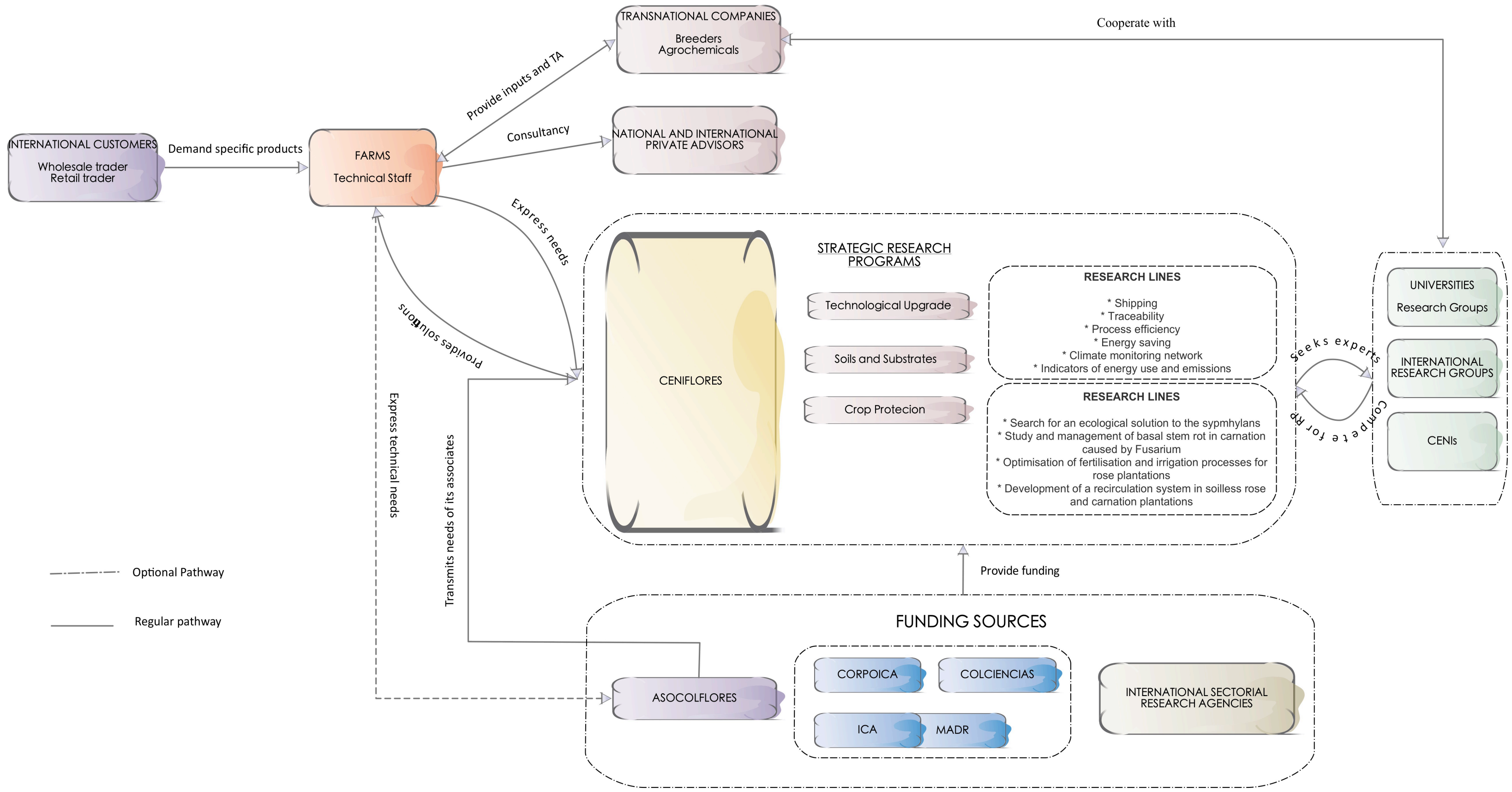

Figure 5.29. Knowledge and technology generation and transfer pattern in the fresh flowers production chain

Source. Made by the author using primary and secondary information.

It has been explored in the previous section how the Colombian flower firms have had a high dependency on foreign knowledge and technology from the creation of the industry until now. The flower companies depend on breeders that provide the rootstocks and also specific agrochemicals. The learning curve has grown and K&T have been adapted to the climatic and environmental local characteristics. In this sense, once the customers express their product requirements, the firms that grow, harvest, do the post-harvest process of classification and packaging (in boxes or design and composition of bouquets), prepare their production in accordance. Most of the firms have their regular clients so they have certain stability of the production size and characteristics they need to have for every production cycle (Sepúlveda Calderón, 2014). When there are problems in the plantations related with phytosanitary conditions or when an optimisation of resources is needed to maintain the profit or to meet clients' requirements (like environmental and social sustainable practices or a specific kind of flower or bouquet), firms contact breeders to get specific variety specifications; international advisors to have field visits or offer remote advice; or Ceniflores to develop bigger research projects that can be useful for the chain. We can see here how the production chain follows patterns of learning economy meeting demand and supply requirements downstream in terms of appropriation and adaptation of knowledge for local production and upstream in terms of feedback on the imported rootstocks and ways to improve them.

Ceniflores does not have a standard periodical procedure to have communication with the technical staff within the firms. The approach followed is that of action-research where through direct communication with the firms, producers manifest their needs and Ceniflores find the human and financial resources to structure a research project. Sometimes there are special workshops with the firms in their farms, this is what the research and projects coordinator in Ceniflores told us (Alfonso Alvarado, personal communication, February 11th, 2015). There is also an annual seminar sponsored by Asocolfores where research projects are socialised in a two-days event, and where national and international experts are invited to present the latest trends in: production systems for ornamental substrates, leachate recirculation, knowledge and management for phytosanitary problems, development of biological control strategies, adapting technologies for flower production systems, improving technical and logistical processes, and the establishment of a climate monitoring network. Ceniflores has a research journal where scientific papers related to common problems of Colombian floriculture are published, but this has not always been a periodical journal.

There are on-going research projects in three strategic areas for the flowers industry: technological upgrade in everything related to machinery and techniques in field and packing and transport techniques; soils and substrates in terms of plant nutrition, integrated systems of pest management, irrigation and fertilization; and crop protection with special use of biological control (Ceniflores, 2014). Then, there are two mechanisms to establish relations with the research groups: Ceniflores approach the researcher directly in the universities with an invitation letter to participate in the projects, or the research groups present projects of interest to the guild to be funded by Ceniflores itself or in association with research funding bodies. Once the projects are structured, they are presented to Ceniflores' board for their approval and to national entities such as Colciencias, the Ministry of Agriculture and Rural Development, Corpoica, ICA, or other international agriculture research bodies to find physical or financial resource cooperation. Also, there is cooperation with other research centres in the country. Since Ceniflores is the youngest CENI, and is a virtual one, it receives advice from other research centres like Cenicaña, Cenicafé and Cenipalma. The collaboration is both about internal procedures and functioning of the centre and cooperation for specific research projects in cases where common laboratories can be used or expertise applicable to the flowers plantations can be gained (Edison Valencia, personal communication, December 15, 2012). For example, Ceniflores uses *Universidad Militar Nueva Granda* labs and the flowers guild has played a part in the development and changes of the biology undergraduate program of this university. Referring to the relationship with Ceniflores, Dr. Fernando Cantor, Dean of the School of Basic and Applied Sciences of the aforementioned university, says:

> Ceniflores knows our profile and knows our line of work. They have seen our results, so when they need to discuss a research project for the sector, they call us. We have presented projects to them also and we have developed close

> research ties. (Fernando Cantor, personal communication, January 22nd, 2013)

Innovation in the Colombian chain can be seen in two levels: product and process. Innovation in product is done through technical treatments to the flower plantations to prevent and control diseases and to prolong the flower vase life when it reaches the final consumer. There is little room for improving the characteristics of the flowers themselves since the rootstocks are imported and come already with specific characteristics that are guaranteed by the breeders and are protected by plant breeders' rights. This is clearly outlined by Edison Valencia, executive director of Ceniflores 2012 – 2014:

> There are some small local developments in genetic improvement for some varieties, but most of the genetic improvement is done through cooperation with breeders, or with companies that have their headquarters in U.S., the Netherlands, or France. R&D is performed in other countries and then we sign intellectual property and technology cooperation agreements with the breeders. (Edison Valencia, personal communication, December 15th, 2012)

On the other hand, actors in the chain have developed innovative procedures and logistics in the plantation techniques, cutting, packaging, transporting, and distribution channels. Higher productivity per hectare, through the use of effective cultivation techniques in soil or flowerbeds has been fundamental to keep the business viable. The strategy has been to keep the same production in tons of cut flowers but using less land and labour. Also, it has been important to shorten the growth cycle of the flowers, so more crops can be produced per year. This aspect is highlighted by one of the general directors of a large flower company, included as a case study in Salom and Sepúlveda's study:

> The situation with carnations is different. The volume has remained stable despite the increase in productivity. In 2003 there were between 1500 and 1600 hectares planted in total; today there are about 800. This promotes price competitiveness. (Salom Serna & Sepúlveda Calderón, 2012, p. 209)

The aim has been to produce more with the same resources or with fewer resources. This is where firms irrespective of their size, have dedicated their research resources. For some large companies this has been achieved through buying plantations of other growers, besides their own production. This strategy allows them to have direct contact with hyper and supermarkets since they have the volume and variety of flowers to export finished bouquets. In the case of medium and small enterprises, the strategy has been to merge or act as a block to negotiate with international clients. However, given the high levels of industrial secrecy in the chain, there is not much vertical and horizontal integration, and it is worse for bilateral horizontal integration between firms (See table 5.8. Cooperation types).

So the research groups supporting the Colombian flowers industry can be classified within biology, chemistry, agronomy, agrochemical engineering, and related areas, to produce knowledge-focus on the planting and harvesting procedures; and groups working on management and logistics to support the post-harvest areas of the production chain. When there are research agreements between Ceniflores and international research groups, the aim has been to have intellectual property rights, or the right to use the technology exclusively for a period of time.

5.5. Conclusion

We conclude this chapter by highlighting that even examining industries within a sector, the innovation pathways and dynamics are very different and follow distinctive development patterns. It is not enough to focus the attention on the firms, particularly in cases as coffee and sugarcane where the growers are at the centre of the innovation systems. The historical and social evolution of the sectors is crucial to understand the type of networks actors build and the power and trust dynamics between them. Innovation is not only an important economic feature that needs to be study and developed. In developing countries, with an important proportion of labour absorbed by the agro-industrial sector, innovation could and should be a source to improve social conditions of poor farmers. Efforts directed towards successful insertion in global value chains with a fair distribution of profits among the growers is a social and economic imperative requirement. In the cases of coffee and sugarcane where knowledge generation and exploitation models have been built over the years, we could find positive results in the evolution of the industries. The initial motivation from the growers to organise themselves and form a producers association have been a key factor to remain viable and innovative.

6. CROSS-SECTORAL ANALYSIS: COMPARISSON OF THE SUB-SECTORAL CASE STUDIES

6.1. Introduction

So far we have studied the Colombian National System of Innovation and the Agro-industrial System of innovation following a top-down approach guided by social, political and economic institutions heavily formalised in the cultural setting of the country. The next step was to study how innovation actually happens and what factors affect it in chosen sub-sectors or production chains. Following the sectoral systems of innovation approach (SSI) to study the sub-sectors and a complex adaptive system understanding, we analysed the industrial setting, technological evolution and dynamic complementarities; the type and structure of interactions among firms and non-firms; the role of demand in each production chain; how sectoral organisations have shaped the evolution and dynamics of the chains; what are the institutional settings, both formal and informal, of each sub-sector and how they have conditioned their innovation dynamics; and finally we studied the way that knowledge and technology are transferred, adopted, and validated in each of the case studies. This analysis allowed us to see the systems of innovation from a bottom-up approach, mixing codified information with perceptions of key actors of each case study. In this section, we analyse the three sub-sectoral case studies: coffee, flower, and sugar cane, comparing how their structural and functional setting have been shaped by the coevolution of institutions, networks, knowledge, technology, and demand.

K.J. Joseph recalls that is important to study sectoral systems in developing countries since the innovation patterns in these economies are different than those observed in countries of the so-called North: "…the challenge of innovation scholars dealing with sectoral systems in developing countries is therefore to highlight the unique characteristics in the South, so that they can contribute towards informed policy making." (Joseph, 2009, p. 184). In this sense, our analysis is novel not only because of the analysis of the particular characteristics of the Colombian Agro-industrial innovation system, but also because through a deeper examination we discovered in our individual cases that innovation is affected by different factors within branches of the same sector. It is not enough to observe complex sectors as a unit of study within national or regional innovation systems. In a sector such as agriculture that has different sub-sectors with diverse economic and social behaviours, it is necessary to have a nuance approach to understand the dynamics of innovation. This study highlights some successful and challenging practices, models, and patterns followed by these particular productive chains that can serve as examples for other sectors or production chains. It ultimately sheds light on key factors of innovative trajectories constrained by the evolution of industries, structural transformation, dynamic competition, technological specialisation, and knowledge and learning properties. By complementing the macro study of the Colombian NSI with our sub-sectoral studies, we portray a comprehensive view of innovation dynamics, identifying the factors that support and hinder national and sectoral mechanisms towards firms' competitiveness.

6.2. Sectors structure, market and non-market interactions, demand

We studied and analysed three sub-sectors within the Agro-industrial sectoral system of innovation. Some of the reasons why we chose these three production chains out of the 37 registered in the Ministry of Agriculture and Rural development (MADR) is because these chains exemplify successful cases within the Colombian economy, represent products for which the country is recognised internationally, and have an associated research centre or CENI. We wanted to investigate the differential factors which have positioned these industries in the domestic and international markets. Now that we have presented a separate analysis of each chain, we will develop a comparative framework guided by the sectoral systems of innovation approach. In this section, we will discuss the industries structure as part of the Agro-industrial sector and as part of the Colombian economy.

