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Science and Technology in Colombia: Status and Perspectives

Natalia Agapitova, Lauritz Holm-Nielsen and Goga Vukmirovic

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Science and Technology in Colombia:
Status and Perspectives

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Goga Vukmirovic
and
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Preface

The Government of Colombia is examining options for improving the higher education sector over the next decade. As part of that process, the World Bank, at the behest of the Government, undertook an assessment of the state of tertiary education and made recommendations on how its funding, governance, structure, and scope could be reformed to better meet the needs of the country and the challenges it will face in a global market economy. The Bank’s analysis will become available in a sector study later in 2002.

Five background studies focussed on issues identified as important for the growth and development of tertiary education in Colombia. The purpose was to move towards operationalizing the substantial knowledge base which has been created about Colombian tertiary education over the last decade. The paper, Colombian Tertiary Education in the Context of Reform in Latin America, by José-Joaquin Brunner, analyzes the underlying causes behind the underdevelopment of Colombia’s higher education system, the challenges it is currently facing and the transformations and policies that could be implemented to forge the necessary changes. The concern about quality in tertiary education and the mechanisms in place to ensure quality in Colombia are discussed in the fourth paper Quality Assurance in Colombia, by Robin DePietro-Jurand and Maria-José Lemaître. The challenges for Colombia’s national innovation system could not be underestimated. In Science and Technology: Status and Perspectives, Natalia Agapitova, Lauritz B. Holm-Nielsen and Goga Vukmirovic demonstrate that while all of the essential elements of an innovation system are present in the country, due to a lack of finance, a poor scientific base, and limited labor competencies, the national innovation system is substantially underdeveloped and incoherent. The marketplace for knowledge is global. How does Colombia fare in this market? Over the last decade, foreign institutions have begun to play an ever expanding role in the Colombian market for higher education, migration of Colombian graduates (brain drain) is on the rise, and globalization in general posing a challenge to Colombian higher education. These issues are discussed in the paper Colombian Higher Education in the Global Market, by Isabel Cristina Jaramillo, Patricia Garcia and Andreas Blom. The economic opportunities are dealt with in Economic Perspectives of Higher Education by Andreas Blom and Thomas Hansen who investigate two central markets surrounding higher education in Colombia: the market for higher education itself and the labor market for workers with higher education. Finally, the seventh paper by Arthur Hauptman, Reforming Student Financial Aid in Colombia: Issues and Alternatives examines the student aid structure in Colombia and recommends principles to guide its reform.

We have decided to make these studies available as LCSHD discussion papers in order to stimulate thought and debate, which eventually will encourage improvement of Colombia’s tertiary education system.

Lauritz B. Holm-Nielsen
Abstract

With average GDP growth around 4% during the early and mid 1990s, institutional stability and years of liberal reforms attracting foreign investors, Colombia seemed to be one of the most promising developing economies. However, the recurrence of the violent internal conflict and the severe economic recession blackened the prospects. Furthermore, Colombia continues to suffer from drastic income inequality, inadequate infrastructure, and underdeveloped S&T capacities. Ranged in the group of scientifically developing countries (RAND, 2001), Colombia reached the average in terms of its technological abilities in the regional context, but lags considerably behind the benchmark countries. All the major elements of innovation system are present, but underdeveloped due to lack of finance, poor scientific base and limited labor competencies among other factors. The national innovation system appears to function in an incoherent manner with limited information sharing between the private sector and the publicly funded research centers.
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1. INTRODUCTION

Colombian economic performance is promising, but the current recession showed the fragility of the economy and the fact that the country cannot sustain growth without major changes in its development strategy. Taking into account the growing gap of science and technology (S&T) level between Colombia and benchmarking economies, Colombia needs to invest in the fundamentals for a knowledge-based economy.

To successfully address the challenges of the knowledge driven economy, the government needs to provide further incentives to promote S&T in society by creating appropriate institutional structures and focusing on the country’s competitive advantages. In order to help the Colombian S&T policy-makers in their quest for optimal development policies, this paper takes a closer look at the actual state of development of science and technology in Colombia.

Understanding the linkages among the actors in innovation is key to improving a country’s technological performance, and it is now largely accepted that the effectiveness of public policies on innovation depends on the capacity of policy makers of a comprehension of innovation as system. Therefore, the National Innovation System (NIS) conceptual framework, described in the Box 1.1, is being applied because it is:

✓ Methodologically developed
✓ Institutionally oriented, and
✓ Widely used, especially by OECD studies

Box 1.1. National Innovation System (NIS)

National Innovation System is a set of distinct institutions that contribute to the development and diffusion of technologies and provides the framework within which policies are implemented. Many different actors are involved in order to create, store and transfer the knowledge, skills and artifacts, which define technological opportunities of the national economy:

- Institutional framework and economic incentives;
- Economic background and its effect on the knowledge economy;
- Factor conditions (human capital, infrastructure, health and environment…);
- R&D.

Innovation systems may vary across countries, for the reason that different institutions reflect different cultures, have different objectives and respond to different incentive mechanisms, but, invariably, the co-ordination of the various institutions is the key issue.


A complex set of relationships among actors producing, acquiring, disseminating and applying various kinds of knowledge includes not only explicit connections, but also all forms of tacit links that are based on everyday interactions within a collective system of knowledge. The most difficult task for a researcher or a policy-maker is to discover, systematize and measure the magnitude of links relating the elements of national innovation system. The majority of statistical databases supply sufficient indicators to identify and evaluate the explicit links; for instance
number of mergers and acquisitions, contractual agreements and other formal contracts. A profound knowledge of a country’s social and economic web is mandatory to discern and quantify the tacit links.