Table 6.1. presents some structural features of the sub-sectors that are important to size the industries within the agriculture and national context. These factors are important to understand the way in which the chains operate and their strategies to

remain competitive in the market. Since innovation is the ultimate aspect we study, we see these characteristics as dynamic complementarities that contribute to the coevolution of actors, knowledge, demand and institutions. As Montobbio outlines it: “In fact, sectors not only display differences in the technological domain but also in economic variables and in their relationships.” (Montobbio, 2004, p. 43)

Production Chain	Geographical Distribution	Area Cultivated	Producers Characterisation	Product Variety	% GDP	Market Composition*	Unions And Associations	S&T Funding Sources	Governance And Governability
COFFEE	Dispersed in different regions, however the central-west region is the strongest one in terms of production volume and use of modern practices.	Up to 2013, 974,000 hectares.	563 thousand families representing up to 96% of the production with plantations below 5 hectares.	Green coffee, roast and milled coffee. Juan Valdez coffee brand. Soluble coffee. Coffee shops.	Up to 2013, 8.05% of Agriculture GDP and 0.53% of national GDP.	92% for exports, 8% for domestic market.	Strong National Federation of Coffee Growers founded in 1927.	Mandatory fee for associates to the National Federation of Coffee Growers. Growers pay a percentage of the final price they get for every pound of coffee exported to fund Cenicafé.	Strong vertical cooperation. The FNC controls the industry and has a hierarchical representative system.
FLOWERS	Mainly focalised in the Savannah of Bogota (79%), followed by Antioquia (17%), and few plantations in the Coffee region, Cauca Valley, and Nariño (4%).	Up to 2013, 6,783 hectares.	600 firms, 55% small, 30% medium, 15% large. However nearly 60% of total exports are concentrated in the large firms.	Fresh-cut flowers. Mainly roses and carnations Foliage. Finished bouquets.	Up to 2009, 6.6% of Agriculture GDP an 0.45% of national GDP.	95% for exports, 5% for domestic market.	Weak Asocolflores founded in 1973.	Funded mainly privately by each company. Those who are part of Asocolflores pay a fee to be part of the association and part of those resources go to fund Ceniflores.	Weak types of cooperation. Vertical backwards integration. Low degree of coordination. Asocolflores represents mostly large flower firms.

SUGAR CANE	Sugarcane for production of sugar and biofuels is concentrated in the Cauca Valley. Sugarcane used for panela production is distributed in 6 different regions of the country.	Up to 2013, 225,560 hectares.	14 sugar mills and more than 2,700 sugarcane growers. The growers own 76% of the production land and the remaining 24% belongs to the sugar mills.	Raw sugar, white sugar, confectionery, spirits, biofuels.	Up to 2007, 0.57% of national GDP and 0.86% of industrial GDP.	40% for exports, 60% for the domestic market.	Strong Asocaña founded in 1959.	Voluntary fee paid to Asocaña in accordance with the sugarcane harvested. This resources are used to fund Cenicaña.	Strong bilateral and multilateral cooperation. However, power is centralised by Asocaña and the sugar mills.

Table 6.1. Structural comparison between the coffee, flowers, and sugarcane production chains.

*Average from 2000 to 2009
Source. Information compiled by the author.

It can be seen in table 6.1. that there are main differences in size, characterisation of producers, market composition, demand type, and institutional setting. Coffee is the sector that has the largest size in cultivated area and number of producers. It is also the sector with the longest tradition in the Colombian agriculture sector, being the most important export product from the beginning of the 20th century until 1990, when oil and oil by-products had a faster growth and greater international demand. This long trajectory allowed the sector to be highly integrated combining national economic policies with special tailor-made incentives to protect and support the growers. In order to remain competitive and to organise the growers, the National Federation of Coffee Growers (FNC[156]) was founded in 1927, being the first producers association in the country. As commercial production was increasing and there were more demanding customers, the FNC decided to invest in research and development creating its own research centre, Cenicafé, in 1938. This was the first agriculture research centre in the country, existing even before a national agriculture research institute. The FNC has remained a strong producers association, with a strong lobby, in the national government characterised by the creation of special privileges for the guild, a market protected from the international coffee price fluctuations, and the construction of a trademark for the international market to get higher prices for the quality seal of Colombian coffee. The sector has evolved through the production of specialty coffees with the use of coffee varieties developed by Cenicafé and with special cultivation and collection techniques that influence the final taste of the coffee. This characterises the sub-sector as a special commodity niche.

The sugarcane sector is slightly younger in terms of having an organised production and modern commercialisation, since it started to have a mass production almost 40 years later than the coffee sector, however, represents the higher participation of the GDP. It was with the creation of Asocaña, the Association of Sugarcane Growers of Colombia, in 1959 that the sub-sector began an expansion process that finally allowed the country to produce its entire domestic consumption of sugar and to export to international markets. The sector actors developed a standard pricing model

[156] Federación Nacional de Cafeteros

where the price of the final product is transferred to the growers. In an attempt to increase productivity, the producers association created Cenicaña, the sugarcane research centre, mainly funded by the producers themselves through a voluntary fee. The industry works as a cluster, with highly integrated production and commercialization processes. Agglomeration of sugar and biofuels production in the same geographical area has been beneficial in building stronger firm capabilities and the effective generation and exploitation of knowledge. In terms of size, the plantations represent less than a third of the total coffee cultivated area, which makes it easier to manage the commercial and technological strategies. The existence of a strong research centre has facilitated the compilation of information for every sugarcane planted plot, or 'suerte', as the sugarcane growers call them. Cenicaña has built a strong geographical information system with meteorological, hydrological, soil information and varieties grown in each *suerte*, as well as socio-economic and commercial information of growers associated to Asocaña. These information systems and their use by the research centre have given the sector a competitive advantage having radical and incremental innovations impacting the productivity, sustainability and profitability of the cluster.

For the fresh flowers sector, the historical trajectory is different. Industrial activity began in the late 1960s through a private foreign initiative to supply the United States market with good quality, and cheap, fresh-cut flowers. From the beginning the flower sector had a clear geographical market segment to export to. This dependency on a specific market moved the chain towards a customer-driven pattern. The main producers association, Asocolflores, was created in 1973 and its aim has been to create effective mechanisms to penetrate international target markets with better prices and conditions for the Colombian flowers. However, producers do not work with each other, and are very jealous of their business models and their on-field plantation techniques. This could be partially explained by the model followed by the producers at the beginning of the industry setting, when replication of good practices from competitors led to attitudes of mistrust and secrecy amongst firms in the industry. The association has been successful in strengthening a beneficial institutional setting for the national industry in terms of law regulations and better export conditions, but it has not been sufficiently strong to promote bilateral relationships between firms for the construction of a good knowledge and technology base for the industry. At the beginning, sectoral production focused on the Savannah of Bogotá and its proximities, this helped the guild to create joint regulations and formal institutions for the sector, as well as finding cheaper and more effective ways to transport the fresh-cut flowers to their final destination. Also, the proximity of the farms to main international airports[157] has been beneficial for delivery logistics. The flower sector is not traditional, not only because it is a young sector and does not represent a staple like most of the other agriculture products, but also because it offers a luxury product for very specific markets and customers' tastes. The chain depends on imported rootstocks to grow specific flower varieties demanded by international clients. Thus, innovation is mostly developed in the logistics processes to achieve the highest possible profit for the firms. The sector established its research centre in 2004, the youngest CENI in the country, Ceniflores. This research centre has a different dynamic than Cenicafé and Cenicaña given its virtual nature, which means that it does not have a research infrastructure (researchers and installations) belonging to the centre, but acts as a bridge between the flowers firms needs and national and international research groups and centres to produce and transfer knowledge and technology.

In the coffee and sugarcane chains, growers are involved -to some extent- in the production of the final products going to the market. There are some other actors involved in later stages of the chains for the production of specialised products, also agents in charge of marketing, commercialisation and transport of the finished products, but growers have a price transfer from the finished products sales. In the flower production chain, the industrial activity is controlled by SMEs and large firms that have their own flower farms and have control over the chain from the growing stage until at least the transportation of the flowers to the port of shipment. In this case, firms hire labour to perform the growing and harvesting activities on the plantations. Since the Colombian flower industry depends on breeder companies to grow the specific varieties required by customers, it is difficult for a small grower to set up their own plantation as an independent part of the chain. Investment in

[157] Air transport is the most used for flowers delivery to their final destination.

greenhouses, fertilizers, irrigation technology, and logistics is high and therefore non-viable for small families to produce flowers themselves, which is different from the case of coffee growers. All of these factors influence the evolution and technological behaviour of the different subsectors, as Katz explains it:

> Understanding the specificity of each environment is, in fact, crucial if we are to proceed toward a richer description and interpretation of the forces underlying inter-country and inter-industry differences in technological behaviour. (Katz, 2001, p. 4)

Even being part of the Agro-industrial sector, the three sub-sectors have developed different trajectories to innovate. These trajectories are path-dependent to their particular industrial setting, technological evolution, and dynamic complementarities.

6.3. Networks

The three production chains have different patterns of cooperation. It is evident that in order to be competitive, firms need to have differential factors amongst their competitors and that an important source of differentiation is the knowledge the firm privately holds for its commercial activity. However, collective construction of knowledge in industrial and sectoral networks has shown to be beneficial for the cluster of firms related directly and indirectly with the economic activity performed by the sector (Kogut, 2000). This is clearly seen in the three chosen cases where cooperation between actors has been crucial. In the case of the coffee sector, cooperation has maintained the sector through the toughest crises; and has made the Colombian sugarcane industry competitive making it the most productive in the world in terms of tons-per-hectare of sugar. The opposite case is seen in the flower sub-sector, where the lack of trust between firms has hindered the construction of an effective cooperation network. Firms do not share knowledge unless a business consortium is set to meet very specific customer requirements. Bridges to share knowledge and technologies useful for the entire chain are weak. This is one of the factors that have caused the sinking of several small, medium and large firms and the requirement of further assistance from the government to overcome the sector’s internal crisis. However, the industry stays viable and has innovated in the logistical links of the production chain, which leads us to think that a stronger cooperation between actors could expand the potential of the business to promote radical innovations.

The network constituted by growers and sugar mills in the sugarcane case has improved the joint performance of the actors within the chain and has engendered routines and rules on how production from cultivation until finished product is done. Growers have seen the necessity of having more productive sugarcane varieties since their payment is subject to the final sugar obtained from the cut sugarcane delivered to the mills. Therefore, Cenicaña is at the centre of the network as the provider of the latest K&T, which is in turn translated into more profit for all the actors in the network.

One possible hypothesis to explain the difference between the network structures in the case studies is the specific characteristics of each sector due to their historical pathways and the market niches where competence is held. In the coffee case, early entry into the international market and the possibility to develop knowledge and technology not only at the local level, but also in a wider global context, accentuated the need from growers to associate and invest in research to preserve a leading position in the international market. Coffee, being a product with a consumption pattern ruled by quality has had a wide framework of action to improve the final product. The strategy was to compete with quality and differentiation against bigger competitors in terms of volume, like Brazil. There were not many available technologies used in the industry so the coffee sector evolved at a similar pace as other strong competitors and was a pioneer in the research of varieties resistant to common coffee diseases.

In the sugarcane case, the initial aim of the sector was to completely supply the domestic market. The infrastructure required for processing sugarcane has a high associated cost, which generated a positive discrimination of the fittest competitors in terms of efficiency and productivity, so production costs can be reduced and the implemented technology can be used at its highest potential. Technologies were available in other parts of the world for sugar production, however, growers during the modern stage of the industry (1960 onwards) realised that having an accurate and complete knowledge of the production units could increase their productivity. The perfect weather conditions were not a sufficient factor alone to be competitive, so research was needed to grow the right varieties according to the soil conditions and later on, varieties resistant to diseases. Then, as it happened with the coffee chain, the sectoral research centre produced technologies to meet producers' needs, creating dynamic complementarities among growers in terms of cultural, social and educational backgrounds to absorb new knowledge and technologies. The pursued objective in the sugarcane sector was not to compete with differentiation, but with productivity. Innovation was focused on efficiency in the growing and processing of raw materials. An effective regional system was built to keep the sector ahead in terms of productivity and later on to diversify the products portfolio into biofuels.

The fresh flowers sector is different from the other two case studies. Colombia did not have a tradition in the fresh flowers market, so the industry was created with the assumption that good climatic and soil conditions, in addition to cheap labour and a relaxed regulatory framework, would make the business profitable. Colombia was a latecomer to the flowers industry, which made it a follower of international leaders. The strategy was to compete with volume of production according to customer demand. The chain is composed by firms rather than by growers, and there is not much differentiation in the products the firms offer to the final client in terms of quality since they all use standard imported rootstocks. Differences remain in the target markets, final price, fair trade strategies, access to larger customers through larger production, effectiveness in delivery logistics, and lately in the offer of finished bouquets ready to sell to the final customer.

The networks formed in the flowers, coffee and sugarcane production chains emerged in response to the systemic interaction of social, technological and institutional factors during the industries evolution. The structure and governance of these networks is an expression of the coevolution of actors, knowledge, demand, technology and institutions changing dynamically according to cooperation ties built within the networks. We observed that for these three case studies, having an entity coordinating the network and representing the sectoral actors in external institutional settings directly impacts the proclivity to innovation. For the agriculture case, producers associations fulfil that role. The representativeness of the growers and producers in the association and the internal governability of the guild affect the industrial dynamics and the sectoral knowledge generation and exploitation.

A hierarchical governability structure like the one seen in the coffee case imposes certain rigidities on the production chain and constrains, to a certain extent, the producers' capacity to survive in the open market. The coffee sub-sectoral innovation system is dominated by the highest authorities of the FNC that also determine the knowledge and technological requirements for the small coffee growers. The system is democratic in the election of authorities but the pyramidal structure of the network makes difficult for the base to have power to influence changes in the evolution of the industry. There are no large or small firms that can compete with the Federation, that besides being the producers association is a competitor in the domestic and international market, selling raw and finished products. In this case, we see a *Burt network structure* (see section 2.3.3.2.), where the FNC is a non-redundant tie between the growers, the cooperatives, the export firms and the final clients. There is no market interaction that is not intermediated by the Federation.

In the flowers case, international suppliers at the start of the chain have influenced the low R&D local efforts. The core innovation source is foreign, leaving local efforts to innovate in the logistics of the production chain. There are dispersed SMEs and a few large firms that compete with each other for clients and technological capacity to respond to the everyday challenges of the business. Asocolflores, as mentioned before, has not exercised an effective role to promote cooperation between the producers. The nature of the chain is also different from the other two in terms of the characterisation of the actors. Asocolflores represents firms, not growers. However, firms own the land and plantations and hire unskilled labour for the planting and harvesting processes. Few professionals with technical skills guide labour. The owners are usually in charge of the administrative and logistical processes. Each firm is an independent unit that only have contact with other firms for specific business opportunities, but always keeping their own knowledge out of the commercial agreements. In this sense, Asocolflores and Ceniflores in most cases operate a one-to-one relationship basis to support firms individually. The nature of this network is ruled by opportunist links between firms, which does not necessarily imply long-term commercial relationships. The network has clusters of small and medium firms that join to gain bigger customers and to compete with larger firms. In this sense, we cannot see a Burt or Coleman network structure, but a network that redesigns itself constantly according to demand dynamics.

The sugarcane cluster works with horizontal and vertical relationships between growers, sugar mills and the existent producers associations. Asocaña is an important actor in the network since it has the largest number of growers associated as well as all of the sugar mills. Asocaña has intermediated the relationship between growers and sugar mills, but the association is not the only bridge between both of them. The growers have bilateral relationships promoted by Cenicaña and share contextual knowledge related with the productivity of their plantations. There are fixed prices set by the sugar mills in accordance to the national and international sugar market prices and there is guarantee that the growers' production will be bought by the sugar mills. The network is not completely flat, because the sugar mills exert power within the cluster, but it is not hierarchical either, because the growers influence Asocaña's decisions, sectoral regulations, and set conditions to the sugar mills for the purchase of their production. In this sense, the sub-sector works more with a Coleman network structure. There are diverse relationships between growers, between sugar mills, and between sugar mills and growers. Knowledge and technologies flow dynamically within the network.

Thus, it is understandable that each industry has different dynamics that leads to different innovation pathways according to their specificities. As Malerba outlines:

> [I]nnovation and industry evolution are highly affected by the interaction of heterogeneous actors with different knowledge, competences and specialization, with relationships that may range from competitive to cooperative, from formal to informal, from market to non-market (Malerba, 2006, p. 15).

We learned from the cases under study that in order to survive, firms and growers represented by the producers associations have to be flexible to adapt to market changes. Flexibility in the knowledge generation base according to sectoral needs and the knowledge cumulativeness of the industry is fundamental to remain competitive. Particular historical evolution patterns and formal and informal institutions have a direct impact on the way governability and governance are built to set different combinations of collective and competitive relationships and new market orientations; and to build effective networks that facilitate interconnection between the knowledge generation and knowledge exploitation systems.

6.4. Knowledge

We found in our study two sub-sectors with similarities in the way knowledge is built and applied and one sector that has a different trajectory. The sources, domains, applications, accessibility and cumulativeness of knowledge (see section 2.3.3.1) play a central role in the sectoral and firm innovation processes and affects the way firms learn and build capabilities (Malerba & Mani, 2009a). This is also highlighted by Joseph: "The evolutionary literature has proposed that sectors and technologies differ greatly in terms of the knowledge base and learning processes related to innovation." (Joseph, 2009, p. 186)

We can see a comparison of the knowledge dimensions between the three production chains under study in table 6.2:

PRODUCTION CHAIN	SOURCES	DOMAINS	APPLICATIONS	ACCESSIBILITY	CUMULATIVENESS
COFFEE	Sectoral Research Centre, Cenicafé; Fundación Manuel Mejía	Genetics; Biotechnology; Agronomy; Biology; Integrated Pest Management; Agrarian Productivity; Economic Viability	New coffee varieties; pest control and use of fertilizers according to plantations soil and weather conditions; agrarian productivity	Mostly internal to the industry and sector through own R&D	After radical innovations in breeding developments, new knowledge and learning processes have been further developed. Specific absorption of market signs for R&D feedback
FLOWERS	International Breeders, local and international researchers	Logistics; management; Integrated Pest Management; Agronomy; Biology	Improved cultivation techniques; improved pest control and use of fertilizers; improved packaging and transport techniques	Mostly external knowledge brought by staff coming from other industries; knowledge transfer by experts and firms and non-firms organisations.	Knowledge and technology development based on foreign innovations. High feedback from the market to guide internal R&D
SUGAR CANE	Sectoral Research Centre, Cenicaña	Genetics; Biotechnology; Agronomy; Biology; Integrated Pest Management; site-specific agriculture; Economic viability	New sugarcane varieties; development of biofuels; pest control and use of fertilizers according to plantations soil and weather conditions	Mostly internal to the industry and sector through own R&D	After radical innovations in breeding developments, new knowledge and learning processes have been further developed; good absorption capabilities from the growers and sugar mills and constant technological surveillance of the broad sectoral development

Table 6.2. Comparison of knowledge dimensions in the coffee, flower and sugarcane production chains

Source. Information gathered by the author.

The existence of strong research centres has been crucial for effective models of knowledge generation and knowledge exploitation in the coffee and sugarcane sub-sectors. The centrality of these research organisations has impacted the productivity levels and the degree of competitiveness at both national and international levels. Moreover, the centres have acted as a bridge organisation between the producers associations and the growers and firms themselves. The generation, transfer, appropriation and validation technology models followed by Cenicafé and Cenicaña have proven to be effective in terms of R&D and solutions delivered to the final recipients.

The intermediation of the producers association for knowledge generation and knowledge exploitation systems has shaped the way each of the industries are structured and the kinds of networks formed between the actors. In words of Loasby:

> The organisation of industry is an organisation of knowledge, and the way in which knowledge is organised shapes the content of the additional knowledge that is produced. (Loasby, 1999, p. 136)

Here, we can see differences in our case studies in how the intermediation between the two systems (knowledge generation and knowledge exploitation) is partially overcome by active private research centres that are in direct contact with the producers. Also, we have found that better regulatory frameworks (as the creation of production chains for the Agro-industrial sector) and public research entities, like Corpoica, that work as bridges between the knowledge generation and the knowledge exploitation systems have a positive impact on closing the gap between producers and R&D results. As it is outlined by Cook for the case of regional systems of innovation (RIS):

> A Regional Innovation System…consists of two sub-systems. The first is the ‘Knowledge Generation’ sub-system. The second is the ‘Knowledge Exploitation’ sub-system. Most regions, and many nations, have poor linkage between the two sub-systems. Where nations or regions have overcome this barrier, it is either through successful working of market mechanisms, set in an appropriate regulatory environment, classically in the USA. Or market failure is overcome by the establishment of state entities that directly or indirectly

> straddle the "exploration" to "exploitation" divide. (Cooke, 2004, p. 79)

The coffee knowledge generation and exploitation model, highly intermediated by the National Federation of Coffee Growers (FNC), developed the required institutional structure so every component of the knowledge and technology cycle was covered by different organisations, as we illustrated in the K&T transfer, adoption, and validation model part of the coffee section (see figure 5.10). Cenicafé generates the knowledge, the extension service is the bridge between the growers and Cenicafé, and Fundación Manuel Mejía provides training to technicians and researchers and lately even to the coffee growers themselves. All these organisations are part of the FNC. The sugarcane industry has followed a similar pattern having a strong producers association, Asocaña, which created Cenicaña. The research centre develops R&D and has developed with Tecnicaña (the association of sugarcane technicians) programs for K&T transfer, adoption and validation. At the same time, the research centre provides training to the sugarcane technicians. The flower sub-sector presents a more dispersed knowledge generation system that it is intermediated sometimes by Ceniflores for covering common problems found in the chain, but there is not a particular methodology or model to develop, transfer, adopt and validate K&T. The knowledge creation and exploitation systems are not highly integrated. The lack of integration can be seen in the composition of the networks with low density in relationships and weak linkages among firms. The relationship with the breeders is sustained at individual levels between firm and breeder. The socialisation of sectoral knowledge produced through Ceniflores is not fluent and does not reach all associates of Asocolflores. In the flowers case actors like Corpoica, the public research centre for agriculture, has a more active role in the knowledge generation subsystem than in the coffee and sugarcane cases. However, Corpoica's influence has been rather limited.

This integration of both creation and exploitation of knowledge in the coffee and sugarcane cases has proven to be successful and has maintained the viability of the industries in the hardest crisis. The importance of such proximity is recalled by Cowan et. al:

> [F]or an economy to have a strong, innovative manufacturing sector, it is necessary also to have correspondingly strong applied and basic research activities situated in close proximity to the production operations themselves. (Cowan et al., 2000, p. 222)

Analysing the boundaries in the knowledge space for codified and uncodified knowledge (Cowan et al., 2000), we can also see differences in the trajectory of the three sub-sectors. In the flower production chain there is circulation and use of tacit knowledge for all activities related with the managerial and logistics links of the chain. Managers bring their expertise from other sectors and adapt their skills to the flower industry. This has been the case since the industry was created and has been maintained over time. Colombian flower firms have tried to keep their *know-how* protected, encouraging low staff turnover and having strict confidentiality agreements. Experience comes with practice of particular skills and then internal firm capabilities are built. This knowledge has remained unarticulated and adapted from generic codified knowledge. Codified knowledge used by the actors comes in the form of artefacts (rootstocks) and technologies (cultivation techniques, fertilisers, irrigation equipment, greenhouse specificities). There is also codified knowledge that is transferred by the international breeders concerning cultivation requirements to guarantee the final expected outcome from the cutting. This codified knowledge is appropriated and adapted to the field characteristics and codified by the technical staff and national researchers in the form of internal technical procedures and academic papers. Around this codified knowledge there is unarticulated knowledge shared by the actors within the farms to have higher productivity levels determined by less use of resources and better protection against diseases. This *know-how*, in the flower sub-sector case is shared in the industry through staff turnover (even when it is tried to be kept low by the firms), since there is not a strong cooperation network between the firms.

For the coffee and sugarcane cases, there is codified knowledge produced by the research centres that has been perfected over time through experimentation in field, and feedback cycles between technicians and researchers. The growers and firms (in the coffee case the firms are the cooperatives, roasters and traders; and in the sugarcane are the sugar mills) are an active part of the knowledge generation and exploitation sub-systems. When technicians interact with the final users, the appropriation and validation phases generate new knowledge that can be used to improve existing solutions or to find new ways of dealing with common problems. This knowledge is partially codified by the technology transfer teams and by the research centres, but most of the knowledge keeps uncodified as part of the *know-how* of the farmers and companies.

We can see different degrees of dynamic complementarities in the three production chains in the innovation cycle. These are characterised by interdependencies and feedbacks between users and producers of knowledge and sectoral agents intermediating the flow of knowledge, as can be seen in table 6.2. However, knowledge transactions -or the way actors transfer, appropriate and validate knowledge within the sectors- (Cowan et al., 2000) have been highly expensive in terms of the production of codified knowledge. The knowledge and technologies used have been normalised in many of the cases, but the codebooks and repositories of codified information have been built internally responding to contextual particularities of production. This process has associated costs that in the coffee and the sugarcane sectors are absorbed by the research centres, and in the flower case is mostly paid by the firms themselves, with internal investment in R&D and hiring of international experts. Ceniflores has sponsored sectoral research projects to support the firms associated to Asocolflores but its influence and impact is still limited.

Finally, a common problem found across the sub-sectors, is the weakness of the formal institutional setting for encouraging and facilitate Intellectual Property Rights (IPR) agreements between universities, research centres and laboratories both public and private, and firms and producers associations. Universities are in the process of exploring different mechanisms to provide services to the business sector and transferring research results for specific sectoral needs. In this case, there is not an effective bridge between the production of knowledge and the absorption and exploitation in commercial solutions. In the three production chains, actors interviewed from the producers associations, research centres and firms complained about the difficulty for having joint projects with all sort of research organisations within the country. For the three case studies, there are more joint-research projects with international universities and international research centres than with national research actors. The reason is that it is easier and more effective to have these agreements with foreign organisations than with national ones. There is a systemic failure in the translation of knowledge into innovative products and services. This weakness has hindered and prevented effective knowledge exchange between the actors of the innovation networks. As explained by Santiago Echavarría, executive director of the Centre of Science and Technology of Antioquia:

> In practice the implementation of policies still favour the knowledge production block of the system, so the system is not complete. There is no knowledge flow and transfer, no learning processes. In innovation there is something that is called 'valley of death'. Between research and innovation there is a whole issue of development. That development process is what is called 'the valley of death'. The Colombian model is focused on strengthening the knowledge generation side, but not much has been done to convert ideas into technological solutions. The universities are not designed to complete the innovation cycle, there is not experience and mechanisms to facilitate the conversion of knowledge into market solutions. (Santiago Echavarría, personal communication, March 16th, 2012)

6.5. Coevolution

The knowledge base of the sectors under study has hinged on their longevity. The early entry position of the coffee and sugarcane sectors impacted positively in the construction of a solid knowledge base incremented through cumulative processes of knowledge generation according to direct feedback from the growers and sectoral firms. The Colombian flower industry is still in a process of maturation and continues to be highly dependent on foreign knowledge production. From this stand point the industry has enhanced its knowledge base at the logistics level, but it has remained steady in the biological knowledge base for developing new flower varieties. In the three cases, the knowledge base has determined the type of networks developed. However, longevity itself is not a critical variable. Without an effective cooperation network of actors to encourage accumulation of knowledge, innovation does not happen.

Besides knowledge base, type of networks and longevity, the demand type has been a main factor in determining the sub-sectoral innovation pathways. As we explained before, coffee and flower production chains have a high dependency on international markets, which has shaped the products characteristics and design. Notwithstanding other factors influencing the sectors evolution, the result of having highly specialised customers has resulted in different innovation dynamics. Since Colombia has been a pioneer in offering Arabica coffee, it has created specific consumption preferences attached to the special characteristics of Colombian coffee. However, given the entrance of more competitors and more sophisticated requests from the final customers (flavour, origin, acidity, etc.), the sectoral actors had to improve their knowledge base to diversify the offer, which resulted in the production of higher coffee quality and value-added products. As a result, the export of specialty coffees has had a sustained growth (see figure 5.6). The Colombian Coffee Growers Federation has also ventured into the production and sale of freeze-dried coffee to cover the range of soluble coffees and has gone to the last link of the chain, having its own coffee shops, *Juan Valdez*, first in the domestic market and expanding afterwards to international markets in South, Central and North America, Korea, and Kuwait. In the flower case, the production is customer-driven, which means that firms adapt their supply to the market tendencies and demand. Therefore, Colombian flower production is highly focalised on the production of roses and carnations, since these present the higher demand. Specialization has come also in the form of finished bouquets. New capabilities in the production process have been added in terms of the composition of different flower varieties, diverse packaging combinations, and the design of final bouquets. This further step has also meant that firms have had to associate to be able to mix different varieties of flowers and transform their production line in order to offer a wider range of final products. However, the product R&D base (rootstocks) remains external to the national industry. The demand patterns in the sugarcane production chain are different than in the previous cases. Most of the demand is internal and there is a domestic market shared by fourteen sugar mills located in the same geographical region. The mills have strategic alliances with confectionery and spirits companies, sell sugar directly to final customers through wholesalers and retailers and from 2006 the cluster has expanded its products portfolio to biofuels. There are five plants for ethanol production owned by five sugar mills. The ethanol production is totally absorbed by the domestic market, given the existence of national biofuels policies that warrants the purchase of internal production, before importing it from different countries.

Political institutions have had an important influence on sectoral policies and their use for supporting the viability of the sub-sectors in the short and medium term. The coffee, flowers, and sugarcane subsectors have had special policy instruments to minimise market failures, information asymmetries and lack of competitiveness in international markets. The main policy instruments designed to support the sectors competitiveness can be seen in table 6.3:

Production Chain	Instrument	Function
COFFEE	National Coffee Fund	National Budget special account. Gets funding from a non-fiscal tax paid by the growers and public subsidies.
	Price transfer	Mechanism to transfer the final coffee price to the growers.
	Purchased warrant	The FNC coffee cooperatives warrant the purchased of a certain volume of coffee at a certain price up to 6 months in advance.
	Preferential export taxes	Lower national taxes to export coffee to international markets.
FLOWERS	The Andean Trade Promotion Drug Eradication Act (APTDEA)	Free Trade with USA.
	Generalised System of Preferences	Preferential tariffs with Europe.
	Russian Generalised System of Preferences	Zero entrance tariff to the Russian Federation.
	Plan Vallejo	Import of raw materials used in the production of export goods with total or partial import taxes exemption.
	Incentive for Rural Capitalisation (ICR)	Special funds given to the firms for renovation of plantations, land improvements, biotechnology developments, among other items.

	Sanitary Incentive	Subside to promote appropriate sanitary conditions in plantations and integrated pest management for export products.
	Revenues protection for exporting products	First called Incentive for the exchange hedging, is a subside to counterbalance fluctuations in the exchange rate.
SUGAR CANE	Andean Price Band System (APBS)	Variable levy system with price floors and ceilings to buffer international price shocks.
	Stabilisation Fund for Sugar Prices (FEPA)	Stabilisation fund that receives transfers generated when the given selling price exceeds the market reference price, and offsets when the price is lower than the reference price.

Table 6.3. Policy instruments design to benefit the coffee, flowers and sugarcane sub-sectors

Source. Data compiled by the author.

The table above shows that the flower and coffee sub-sectors have had access to a broader set of instruments. A question remains behind the evolution and sustainability of the studied sub-sectors. Is the viability and permanence of these industries subject to protectionist policies coming from the central governments? The coffee sector has had a strong vertical integration to lower transaction costs and has been consistent with investments in R&D and K&T learning processes. This strategy has determined the type of sectoral networks formed, which at the same time have been shaped by the knowledge generation and exploitation dynamics of the sector. The flower chain had backward vertical integration in the first stage of development, characterised by a supply chain composed of specialised firms to intermediate the transport and distribution of the final product. In a second stage the firms underwent a process of forward integration with the final buyers, controlling the whole value chain from the production until the direct sale to the final customer. The sugarcane sector has maintained a consistent vertical backward and forward links between growers, sugar mills and final customers. The transaction costs have been reduced with the construction of internal capabilities so the sectoral research centre has absorbed the search and information costs, and the sector has achieved standard procedures to minimise the bargaining and enforcement costs. However, the coffee and flower chains have struggled to remain competitive and to generate enough profit for the growers in the coffee case, and to the firms in the flowers case. The one-day successful production chains have gone through a re-structuration process that was delayed by the subsidy policies. Excessive protectionism could hinder the overall competitiveness of sectors, causing dynamic policy inconsistencies. However, state intervention to encourage the modernisation of sectors and a trade-off between market pressure and protection of small growers can help to build capabilities in the medium and long term. A balance between strategic protectionism and mechanisms to promote sectors' modernisation needs to be built according to the assessment of the different policy mixes that have been tried already.

6.6. Conclusion

It is worth answering the question: what is co-evolving with what? In the cases under study we can conclude that the market size of each chain has co-evolved with the type of demand, mostly customer-driven for each case. The knowledge base and knowledge transactions have depended on the productive capabilities of the firms and the growers at each stage of development. The producers associations are a central piece in the system structure and functional dynamic, being the main engine to determine the industrial expansion and contraction strategies, and the development of the sub-sectoral research centres, as the main pieces for capability building. In the cases of coffee and sugarcane, given the predominance and importance of Cenicafé and Cenicaña, the networks have redundant ties between growers, the research centres, firms, and the producers associations. The coffee production chain has a stronger hierarchical structure that can be seen in the Federation being the strongest path between the growers and the subsequent coffee conversion processes. The flower sector does not have strong ties between the actors, represented by disperse SMEs and few large firms that have their own distribution channels and direct relationship with the final customers. In this case, the producer association, Asocolflores, has lost representativeness and power and the prevalent behaviour among the actors is of competition and lack of trust. This is the opposite case of the sugarcane chain, which is characterised by problem solving, communication and trust between the actors. Thus, the knowledge base and transactions have influenced the way the networks operate in each of the sub-sectors.

As Montobbio states: “Institutions and organizations can no longer be considered exogenous to the agents’ innovative activity but, rather, are often created to accommodate a specific trajectory of technological specialization. Innovative success in some countries and sectors can be the result not just of the appropriate institutional package but, rather, of the flexibility of the institutional environment to adapt to the new technological challenge posed by firms.” (Montobbio, 2004, p. 65)

7. CONCLUSION

7.1. Introduction

This thesis developed a study of the evolution, application and results of science, technology and innovation (STI) policies in Colombia, along with a study of the dynamics of innovation at sectoral levels, as a particular case study of a developing economy within Latin America. The research took a specific direction towards the National System of Innovation (NSI) approach. From the constitution of Colciencias in 1968, S&T policy-makers were reflecting on research and production systems and their interactions; and adopting the Latin American Structuralism Approach (LACSA) as the basis for these reflections. This approach highlighted the necessity of building internal S&T capabilities for achieving economic growth, which focused on competitiveness at the firm level.

There was also a clear understanding about the role of the universities, the business sector and the public agencies in the development of effective national strategies to boost the national economies. Ernesto Sábato, Latin American politician and academic, developed a model for encouraging links between public, private and academic sectors to improve the knowledge generation and exploitation systems called *Triángulo de Sábato* or Sabato's triangle. He proposed this idea in 1968; much earlier than the diffusion of the triple helix (1990). However, the *Triple Helix* (Etzkowitz, 1993) and the NSI approach were adopted from the 1990s and have prevailed since then to build STI policies in Latin America.

Having explored the development of the formal institutional framework of Colombia's NSI, we realised that we needed to understand how innovation patterns actually take place; and that to do this, we needed to investigate deeper into sectoral cases. We initially chose agriculture as our case study. However, given the complexity of the Agro-industrial sector, we found the need to apply an even finer degree of granularity and to study the knowledge generation and exploitation dynamics in particular agriculture production chains or sub-sectors. We had to constrain the scope of the research when we found deep differences between the sub-sectors, so we focused our attention on the comparison of three sub-sectoral cases.

This part of the research represents the second thematic pathway; a comparative study of innovation dynamics.

In this chapter we bring together empirical, theoretical and practical findings to answer the research questions that started this doctoral journey. In the first section, we summarise the main aspects developed in the two thematic pathways to respond to the research questions. The second section presents the concrete theoretical contributions to knowledge derived from the research. A third section presents key contributions for practitioners and policy-makers that include comprehensive learning of policy building processes and considerations related to the actual operation of the so-called innovation systems. The final section presents issues and considerations for further research, limitations and lessons for the future.

7.2. Empirical Results

In this thesis, we followed two thematic pathways: STI policy development, implementation and outcomes in the Colombian context at the national level; and the study of particular innovation dynamics through the analysis of the coffee, flower and sugarcane subsectors within the Colombian Agro-industrial sector. We then presented an empirical analysis and discussion to answer the research questions that guided the study. In this section, we re-state these research questions and sum up the main findings.

1. *How has Colombia attempted to establish a national system of innovation?*

Colombia, as part of the Latin American and Caribbean Region, was not exempt from the regional economic and political structural changes, which began after the Great Depression in 1929, and continued through to the economic opening of the countries of the region from the end of the 1980s. Under the influence of transnational organisations such as the ECLAC, OAS and OECD, Colombia established Colciencias, a national institute for the promotion of science and technology, followed by the promulgation of national laws and instruments promoting the construction of S&T capabilities to encourage social and economic development. This model, perhaps unwittingly adopted a public science-push approach, led to an emphasis on the weakness of university-industry linkages. The NSI was understood and applied as a modernisation recipe for developing economies; even though it was not developed as such by its originators. Embracing of this view generated an implied gap – a gap that did not exist before - and gave greater importance to universities as the main actors for generating suitable knowledge for the business sector. This was an oversimplification in the promotion and encouragement of innovation dynamics by coupling science and production systems. When adopted, it overwrote the Latin American School of Thought (LAST) that had a stronger focus on the industrial system and firms as the engine of development. With the changing paradigm, Latin American scholars started to shift to a particular reading about what a national system of innovation should be, which gave central attention to the promotion, advancement and exploitation of public sector research.

Colciencias followed the aforementioned approach and adopted this narrower reading of the NSI model. Colombian policy-makers attempted to create a NSI on these lines, and did so using formal institutional measures based on OECD innovation indicators. It declared the existence of the Colombian NSI in the first law created for S&T. However, the implementation of the law was not exempt of shortcomings. After two decades, this designated NSI still faces many problems rooted in a deficient governability and governance of the system, lack of systemic relationships between major players of the system, scarce financial resources that are deficiently allocated given the absence of national consensus about the strategic areas to be developed, and a low valuation of science and technology as engines for development and innovation in the productive sector.

While the Colombian NSI appeared to be perfectly defined on paper, the evidence shows that it has had a sluggish performance, characterised by lack of systemic relationships and a poor transformation, adaptation and validation of knowledge in the business sector. Findings suggest that the adoption of the NSI as a political device has failed. LAC countries are moving now towards the promotion of innovation strategies through the building of critical mass to trigger innovation and structural change-led economic development. This is coupled with emphasis on macro structural conditions that can support the imperative paradigm of having an efficient national system of innovation, such as market size, exports structure, support to technology-base SMEs, among others (Dutrénit, 2011).

The defining components of the Colombian NSI can be seen in figure 7.1. Although the blocks are present in the diagram, many of them are in process of construction or re-structuration, as it is the case of *supportive infrastructure* and the *intermediaries*.

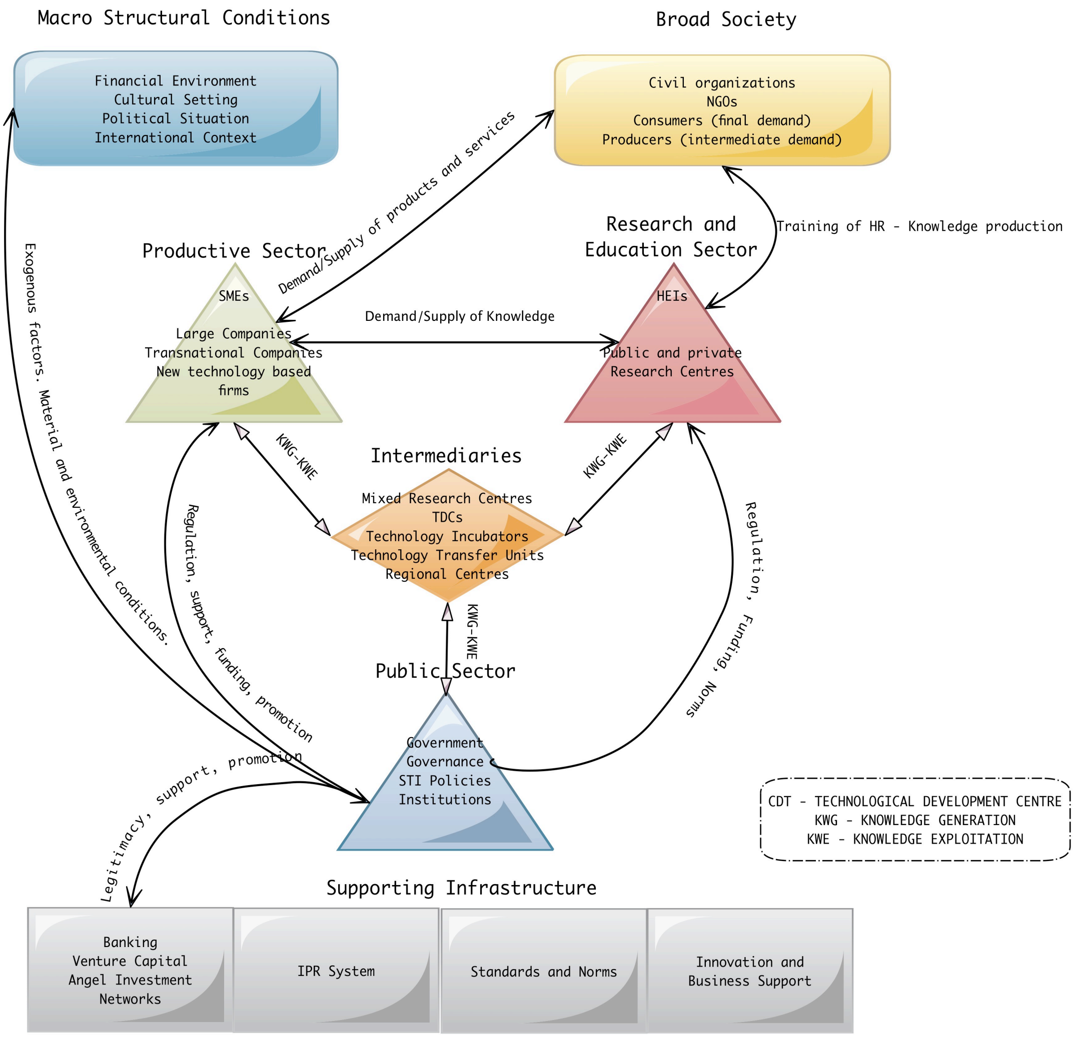

Figure 7.1 Colombian NSI structure

Source. Made by the author

While Figure 7.1. suggests a formal system of innovation, which is also stated in the national policy of science, technology and innovation, there are deficiencies in the three main blocks (public, productive and research/academic), and in the infrastructure block which is expected to support the innovation dynamics. In reality, a 'linear-plus' model (Tait & Williams, 1999) is followed in the policy-making side, which adopts ever more elaborate policies and incentives that seek to get knowledge to flow from public sector research and be applied in industry; to get the innovation system to operate in a linear, science-push manner.

There has been a strong focus from Colciencias on strengthening knowledge generation through the education and research subsystem. However, there is a weak knowledge exploitation side in the productive sector. In this sense, promoting industry-academic links has become central, along with setting up technology-based SMEs and spin-off companies. In promoting these activities within the NSI approach, there was an anticipated direct connection between players in the innovation arena. Nevertheless, putting financial resources into the research system has not directly translated into innovation. The idea of building 'bridge institutions' to reduce the transaction costs for firms has remained central to how knowledge flows should be, and how quickly they should happen. However, evidence has shown that it is the embodied knowledge that produces innovation (Cowan et al., 2000; M. Teubal & Andersen, 2000), not the production of basic research to be further applied to business solutions. Universities remain as central actors for training needed human resources that can bring their knowledge and expertise to the productive sector, but not necessarily as the main block to produce applied knowledge. This narrow NSI approach ignores knowledge flow complexities and the crucial role of embodied knowledge as main driver of innovation. It also ignores evidence which suggests that these flows usually happen slowly and indirectly (N. Clark & Chataway, 2009).

This suggests that the functional structure of the NSI is 'messy,' especially in the delineation of the expected roles from the actors. Following this idealised model of innovation within a national system of innovation, Colombia has failed to achieve the goals for which the system was created. The scarcity of agencies performing the role of intermediaries or bridges between the research centres and universities and the productive sector has resulted in inventions failing to be exploited and commercialised as innovative solutions. In terms of the networks between blocks and actors of the system, there are meagre flows of knowledge and a dearth of learning processes within firms and sectors. We therefore question the existence of a system, which is explored in the fourth chapter.

We found that there are specialised networks between actors in the public, private and academic sectors that emerge through personal relationships, not because of the existence of an operational system. There is an idea of something called national system of innovation, but that is not tangible in practice. It is not clear who are the actors of that system (beyond the labels of public, private and academic actors), how actors benefit from each other, and what support instances are available.

Colombia's STI policies, solidly ensconced in the NSI approach, may have had positive outcomes in S&T capability building, increasing financial resources for STI, development of strategic sectors, and a higher social appropriation of science. There is an institutional framework that facilitates and enables action from firms, universities, public research centres, technological development centres, and other public agencies to generate and exploit knowledge. However, results appear distant from the goals set from the very first mission to encourage development through science, technology and education. Stronger intellectual property systems, banking and venture capital, agencies supporting innovation, standards and norms that make the Colombian firms more competitive in international markets are still in a consolidation process, although they exist in the national context. Firms have slowly increased their investment in R&D and S&T activities, however it is still low and in isolation with other actors in the innovation system. Training of human resources at the higher education level has been improved in terms of population coverage, quality standards and updated curriculums in tune with needs of the labour market, but this process remains slow and defocused from technology-intensive sectors needs.

We conclude that Colombian policy-makers continue to design policy instruments that respond to a linear reading of innovation, which has generated a misperception of an uptake lag. We suggest a mismatch between the formal institutional frameworks and the practice.

2. *What are the main innovation dynamics differences in the Colombian coffee, flower, and sugarcane sub-sectors?*

In directing our study to specific case studies to generate a deeper understanding of how innovation actually happens within the production system, we were surprised to encounter major differences in the capability-building strategies, technological evolution, knowledge networks, and the institutional setting at the sub-sectoral level. We chose a traditional and strategic national sector, agriculture, and three sub-sectors within it, which are recognised nationally and internationally as successful.

We found that even at the sub-sectoral level, there are significant differences that determine the innovation pathways of specific industries. Dynamics between firms and non-firms organisations, formal and informal institutions, type of networks and demand, and the longevity of the production chains have determined their evolution, competitive advantage, and position in the marketplace. The research and technical assistance subsystems within the Agro-industrial system have contributed very little to the innovation patterns of the cases under study. The research and technical assistance sub-systems have had a limited impact in the R&D and S&T activities within the chains, especially for the coffee and sugarcane cases. For example, although Cenicafé, Cenicaña, and Ceniflores have received funding from MADR and Colciencias, these have not been their main funding sources. Technical assistance and transfer processes have been offered using internal mechanisms, as we explained in each of the sub-sectoral chapters. The extension service of the Coffee sector offered by the National Federation of Coffee Growers and the technology transfer, adaptation and validation groups led by Cenicaña have been effective to cover the sub-sectoral needs. These chains do not use the national technical assistance units.

In the case of the flower chain, even when Ceniflores does not have an explicit model to provide knowledge and technology transfer and assistance, the firms do not use the Agro-industrial technical assistance mechanisms either. The structure of the technical assistance subsystem does not work with the same standards in every region, which makes it operative and useful in some regions and for some production chains, but not for the totality of actors. In three cases recognised as successful within the Agro-industrial system, the technical assistance subsystem does not play a central role, nor has there been an intended learning process from successful experiences to provide technical assistance and generation and exploitation of knowledge, such as coffee and sugarcane, to share and strengthen the agriculture sector overall, much less to other national sectors. The sub-sectoral strengths have not risen to higher levels.

Producers associations have been the main non-market organisations within the Colombian Agro-industrial System of Innovation, as was seen in the section 4.5. In the three sub-sectoral cases, the associations have been crucial for developing the sectors and have enhanced their competitiveness in local and global chains of production. In terms of representation within the Agro-industrial system, the associations have been an important link between producers, firms and the Ministry of Agriculture and Rural Development (MADR), Corpoica, Colciencias, other support organisations and training agencies (Look at Figure 4.21. Actors of the Agro-industrial System). They have also been the first step to constitute the production chains, since there can be just one chain by product.

In this sense, the system has contributed formal institutional processes, standards, protocols and platforms for exporting Colombian agriculture products, but has failed to provide extensive support to growers and firms that do not have strong representation. Also, structural problems have affected the whole sector such as lack of legal clarity about the use and land tenure; lack of adequate infrastructure for competitiveness; high cost of agricultural inputs; fall in the price of agricultural commodities; and exchange rate appreciation against other countries of the region with better exchange rate controls and protections.

Through our case studies, we found that there were significant differences in the structure of markets and the dynamics of competition between the case studies. This is clearly seen in sectors that have a great dependency on international markets. When customers have an important influence on the volume, type of product, quality and market tendencies, the industries shape their productive capabilities to respond to these requirements. On the other hand, the knowledge base and knowledge transactions determine the productive capabilities and the networks structure. This knowledge base is built in a long and path-dependence learning process that determines the growers and firms *know how.*

Finally, we found that the governance and governability of the production chains help or hinder the innovative capacity of all the chain actors. When there is a balance between management, control, execution, planning and consultation with all the actors in the chain, the knowledge generation and exploitation cycles flow easier and bring higher productivity to growers and firms upstream and downstream. Trust and power are two main elements that affect these dynamics. There are constant negotiations between actors to deal with uncertainty and complexity. However, powerful narratives close down policies and strategies according to particular interests and purposes. This can lead to a general lack of trust that affects network dynamics and therefore collective learning processes.

3. *How are top-down and bottom-up innovation dynamics within sectoral levels developed and enhanced?*

This question was answered implicitly through the empirical and discussion chapters; however, we will explicitly bring together the main considerations that have affected synergy processes between national and sectoral policies and the impact of both in actual sectoral innovation pathways. Opening up the analysis to integrate national and sectoral initiatives is one of the main empirical and theoretical contributions. By exploring the state support through a set of policy instruments, and the analysis of sectoral dynamics, we could advance in the understanding of national systemic failures and to integrate sectoral actors initiatives towards innovation at all stages of the production chains.

We found disconnections in all the levels of analysis. At the macro level, there is not continuity and synergy between industrial, economic, educational and planning regulations and laws, which directly impacts in the STI policy programs and the resources to support them. At the meso level, the competitive and technological space ruled by standards, intellectual property rights, and non-firm support organisations is still under process of formation and the institutional setting is not always responding to specific sectoral needs and dynamics. At the micro level, there is a weak business sector in terms of dynamic innovation capabilities. As it is referred in the latest report of the OECD about the Colombian NSI (OECD, 2013), most of the innovation activities are carried out within the firms with poor or non-existent linkages with other actors of the system. When links exist, they are mostly with other firms within the sector, and the relationship with universities and research centres is limited to expand traditional activities of the firm, such as design and specific technological developments.

Overall, our results suggest that the Colombian NSI lacks of a shared vision or purpose to follow in the short, medium and long time framework. There are different agendas at the sectoral, regional and national levels that have been built up in isolation according to particular purposes. Thus, it is not surprising that there are misconceptions among the actors about the role and purposes of the non-firm organisations, the difference between competitiveness and innovation, and the role of science and technology as sources of wealth. In terms of the instrumentalisation of policies, since the vision is unclear, the strategies and priorities are disconnected. Therefore, incentives supporting measures and mechanisms to trigger sectors and regions do not follow a systemic approach either. Dominant agendas from each changing government deepen narrow and highly incomplete approaches towards economic development strategies. This affects the STI policy mixes and the resources supporting the previous and new policy programs. Without financial resources, plans and projects cannot be executed.

And finally, there is confusion between the innovation systems and the actors within them. The systems are not the agents, which have led to a generalised disinformation from actors about the availability of instruments to support the innovation processes and a tendency to believe that the only problem that the Colombian NSI has are the weak linkages between actors. This is what we mean when we say that there is not a NSI in the sense of a system, since there are poor connections - not only between the actors in the systems, but also between the main components or sub-systems. If there are not clear agendas to develop a national innovation strategy, there will be poorly aligned instruments that do not respond to a strategic vision. This is problematic and spills over from the national level to the regional and sectoral levels. A graphical representation of these dimensions can be seen in figure 7.2.

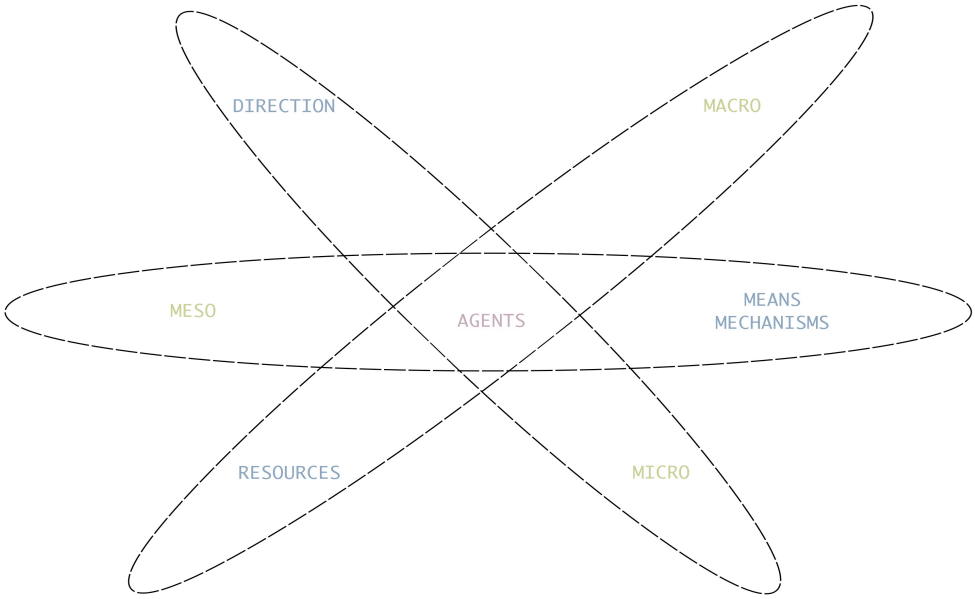

Figure 7.2. NSI levels and functional blocks

Source. Made by the author based on (Katz, 2001) and (Santiago Echavarría, personal communication, March 16, 2012)

The utility of the national policies and a national system of innovation, as an enabling framework to encourage and promote innovation networks between different national, regional, and sectoral domains, have not been completely fulfilled during the years. Table 4.7 (Investment in S&T as percentage of GDP proposed by several public documents) suggested a long inconsistency between formal policies and their implementation. This is exemplified by the fact that, even though from 1994 the national goal was to increase the investment in S&T to 1% of GDP, in 2012 the joint investment in R&D and S&T activities did not surpass 0.62% of GDP. This inconsistency and lack of coherence between policies has affected the connection of the macro, meso and micro levels. National strategies have not been successful enough to reach productive sectors; therefore, most sectoral industries have developed technical capabilities and innovation niches on their own, separately from the national dynamics. The latter approaches are much closer to the earlier ECLAC approach followed by Latin America during the 1960s and 1970s to promote competitiveness from the firms, having a profound insight of the value chains and intervening specific links within them. The aim was to focus on changing production patterns at the firms level to enhance social equity (Economic Commission for Latin America and the Caribbean ECLAC, 1990).

Our findings suggest that a significant part of the success of the three sub-sectoral cases can be explained by the development of their own R&D centres and their own knowledge transfer, appropriation and validation dynamics. Corpoica, the Colombian Corporation for Agriculture Research, has not only been an unimportant source of support for the three production chains we studied, but also competes with them for financial resources from the public sector. The richness of the empirical cases under study showed that the weak and dysfunctional national system is not an indicator of failure at sectoral levels. Policy instruments gaps and lack of support to build technological and scientific capabilities have been overcome by sectoral actors through different governance patterns and the construction of R&D centres supported by producers associations.

We found little evidence to support the proposition that national policies embedded in the so-called Colombian NSI had succeeded in overcoming the lack of innovation in the industrial system. The NSI, as a general framework, was thought to provide enabling conditions in which firms and sectors could build their own competitive advantages. The NSI approach emphasises the need to have an effective knowledge generation system coupled with the interaction of diverse actors that could use, adapt and exploit that knowledge to compete successfully in the marketplace. However, evidence suggests that the Colombian NSI has failed, given the lack of a key foundation in terms of a strong research system and industrial support infrastructure. Crucially, as our research has shown, it only has weak links and connections with the innovation structures and governance systems of the industrial sectors with their particular dynamics. We can say that the construction of the system has been artificial and policies have been focused on parts of the system that are just under construction. Therefore, we can understand why the system goals have not been achieved.

The influence of good and bad practices cannot be seen in the inverse case. We only studied three sub-sectoral cases within the Agro-industrial sector. However, with the analysis of the data collected, we could not find bottom-up permeation from the sectoral to the national spheres. Although agriculture research centres cooperate between them, their successful knowledge generation, transfer, appropriation and validation practices have had a reduce influence in the innovation dynamics of other industries and have not contributed to learning policy processes at the national level. When we carried out the second specialised focus group - where national and sectoral actors participated and showed their advance towards innovation - many industrial, academic and public agents were surprised of the existence of validated models to promote innovation at the sectoral level. There are weak learning cycles integrating national and sectoral experiences and providing feedback to practices at both levels.

Nevertheless, we cannot say that the State intervention, funding and legal framework to provide a suitable environment for promoting innovation has been a total failure. A long trajectory of political thought and action cannot be disregarded as completely obsolete or ineffective. We emphasised throughout this thesis that innovation is the result of the interaction of complex dynamics between social agents that have their own agendas and political interests, where decisions are taken under incomplete knowledge dimensions. If we accept that dynamism, uncertainty and complexity dominate today's world (Leach et al., 2010), this cautions us against taking a simplistic and linear reading of messy, fuzzy and constantly changing contexts. Unfortunately, although the Colombian White Papers for STI policies emphasise the systemic character of innovation, the instrumentalisation strategies followed by policy-makers reflect a linear approach. Public funding for innovation has been always higher than the investment for S&T activities and R&D from the private sector[158], and the State has invested steadily in basic research for fundamental areas such as health, agriculture, oil and mining, ICT and biotechnology. In this sense, we recognise the role of the State in the establishment and strengthening of the knowledge generation side of the innovation system, but found profound deficiencies in the support and design of effective means and mechanisms for the knowledge exploitation system. Without doubt, the State has had an active role in shaping the scientific and technological trajectory that has led to innovation in different sectors. It has not been a mere entity to 'fix market failures' or to just 'nudge' the private sector to facilitate innovation, as happens in all countries (Mazzucato, 2013). The Colombian State has had an active role to promote innovation, but the expected outcomes have not been achieved yet and the efforts have been insufficient.

Therefore, the (top-down) national STI policies have been theory-driven in terms of the declaration of the existence of a National System of Innovation, and practice-driven at the (bottom-up) sectoral level in order to respond to particular needs of firms and market interactions. The connection between them is limited and not efficient. However, it is clear from this study that sectoral innovation dynamics have been effective within the circumstances of their particular value chains, which have kept the sectors under study as viable in the national and international markets. We believe that sectoral studies need to be taken into account in the construction of national policies since they can give an account of real systemic innovation dynamics and learning cycles to produce contextualised knowledge.

7.3. Contributions to Theory

The conceptual and formal definition of the Colombian NSI follows the general guidelines of the NSI approach. However, intended development trajectories specified in the strategies and goals of the NSI have not been achieved. There are clear functional and structural failures. The OECD model for having national systems of innovation could not be applied as had been expected in most developing countries, certainly not in Colombia. In Latin America an alternative analytical

[158] The average of public investment 2002-2012 from public sources for S&T activities was 52.36%, and 54.73% for R&D, with a counterpart of 44.07% and 40.30% respectively from the business sector (Lucio et al., 2012).

approach to the study of innovation began from the micro level, looking at the firms, understanding the factors that make enterprises innovate. Afterwards, the tendency migrated to the integration of technical change and role of innovation in the economic growth of countries at the macro level. The Latin American economists and policy-makers focused their attention on the generation and propagation of technical progress to boost productivity, drawing attention to genuine and spurious competitiveness and the systemic nature of innovation (Economic Commission for Latin America and the Caribbean ECLAC, 2008). This line of thought was part of the Latin American Structuralism Approach (LACSA). After the period known as the 'lost decade' for the LAC region, when import substitution-led industrialisation failed and the intended gradual economic openness to maximise the economy performance exhibited flaws in its structural change, the NSI approach emerged as a response to the dominant neoclassic macroeconomic measures where general equilibrium was assumed and the role of the State should be reduced to correcting market failures. In this vein, when the approach started to be popular within the political circles, mainly in Europe with the impulse given to it by the OECD, its diffusion as a political and social artefact began. In the 1990s, most of the LAC countries included the general guidelines of the NSI in their STI policy construction, leaving behind the emphasis put by LACSA in the generation of technical change from the industrial system, intervening at the sectoral level.

We advocate for having an alternative *Weltanschauung,* or worldview, to understand the particularities of the south region in order to design contextualised STI policies beyond the reified NSI approach. Hybrids and borderlands need to be built in developing countries (Delvenne & Thoreau, 2012). Our study shows that the NSI approach - in its generic and narrow reading - does not consider particularities and complexities of developing economies and social problems, such as the sustained internal conflict and high levels of corruption, as is the case of Colombia.

We only partially agree with Delvenne and Thoreau (Delvenne & Thoreau, 2012) on directing the attention to the construction of a world-system analysis to enrich the NSI approach. We support the initiative to look beyond the nation-state borders, in the understanding that global value chains - where the national and regional sectors are involved - are predominant in a globalised world. We also believe that the division between northern and southern countries in terms of economic performance, industrialisation and urbanisation, among other criteria, has been encouraged by the NSI when calling for normative indicators that ultimately give a major relevance to the countries' GDP growth. Nevertheless, we advocate strengthening local views and analysis of innovation within sectors and particularly to the firms' level. If it is true, as we have shown with our case studies, that innovation is path-dependent and can get lock-in to certain actor's practices, we encourage integrating further the NSI approach with regional and sectoral innovation systems without losing the broader global dynamics.

The NSI approach has evolved over time with the inclusion of new economic realities, social movements, environmental pressures, and lately has begun to take account of national innovation dynamics in newly industrialised economies and in developing countries. However, flaws remain in its understanding and in its utility as a political device. It is important to turn our gaze back to the roots and ask; science and technology for what? As it is presented in the NSI approach, S&T lead to industrial innovation, which in turn brings wealth generation, that can be measured in GDP growth, so there can be social distribution of economic growth and innovative solutions to solve everyday problems; ultimately, in the case of developing economies, to contribute to overcoming social obstacles that cause social inequality and to change the unfavourable geopolitical situation of remaining on the periphery of the world economy.

However, we argue that this is a linear view of progress and social welfare. We can see a reduction in complexity and a linear reasoning on the impact of effective STI policies. Although science, technology and innovation are thought of in a systemic way, where several actors and components interact to maximise technical progress, the intended results from this system evolution is perceived as another link in the development race. The pitfalls of neoclassical economics prevail when it comes to the social effects of innovation in countries.

Certainly, the NSI approach fails to provide strategies to contexts where initial basic conditions[159] implicitly taken for granted are missed. This can be explained by its origin as an analytical device to explain the way innovation was impacting the economic progress of industrialised and developed economies and used afterwards as a political device to encourage particular strategies for countries from the North. Although the approach focuses on the encouragement of innovation and on technical progress and does not have to give account for every social and political problem, it lacks robustness to deal with countries from the south. We therefore encourage a deeper and explicit bottom-up study of innovation dynamics that takes context into account.

The NSI became, for Latin American countries and for Colombia in particular, an omnipotent approach to understand and to design STI policy. As Sharif (Sharif, 2006) noted, the approach acquired an air of inexorability and appeared to be the best, and only, theoretical and practical framework to promote successful innovation patterns in privileged industrial sectors. It seems that the region is locked-in to the NSI approach. Even when Latin American scholars have pointed out the deficiencies of the systems of innovation (SI) approach in dealing with the complexities and particular historical and economic trajectories of the countries of the region, the analysis and proposals keep standing within the SI base (Delvenne & Thoreau, 2012). It seems that use of the same political language from the Northern countries is beneficial for the economic and political interests of the region, but at the same time continues the replication of dominance from one part of the hemisphere over the other.

What is certain is that a narrow version of the NSI approach has been used in the LAC region, which was driven by the OAS and UNESCO first and then supported and maintained over time by the OECD. Standardized indicators only recognize the production of knowledge in terms of R&D, patents, scientific production, technology-base companies, and expenditure in science, technology and innovation. It is true that there must be measures for comparing the level of innovation of

[159] Transport infrastructure, effective labour system, quality and maturity of the research and education system, degree of corruption in public and private negotiations, internal political and social problems.

countries and sectors, but these types of indicators are simplistic and do not add much in terms of understanding good practices, relationships between users and producers, and different types of learning, production and exploitation of knowledge.

Ultimately, we highlight that since the NSI is an approach and not a theory, with this viewpoint supported by many of the main scholars developing the concept, it is important to bring more case studies to strengthen its theoretical corpus. By highlighting differences in regional contexts such as Latin America and particularities of developing economies with deep social and political problems such as Colombia, we are extending the scope of the approach.

We face two complementary postures. On the one side are those who seek to replace the NSI lens with other perspectives that can bring together different realities and particularities of developing economies (which present very different historical and technological trajectories to those in the developed countries where NSI emerged) and that offer other analytical devices and intervention methods when it comes to STI policy building and supporting instruments to promote innovation. On the other hand, we see attempts that seek to retain the NSI approach as an analytical base but that attempt to revise, elaborate and strengthen it through more case studies in peripheral countries.

The sectoral systems of innovation approach can be also extended to deal with more detailed cases where particular non-market institutions play a central role in the evolution of innovation patterns within the firms. In sectors such as agriculture, the basic units are not just 'firms' (and firms themselves differ enormously between SMEs, large firms and MNCs), but include more particularly the producers or growers (who may have very different organisational structures). When we have sectors that are immersed in and are highly dependent on international market interactions, the State is called upon to play an active role to protect the industries in their infancy and promote innovation through diverse incentives and instruments afterwards that help them to balance their internal catching-up processes with healthy marketplace pressure. The complexity of innovation in a globalised world requires expanding the scope of analysis and intervention to specific local dynamics and their connection with world trade systems.

Hence, keeping the analysis within a national boundary does not give account of sectoral innovation dynamics and their connections with the international marketplace. We found that a deeper understanding of the industries, the actors involved in the value chains and their historical, cultural and economic context, are crucial to give account of their evolution and to trigger their innovation pathways. Policy-makers are locked into national views of innovation that have a mismatch with sectoral realities; as a result, STI policies in Colombia have not penetrated industrial needs. Therein, national and sectoral policies are not in tune to promote higher business innovation to make firms more competitive both at national and international levels.

In summary, we have sought to understand the effectiveness or failure of the innovation systems in their national context, and explore the distinctive relationships between industrial players. When looking at the industrial players, we found very distinctive dynamics within each sub-sector that were rooted in the geography, political history, social structure ownership, governability and governance, supply chains and the place of each production chain within the economy. This study has engaged with two dimensions. Initially we focused on the development and implementation of the NSI policy framework as the enabling artefact to promote or hinder innovation at national and sectoral levels. However, that was not enough. We therefore sought to analyse innovation dynamics within industrial sectors. To achieve this, we encountered the need to incorporate perspectives from sociology, ethnographic and historical research to supplement the vanilla generic NSI models. The NSI, as currently cast, does not have tools to engage with these dimensions, and that is why innovation studies need to be complemented with other research areas.

7.4. Contributions to Practice

Our study followed the premise that policy building is not a single process. Multiple narratives and policy framings are present during the processes of definition, implementation and assessment of policy outcomes. In this section, we present contributions for practitioners and policy makers in charge of design and implementation of STI policy mixes, although the recommendations can be generalised to any kind of policy processes.

In terms of political institutions, we found that there is a tension between the heavily formalised political and legal Colombian framework and its translation to practical policy mixes. There is a gap between policy definition and policy implementation. Even though there is a formal declaration of a National System of Innovation and a National Agro-industrial System of Innovation, in practice, policy initiatives follow a linear innovation model based on science push. Colombian policy-making shifted from neo-liberal policies focused on market mechanisms that were hoping to promote competitiveness to a systemic approach to innovation. This was in some respects rhetorical - in the sense of aligning with the dominant political narratives of transnational organizations as the OECD. The means and mechanisms proposed are not systemically developed and have not strengthened the fundamentals of the Colombian NSI as the education and industrial sub-systems. On the other hand, the governability structure is weak, given the lack of power decision of the councils, the low representativeness of members that end up attending the councils and an unbalanced participation of the tripartite forces with a strong academic sector, a disinterested business sector and a low strategic vision from the public sector. Instead, successful bottom-up innovation dynamics are emerging at the sectoral level.

We found networks at the sectoral level supported by collaboration relationships between members of the production chains as a mean to optimise resources and social benefits. Governance trends are not exempt from mediations of power between dominant players, social systems are complex and at the same time adaptive. Nevertheless, bottom-up initiatives of distributed governance between main innovation players take place at the sub-sectoral and sectoral levels. Once again, we emphasise the importance of having a bottom-up approach towards innovation dynamics and the social, political and economic dynamics shaping it.

We found that Colombian policy-makers are reactive rather than strategic. There is a lack of long-term vision - a product of the continuous changing of priorities of every government -. There is not a clear strategy and neither the means nor mechanisms to materialise national priorities of investment and development. In short, there is a lack of consistency between state and government policies, national and sectoral policies and industrial, education and STI policies. Without a level of synergy to achieve a consensus view of the country, efforts will keep responding to temporal problems and interests of powerful actors without continuity in time. Also, this identifies the tension between public agencies to encompass as many resources as they can, using the label of innovation. There is not clarity about what is the leading national agency in charge of innovation policy and the collaborative work with other agencies to achieve a common purpose. There is tension between ministries and regional agencies to co-ordinate innovation programs.

On the policy side, we find a tendency in Colombia to think that failures and weaknesses of policies are to be improved through more policies. This is a policy-making fallacy. Since there is a "linear-plus" thinking towards policy building processes, formal definition of laws are made following a "rational" criteria to solve perceived and well-defined problems. However, when it comes to the implementation and assessment of intended outcomes of national and sectoral policies, policy-makers are reactive and take a long time to adapt to real scenarios and to learn from strengths and weaknesses of previous political programs. In most cases, policies are changed and shaped informally by the actual recipients. One clear example of this is the formal institutional upgrade of Colciencias through the years (see figure 7.3.). One of the main changes of the S&T law of 2009 is the higher administrative level of the agency, giving its status as an administrative department that has power as a ministry. However, in reality the Administrative Department not only does not have a higher budget, but its budget has been reduced and its action has been limited. This suggests an ongoing inconsistency between formal and informal political institutions, with formal policies operating in practice as an isolated silo.

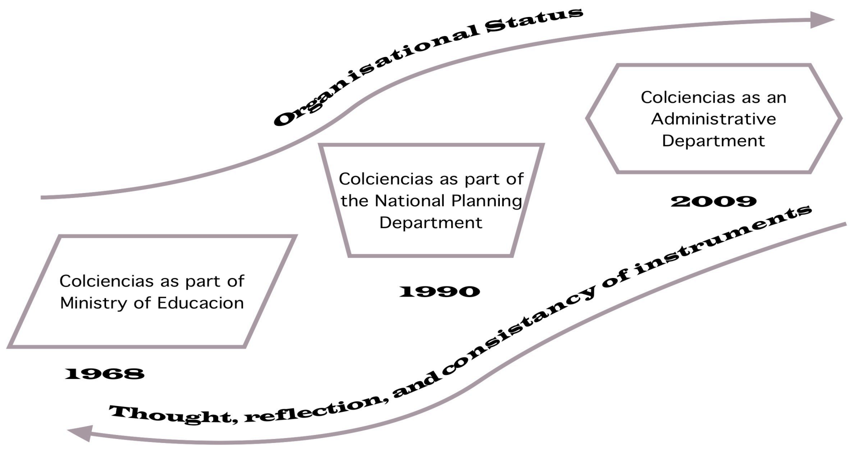

Figure 7.3. Colciencias organisational status transition

Source. Made by the author.

It was recognised in CONPES 2739 of 1994 that:

> Although market opening and liberalization of the economy generates more pressure on innovation and technical change, this opening is not a sufficient factor in itself to ensure the development of an innovative and dynamic productive sector. The formulation of appropriate macroeconomic and sectoral policies plays a crucial role in the generation of effective demand that fosters a close relationship between science, education and development. (DNP, 1994, p. 20)

The above statement stresses the importance of having coherence between national and sectoral policies and their impact on the kinds of relationships forged between the education, productive and economic systems. It is important, from the policy-making side of the system, to offer policy mixes that incentivise the demand of knowledge and technological services from the business sector in order to support a higher level of competitiveness and dynamism in the marketplace.

In terms of accessibility to resources, incentives and instruments, the linear-plus thinking is clear when most of the instruments[160] are focused either on the research side or on the commercialisation side. There is little to support the systemic

[160] Categorised in instruments for: R&D projects, human resources training, tax incentives for research and innovation and other kinds of support (Look at figure 4.7.)

processes of production of knowledge, use, test, implementation, adaptation and validation of applied knowledge and technology. There is also a major problem about the coverage, diffusion and use of the available instruments.

We found that enterprises have a low use and trust in public instruments and incentives. The main problems identified by businessmen, when asked about the low use of the available mechanisms to help their internal innovation processes, were: ignorance of the available instruments; lack of information about the requirements to apply to them; and the long and complicated process to apply to them, with the risk of not gaining the allocation of resources or incentives.

We identify that innovation policies should not be thought of as substitutes for social and industrial policies. STI policies are complementary with other national policies; moreover, they rely on having certain minimum conditions covered in order to maximise the potential and impact of strategic national plans. Insufficient mobilisation of human capital, a stagnated business sector, high levels of business informality, and low investment in publicly funded research impacts negatively on STI policy programs. There should be alignment of forces and definition of particular strategic sectors to invest in and to promote so the already scarce resources can be allocated in the best possible way, maximising their impact.

Finally, we identify that an excessive formalisation of political institutions, rather than bringing better policy programs, has led to the circumvention of laws by actors in the system. There is a proclivity to find ways to escape the rigid limits of laws, that ends up giving more power to actors that are already powerful and that can exert pressure on the policy system. This has also meant that informality prevails in practice, resulting in a non-transparent action space. This could be overcome through a more participatory policy-making process with the intervention of sectoral actors. There is a common complaint about the design of STI policies and instruments, where actors are only informed about changes in the legislation and programs, without any real participation in the policy design process. Such involvement could also help to rebuild trust in public institutions. Colombia, having a long-term violence problem and a high index of corruption, presents a particular setting where the construction and implementation of STI policies is more challenging and complex than other contexts. These specificities need to be taken into account.

So why is it that in Latin America, and specifically in Colombia, having diverse conceptual and empirical studies, it is so difficult to design and implement STI policies? Sagasti says: “It is possible to see a disconnection between the ideas and the science and technology political praxis” (Sagasti, 2010, p. 1). We think that Colombia has very particular social and political threats that make even more complex and uncertain the processes of policy construction.

7.5. Limitations, extensions and lessons for the future

We consider it important to reflect on the research choices made during this doctoral journey and their consequences for the new knowledge generated. We explained that when we started this research, we were drawn into the systems of innovation approach, since the formal institutionality to build STI policies in Latin America and Colombia used the NSI approach as a political artefact to shape the processes of policy development, implementation and outcomes assessment. However, we retained an analytical distance from our object of research. In part this was based on the generic principle of the system approach, which emphasises that this is just one way among many analytical means to understand reality, and that it is therefore important to make explicit the view of the analyst (consultant, policy-maker, academic, member of a non-market organisation) when understanding and defining the situation under analysis. We recognise that the system view is an idealisation of a desired outcome, but has shortcomings since it cannot completely explain the complexity and variable dynamics of the social systems. In other words, it does not represent a complete analytical model and it is not the only, nor always the best, way to promote innovation in the business sector.

We believe that in order to integrate sectoral innovation dynamics and to analyse their connection with global value chains, more sectoral studies are needed. In interviews with relevant national actors, we found a common claim to have systemic instruments coupled with human and financial resources to invigorate the Colombian business sector. It seems that the NSI approach - in the way that it has been used in the Colombian political arena - has failed to give account of the business dynamics and needs, as the core of any innovation system. Although policies can never be regarded as optimal (Foray, 2009), we question the suitability of the NSI approach towards the construction of STI policy mixes. A broader analysis of sectors recalled as strategic by different White Papers, could give a more solid base to reflect about structural and functional changes to support and promote innovation more effectively. A comprehensive view of industrial sectors, and sub-sectors within them, can bring a wider impact on the understanding of the trajectory and intended outcomes of the Colombian STI policies. It is also beneficial to open new debates about the conceptualisation and instrumentalisation of innovation strategies that can bring wider social impacts, privileging the social distribution of wealth and therefore welfare over the ultimate goal of economic growth at any cost.

During our fieldwork, we gathered information about a new policy to fund science, technology and Innovation in Colombia. However, since the initiative is very new, we could not include its operation and outcomes in our research. In 2011, the national government decided to invest 10% of mining and petroleum royalties in projects for development of S&T capabilities in the regions. The distribution was formalized with the legislative act Number 5 of July 18th of 2011, which enacts that 10% of total incomes produced by regional royalties are invested in a Science, Technology and Innovation Fund that has representation from public national and regional entities, universities and the business sector.

However, the mechanisms to allocate those resources are not clear to the actors of the system. The resources have to be invested in the regions where the royalties come from, which not coincidentally are those with lower productivity rates and social equity, and present higher rates of violence and corruption. If well managed, these resources can generate higher regional development and competitiveness to the most economic and social depressed areas of the country, so there is need of research in this area. Nonetheless our analysis raises doubts about the design of policy programs following the same rationale and within the boundaries of the NSI approach.

In terms of further research, at a general level, more comparative research between sectors and regions across peripheral countries is also needed with a prevailing qualitative base. Innovation processes involve more than normative performing indicators. In order to understand complex and uncertain social dynamics that govern the political and economic space, researchers have to examine the actual interactions between actors at the core of the so-called innovation systems, individuals and firms that create the progress of sectors and countries. In order to strengthen the use of the systems of innovation approach as a boundary object used by different epistemic communities, we support the line of reasoning of the scholars working on this research area that promotes a flexible understanding and application of the approach both at the academic and the political levels.

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APPENDIX I: NVIVO PROJECT SUMMARY REPORT

Hierarchical Name	Item Type	Created By Username	Created On	Modified By Username	Modified On

Memos

Hierarchical Name	Item Type	Created By Username	Created On	Modified By Username	Modified On
Memos\\Agriculture System	Memo	dianavelasco	08/05/2013	dianavelasco	18/01/2015
Memos\\Cambiar forma de pensar el sistema	Memo	dianavelasco	29/11/2012 17:51	dianavelasco	12/02/2014 03:24
Memos\\Coding process	Memo	dianavelasco	24/09/2013	dianavelasco	18/01/2015
Memos\\Coffee sector	Memo	dianavelasco	30/06/2014	dianavelasco	08/09/2014
Memos\\Colciencias	Memo	dianavelasco	05/05/2014	dianavelasco	05/05/2014
Memos\\Documentary Analysis	Memo	dianavelasco	20/07/2013	dianavelasco	07/03/2014
Memos\\Flowers sector	Memo	dianavelasco	15/06/2014	dianavelasco	25/01/2015
Memos\\Interview analisys notes	Memo	dianavelasco	01/11/2013	dianavelasco	08/12/2013
Memos\\Introduction	Memo	dianavelasco	03/02/2015	dianavelasco	12/02/2015
Memos\\Literature Review	Memo	dianavelasco	19/08/2014	dianavelasco	30/01/2015
Memos\\Project Journal	Memo	dianavelasco	05/03/2013	dianavelasco	18/01/2015
Memos\\Research Proposal Boarding Panel v 2	Memo	dianavelasco	19/06/2013 10:14	dianavelasco	19/06/2013 10:14
Memos\\Sugar cane	Memo	dianavelasco	31/05/2014	dianavelasco	24/08/2014
Memos\\System Analysis Models	Memo	dianavelasco	15/11/2012	dianavelasco	15/11/2012

Nodes\\Documentary Analysis

Hierarchical Name	Created By Username	Created On	Modified By Username	Modified On
Nodes\\Documentary Analysis\\Agriculture	dianavelasco	21/07/2013 00:28	dianavelasco	15/08/2013 18:59
Nodes\\Documentary Analysis\\Institutions	dianavelasco	21/07/2013 00:55	dianavelasco	18/04/2015 13:04
Nodes\\Documentary Analysis\\Policy Processes	dianavelasco	18/04/2015 13:01	s1100389	24/04/2015 14:25
Nodes\\Documentary Analysis\\Policy Processes\\Assessment	dianavelasco	21/07/2013 00:07	dianavelasco	07/03/2014 03:40
Nodes\\Documentary Analysis\\Policy Processes\\Education	dianavelasco	28/07/2013 17:22	dianavelasco	07/03/2014 03:40
Nodes\\Documentary Analysis\\Policy Processes\\Entrepreneurship	dianavelasco	15/08/2013 17:52	dianavelasco	15/08/2013 17:52
Nodes\\Documentary Analysis\\Policy Processes\\Funding	dianavelasco	20/07/2013 22:30	dianavelasco	07/03/2014 03:49

Nodes\\Documentary Analysis\\Policy Processes\Incentives	dianavelasco	20/07/2013 22:34	dianavelasco	22/11/2013 18:16
Nodes\\Documentary Analysis\\Policy Processes\Regulation	dianavelasco	23/07/2013 23:06	dianavelasco	17/08/2013 14:57
Nodes\\Documentary Analysis\\Policy Processes\S&T Capabilities	dianavelasco	28/07/2013 19:35	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\Policy Processes\Social appropriation of S&T	dianavelasco	20/07/2013 22:39	dianavelasco	05/05/2014 23:10
Nodes\\Documentary Analysis\\Policy Processes\ST&I public and private investment	dianavelasco	21/07/2013 00:21	dianavelasco	18/08/2013 12:20
Nodes\\Documentary Analysis\\Policy Processes\State responsability for promoting STI	dianavelasco	20/07/2013 22:04	dianavelasco	13/08/2013 16:01
Nodes\\Documentary Analysis\\Policy Processes\Strategies	dianavelasco	21/07/2013 00:38	dianavelasco	18/08/2013 16:05
Nodes\\Documentary Analysis\\Policy Processes\Strategies\Colombia construye y siembra	dianavelasco	08/08/2013 17:12	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\Policy Processes\Strategies\CONPES 3882	dianavelasco	13/08/2013 15:42	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\Policy Processes\Strategies\Prog Endogenizacion de la S&T	dianavelasco	31/07/2013 17:40	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\Policy Processes\Strategies\Prog Transformacion Productiva	dianavelasco	05/08/2013 23:27	dianavelasco	05/08/2013 23:51
Nodes\\Documentary Analysis\\Policy Processes\Strategies\Vision 2019	dianavelasco	06/08/2013 13:27	dianavelasco	07/08/2013 16:42
Nodes\\Documentary Analysis\\Supporting nodes	dianavelasco	18/04/2015 13:09	s1100389	24/04/2015 14:26
Nodes\\Documentary Analysis\\Supporting nodes\Bright Ideas	dianavelasco	28/07/2013 17:33	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\Supporting nodes\Definitions	dianavelasco	01/08/2013 11:54	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\Supporting nodes\Diagnostic	dianavelasco	04/08/2013 14:24	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\System structure and function	dianavelasco	20/07/2013 23:10	s1100389	24/04/2015 14:26
Nodes\\Documentary Analysis\\System structure and function\Innovation	dianavelasco	22/07/2013 12:43	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\System structure and function\Intelectual Property	dianavelasco	22/07/2013 19:45	dianavelasco	17/08/2013 15:11
Nodes\\Documentary Analysis\\System structure and function\Intermediaries	dianavelasco	23/07/2013 23:14	dianavelasco	07/03/2014 03:49
Nodes\\Documentary Analysis\\System structure and function\Knowledge	dianavelasco	30/07/2013 00:47	dianavelasco	15/08/2013 15:09
Nodes\\Documentary Analysis\\System structure and function\Strategic Sectors	dianavelasco	23/07/2013 19:56	dianavelasco	06/05/2014 23:00
Nodes\\Documentary Analysis\\System structure and function\Strenghts	dianavelasco	05/08/2013 17:51	dianavelasco	08/08/2013 17:46
Nodes\\Documentary Analysis\\System structure and function\Sustainability	dianavelasco	30/07/2013 00:59	dianavelasco	08/08/2013 17:43
Nodes\\Documentary Analysis\\System structure and function\Systems of Innovation	dianavelasco	18/04/2015 13:05	dianavelasco	18/04/2015 13:05

Nodes\\Documentary Analysis\\System structure and function\Weaknesses	dianavelasco	23/07/2013 23:15	dianavelasco	07/03/2014 03:49

Nodes\\Interviews and Focus Groups

Hierarchical Name	Created	ByCreated On
Nodes\\System\\ Policy Processes	dianavelasco	10/09/2012 01:49
Nodes\\System\\ Policy Processes\Assessment	dianavelasco	16/11/2013 23:53
Nodes\\System\\ Policy Processes\Colciencias	dianavelasco	10/09/2012 02:08
Nodes\\System\\ Policy Processes\Councils	dianavelasco	29/11/2012 14:34
Nodes\\System\\ Policy Processes\Definition, application, evaluation	dianavelasco	10/09/2012 01:53
Nodes\\System\\ Policy Processes\DNP	dianavelasco	14/11/2013 14:33
Nodes\\System\\ Policy Processes\Evolution	dianavelasco	15/11/2012 22:17
Nodes\\System\\ Policy Processes\Incoherence	dianavelasco	05/11/2013 15:06
Nodes\\System\\ Policy Processes\Instruments	dianavelasco	10/09/2012 01:50
Nodes\\System\\ Policy Processes\Models	dianavelasco	11/11/2013 23:01
Nodes\\System\\ Policy Processes\National Innovation Strategy	dianavelasco	15/11/2013 08:23
Nodes\\System\\ Policy Processes\Politics of policy	dianavelasco	20/11/2013 18:22
Nodes\\System\\ Policy Processes\State vs. Government	dianavelasco	29/11/2012 14:04
Nodes\\System\\Actors	dianavelasco	15/11/2012 21:47
Nodes\\System\\Actors\Businessmen	dianavelasco	04/03/2013 16:56
Nodes\\System\\Actors\Intermediaries	dianavelasco	13/03/2013 15:40
Nodes\\System\\Actors\International Networks	dianavelasco	15/11/2012 22:03
Nodes\\System\\Actors\Perception of Value	dianavelasco	03/12/2012 16:11
Nodes\\System\\Actors\Politicians	dianavelasco	04/03/2013 16:09
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APPENDIX II: SPECIALISED FOCUS GROUP – FIRST PHASE

Specialised Focus Group about the Evolution and Effectiveness of ST&I Public Policy in Colombia (Bogotá, December 6, 2011)

Although I had problems with the workshop date (That day there was a national protest and all people arrived to the central downtown square, very near Universidad del Rosario were the workshop was, so arriving and leaving was very difficult that day), there was a good assistance. I had representation of the three sectors, academia, private and public.

The agenda was:

Time	Activity	Responsible
8:00 a.m.	Opening. Explanation of the objectives and dynamics of the event	Diana Velasco
8:15 a.m.	Identification of barriers that diminish the effectiveness of ST&I policies – Carousel	Participants
9:00 a.m.	NSSTI future visions. Construction of ideal scenarios – Metaplan	Participants
10:00 a.m.	Coffee Break	Participants
10:30 a.m.	Articulation of the key players within the NSSTI. Knowledge flows between firms, universities and government - Thinking hatas.	Participants
11:30 a.m.	Main conclusions and building agenda for future meetings	Diana Velasco
12.00	Closing	Diana Velasco

Conclusions from each of the workshop sessions

Identification of the major barriers that diminish the effectiveness of policies for STI - Carousel

Carousel: 3 flipcharts were positioned at stations around the room each headed with one different but related question. There was the same number of groups as questions. The groups rotated around the stations until each one was visited. Each successive group had a different colour marker pen for recording their answer to the questions. The idea was that each successive group reflects on, elaborates and adds to the answers of the previous groups, so producing a fairly comprehensive view in a short period of time.

Question 1: Do you think the current STI policy framework is sufficient, appropriate, and consistent to the Colombian context?

The answers to this question can be classified into four categories.

The first category relates to the *coherence of public policies on ST&I with other political systems.* It is considered that there is no real link between S&T policies with economic, social, and industrial policies. There was also mentioned a governance problem of the NSI. Although there are laws, decrees, rules, systems, each ministry and incoming government interpret policies according their convenience, which leads to interference in policy implementation and long-term strategies. There is a serious problem with regard to the prevalence of short-term government S&T policies in contrast to state vision, which involves long-term planning. Participants argue that previous S&T Law (Law 29) was implemented successfully and that it produced good results with regard to S&T capacity building. It is argued that the content and structure of this law is much better than the current S&T Law (Law 1286 of 2009), as the last did not cover previous law gaps, either is driving any advance over the previous law.

As a second aspect of discussion, it was said that there is not enough *human resources* to sustain NSI bases. Looking at the data from the latest national manufacturing survey, it can be determined that staff education level in the industry is not concentrated in the higher education levels. This is also reflected in the low number of patents the country has. Some participants argued that copyright law is not strong enough to encourage researchers to produce more and better knowledge. Other actors controvert this criticism, arguing that the problem is not the content of the law, but the way it is understood and executed.

There was also discussion about *Francisco José de Caldas Fund* of Colciencias for training of human resources. Some participants argue that the background is not sufficiently flexible in allocating resources, and it is falling short in attracting resources from other funding sources while it is not increasing the S&T budget.

Finally, there were several criticisms about the current *ST&I funding*. The government's strategy to increase funding for S&T through royalties is considered not suitable for development on S&T capabilities of earmarked funds. It is considered that S&T must be funded through the national budget. Science should be clearly in the public agenda and should not be dependent on particular public and private actors.

Question 2: What are the main problems, barriers or challenges the NSSTI has today?

A recurring problem mentioned by the groups, focuses on the *failures for defining and implementing public policies.* There is a lack of continuity and consistency in policy definition. This can be seen in the inconsistencies between policies, strategies and instruments. Another issue that arose in this question was the absence of government policies that would allow a long-term vision, since there is a prevalence of government policies.

Another problem concerns the *policy makers' lack of knowledge about science and its dynamics.* There is an absolute absence of research and reflection on the conceptual body of S&T policy. Therefore, there is not feedback to the public sector in its policy-setting exercise. Whilst the social imaginary of science remains as an isolated aspect from social life, there will be a gap between policy and the science practice.

The *lack of financial resources for investment in S&T* affects the generation of innovation. One way to increase investment in S&T could be through greater investment from private sector, however, businessmen are not convinced that this investment will result in economic benefits, or an important differential for their economic activity. It is suggested by some groups to give greater tax incentives for R&D to overcome this problem. This would also help to mitigate investment risk. However, it was disagreement on this point, since the incentives exist and they have not been successful. It is suggested that the economic incentives should be accompanied by programs focused on the development of understanding and capacity building on S&T in the Colombian companies, being them small, medium or large. It is emphasized that the economic benefits and programs to promote capacity building, should reach SMEs, as at present, this type of initiative remains largely profited by big companies.

Question 3: Do you think there is a balanced participation of academia, public and private sectors for building and implementing ST&I policies?

The answer to this question is somehow outlined in the above ones. NSI actors are unlinked, which is evident in the unequal participation of them in the national, departmental and national S&T councils. The issues related to the understanding and use of S&T for innovation, is still relegated from the public agenda. In addition, there is an absence of pressure groups to keep alive the discussion about the importance of S&T to generate development in the country.

The institutional framework for S&T policy does not help to create links between actors. For example, efforts are replicated between the strategies of the National

Competitiveness System and the NSI, and sometimes initiatives from each system are contradictory.

It is clear that the public sector should undertake joint policy making exercises with stakeholders, as many of the policies developed in the last period are unfocused and do not respond to recipients and implementers needs. For the private sector, it is evident the low level of interest in S&T issues caused by the lack of knowledge about how S&T can impact productivity, and a low level of confidence in the effectiveness of S&T policies. The academic sector argues that there must be more and better reflection on the exercise of conceptualization and implementation of S&T policies and re strengthening of the science as a social activity.

NSSTI future visions. Talk about ideal scenarios – Metaplan

Metaplan is a two-stage exercise. The first involves individual brainstorming without judgement or interaction, to come up with 3 responses to a set of questions. The second stage is an interactive clustering exercise in which the whole group making decisions about which individual contributions sit together and what categories are appropriate. Metaplan was mixed with future visioning. There was set a question about the NSI future and then the metaplan exercise began.

The exercise begins with the following question:

It's 2019, and the NSSTI has evolved. Do you like the dynamics and outcomes that have been achieved. What are the three things you most pleased about what you see?

The workshop participants responses generated seven categories about ideal NSSTI states, which are detailed below:

- Coordination between actors

There is a strong and continuous work between universities and industry to strengthen clusters. This workflow has been achieved through a fluid, participatory structure between government, academia and the productive sector in public policy making. Policies are contextualized to the needs of individual sectors and the country's reality. This close relationship has been achieved through successful experiments on the participation of civil society groups about the definition of investment priorities for ST&I resources at regional and national levels.

The academic sector produces knowledge relevant and useful to the public and private sectors, resulting in successful cases of innovation. This was achieved by stimulating the production of knowledge aligned with the interests of national and sectoral development, through public policy. Thus, in 2019 there is a smooth coordination and articulation between policies, instruments and actors of the system, at local, regional and national levels.

- Definition and implementation of policies

Colombia has a state ST&I policy consistent with a solid long-term vision. There is coordination and integration between sectors, organizations and government officials, which is reflected on the definition and implementation of ST&I policies for the short, medium and long term. Thus, there is clearly a dynamic consistency between public policies in the country. Finally, the National Competitiveness System and NSI are highly coordinated. All this has been possible thanks to the strong institutions specialized on the design of efficient instruments, on the execution of resources, and on the identification of key actors demands.

- Sectors

New sectors have emerged based on productive innovation. The emergence of these sectors has been supported by ST&I sectoral policies. These policies are based on studies that identify country's competitive capacity at local, regional and international level. This was made through monitoring and prospective exercises. Result of these exercises, Colombia dominates the exploration and exploitation of natural resources and participates in leading sectors such as aircrafts and agribusiness.

- Science and Technology Observatory

The Observatory is structurally and financially consolidated for information management useful for long-term planning to guide the direction and political ST&I thought. This means the Observatory, in addition to produce S&T indicators, performs social studies about S&T in Colombia. Thus, the NSSTI is based on the knowledge and results produced by the centre.

- Social appropriation of science

Public understanding of science and the appropriation of it as a social process is central to the strategies of NSSTI. This is reflected on national, regional and local programs to popularize S&T dynamics. These programs respond to the central interest of bringing ST&I process to the public, showing how they respond to social needs.

- Funding

The investment budget in S&T exceeds the budget of war (armed forces). The country has evolved to have in 2010 8% of GDP spent on defense and 1% of GDP in S&T, to have at the time the reverse situation. But not only has increased public investment, it have also been created operational and private venture capital R&D funds.

- Number of human resources with higher levels of education

The number of highly qualified human resources has increased. Colombia went from being in sixth place in Latin America to be in second place in terms of number of doctoral graduates. These doctors, in addition to being concentrated in the universities and research centres, have been inserted into the productive sector and leading laboratories of R+D+i in the private sector.

Articulation of the key players within the NSSTI. Knowledge flow between firms, universities and government - thinking hats

Thinking hats: The underlying principle is that there are three ways of thinking about something (to which he attaches different colours):

Critical judgement (black): logic applied to identifying flaws or barriers, seeking mismatch.

Positive judgement (yellow): logic applied to identifying benefits, seeking harmony.

Creativity (green): statements of provocation and investigation geared to coming up with new ideas, seeing where a thought goes.

Participants began to consider three questions analyzed from these three different hats. They managed to answer the first two questions.

Q1. Does the current relationship between the academic, private and public sectors allow generation of knowledge that results in innovation?

Today, there is no coordination between sectors that results in knowledge generation. For example, nowadays there are not processes where the industrial sector expresses real needs to the academic sector with support of the public sector. Without an academic foundation, innovation clusters do not exist. But without a business sector that has the financial muscle, either. At the end, it can be said that there is not a fluid, long-range relationship among the three sectors.

But if you look at specific sectors, there are different scenarios. The case of agriculture, for example, shows an effective integration between the three sectors. This does not mean that there is not competing interests. But some productive chains have set up their own private research centres (e.g. sugar, rice) contributing to generation of relevant knowledge. This is complemented by the central role Corpoica (Colombian Corporation of Agricultural Research. Decentralized public organization) has for developing basic science that is transferred to the private sector. Although this relationship is not established completely, the agricultural case has been an example of integration. Another case where it can be seen a good coordination between actors in the three sectors, is in the hospitals. Today, the relationship between the university and the hospital is essential. High-level hospitals know this relationship is fundamental. A successful case is that of San Vincente de Paul in Rionegro, Antioquia. In this case, the driver was Antioquia's health cluster and there it can be seen a case of successful synergy between the private sector and academia. This is a successful example of strategic partnership between Proantioquia (Proantioquia is a non-profit, privately operated foundation, established in 1975 by a group of prominent entrepreneurs from Antioquia) and Universidad de Antioquia.

Then it is necessary and important to perform studies of successful cases to integrate learned lessons for replication elsewhere in the country. This can be done by economic sector (agriculture, health) and also by region (Antioquia). Nevertheless, it must be clear that trying to generate a single model for capacity building for the whole country, all regions and all sectors, it is not viable.

While the country does not consider case studies it will not learn. This must be done from social studies of science, which the country left. There is not a single call for promoting studies on science and technology policy. In the 70's there was S&T thought, not now. Again, it is important to study the sectoral success stories. These innovative cases occur despite the state. The second issue imperative to study, refers to the behavior of Colombian business. The current mistake of Colciencias is to believe that private sector is driven primarily from chambers of commerce. The success story of Antioquia is Proantioquia, not its chamber of commerce. Among the successful cases of joint regional actors can be counted on Route innovation in Antioquia, ICESI, Lili Valley Foundation. In the case of Valle de Lili Foundation (Hospital organization), the Valle (department or state of Colombia) business community know that without science, there is not dialogue with the nation. It is a different business thinking, so it is important to promote again these kind of studies. In these studies, it should include and give priority to small industry. The only social topic that is driven from the public sector is that of peace, the rest is left out, which is a costly mistake for the country.

Q2. Does the current NSSTI structure promote and encourage the formation of learning cycles to generate useful knowledge in the productive sector?

The system is not systemic. Successful experiences happen because of members of civil society, but not because the structure of the system facilitates these processes. However, it is a mistake to put on the head or structure of the system, a responsibility that goes far beyond the system. Those who create learning cycles are the companies and their networks.

However, it is important to boost from NSSTI different levels of science utility. Scientific activity has objectives that eventually may result in concrete application, but not necessarily start with a particular purpose. If there is not clear that all sectors of scientific activity should be supported with the same intensity and financial support there will not be S&T that allows innovation. For example, when Colciencias decides that only supports social research topics on violence and disasters, is receding. There is a total misunderstanding of what S&T as a social investment mean for the generation of innovation and development.

In this sense, the problem the country has is that always stays in form and not in substance. When talking about the system, we talk about a set of relationships, it is much more than just a formal issue. It is imperative to address the internal rules of the game, underlying articulations, dynamic consistencies or inconsistencies between public policies, beyond what is formally prescribed. Public policy is being captured by officials, maximizing the income of each institution. Then studies must go beyond the formal system.

Another aspect that must be developed is monitoring and evaluation of policies for policy design and building. Further impact studies should be made. There must be clear roles between design, implementation and evaluation of policies. The assessment documents are repetitive, and are not being used for feedback. If there is not research on the dynamics of S&T, it is impossible to learn. However, although impact assessments are made and cost large amounts of money, the evaluated programs and policies change or disappear before results are presented. This makes no sense.

With regard to the productive sector participation, Colciencias fails in its calls to the private sector, because its conditions and specifications are difficult to understand and follow for employers, especially for small and medium enterprises. This result in the participation of very large companies in the projects, which already know how to respond to the complicated requirements of Colciencias, but small companies feel overwhelmed before starting the process.

It is also important to divide the functions of design, implementation and evaluation of S&T policies. Recently it has begun a restructuring process to divide science policy design and implementation in Colciencias. On the other hand, the policies concerning innovation will be centralized in Bancoldex. However, it remains unclear how it will be the division.