Although the existing Colombian statistical information is relatively comprehensive, the available indicators do not reflect the implicit knowledge sharing. However, policy-making, especially in such a complex field as innovation, requires an accomplished understanding of the functioning of every NIS element and interactions among them. Therefore, this study primarily aims to describe the key elements of the Colombian NIS and identify its strengths and weaknesses. Yet, an extensive characterization of the country’s national innovation system that could lead to specific policy recommendations requires additional information regarding the variety of links and their possible use for Colombian S&T development.

The paper is organized as following:

Chapter 2 introduces the key economic indicators of Colombia, comparing the country to the regional average and benchmarking economies. In the global perspective, the greatest barrier is political instability, aggravated by the recent economic crisis. In the longer term the challenge will be to develop a harmonized national innovation system, serving as a basis for high and sustainable economic growth.

Chapter 3 summarizes key elements of the institutional framework of the Colombian innovation system, existing economic incentives and government policies. Colombia enjoys a well-developed institutional structure and a long-term experience of government support of S&T. Nevertheless, public investment is limited and favors traditional sectors and powerful regions, which aggravates regional disparities.

Chapter 4 focuses on the implication of S&T in the Colombian economy, especially innovation capacities of industrial enterprises and the development of knowledge-based industries. The most important issue in this respect is promoting industrial clusters, stimulating innovation and strengthening government programs for technology diffusion.

Chapter 5 examines factor conditions for S&T development, especially human capital and information infrastructure. Whereas considerable progress has been made in infrastructure development, the low-skilled labor stands out as the most important limitation to an enhanced science and technology diffusion.

Chapter 6 summarizes the challenges of scientific research and experimental development in Colombia and the coordination of previously discussed elements. Colombian scientific performances are inadequate. The recent development of the chemical industry, classified as knowledge-based in OECD statistics, has had several positive effects, including the rising number of patent applications and growing integration of the universities into industrial research, which underlines the importance of high-technology industries to the innovation and science development.

Finally, the concluding section highlights key issues of the Colombian NIS and proposes some policy recommendations.
2. GENERAL INFORMATION AND HISTORICAL BACKGROUND

With a population of 42.3 million, area of 1.1 million square kilometers, and GDP of US$81.3 billion in 2000, Colombia is a country of noteworthy resources and potential. Still, it is a developing country classified in a group of lower-middle-income economies. Colombia’s economy enjoyed relative stability and growth for most of the 20th century, and, despite the slowdown in the 80’s, the fall in output experienced by other economies in the region was avoided, and in the second half of the decade, the level of growth was among the highest in Latin America. With average GDP growth around 3% during the last 10 years, deepened integration in international trade, increasing productivity and foreign direct investment (FDI) and in spite of its internal conflicts and recent economic recession, Colombia seems to be one of the most promising developing economies of the region (Graph 2.1.).

Graph 2.1. General performance indicators*

The relative institutional stability and liberal reforms (‘apertura’ program) in early 1990’s attracted foreign investors in the most important economic sectors. GDP growth reached an average of almost 5% per year in 1992-95, but such rapid expansion proved unsustainable. High interest rates compensating for the growing fiscal imbalance restricted investment in manufacturing and inflated the exchange rate, reducing competitiveness. As a result, manufacturing output stagnated between 1995 and 1999, and overall growth slowed to an average of less than 2% in 1996-98. The strong exchange rate contributed to a widening current-account deficit, and collapsing investor confidence at the end of 1998 precipitated a recession,
with GDP contracting by 4.2% in 1999. Recovery in 2000 was not strong, with growth reaching a modest 2.8%, led by exports encouraged by a more competitive exchange rate.

The penetration of imported manufactures into the Colombian market, followed by trade liberalization, put the local industry under pressure: in order to be competitive in the new environment it was necessary to improve the quality of production and to cut costs by adopting more flexible employment practices and by outsourcing. Although there has been progress in terms of productivity, competitiveness remains heavily dependent on the exchange rate. The last decade uncovered the fragility of Colombian economy and the growing need to its adjustment towards a modern ‘knowledge society’\(^1\). At this prospect, one of the first priorities of the development policies for Colombia is not to miss the knowledge revolution and to assure a proper functioning of its’ national innovation system.

**Graph 2.2. Technological and Innovation Indicators**

- **Research collaboration between companies and universities (2000 WEF)**
- **Entrepreneurship among Managers (2001 IMD)**
- **Easy to start a new business (2000 WEF)**
- **Availability of Venture capital (2000 WEF)**
- **[ln] Number of technical papers per million people 1997 (2001 WDI)**
- **[ln] Patent applications granted by the USPTO 2000 (per million pop.) (2000 USPTO)**
- **High-Technology exports as % of manufactured exports, 1999 (2001 WDI)**
- **Private sector spending on R&D (2000 WEF)**

* In the original WBI database the number of scientists and engineers in R&D was missing. We completed the database by the RICYT statistics, available only for 1996-1998. Two points should be taken into account: the number for Colombia would probably be smaller for 1987-1997, but since for general Latin American indicator only the most developed countries supplied information, both numbers could actually be smaller, but approximately at the same level.

** The appreciation of the level of collaboration between universities and private firms is controversial in different sources. While both EIU study (2001) and the US Department of Commerce study point out that no close links between universities and industry have been developed, the WEF Global Competitiveness Report used in the actual scorecard is much more optimistic.

Ranged in the group of scientifically developing countries (RAND, 2001), in the regional context Colombia reached the average in term of its technological abilities, but it remains considerably behind the benchmark countries in all areas except entrepreneurship (Graph 2.2).

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\(^1\) The concept of ‘knowledge-based economy’ and ‘knowledge society’ in this paper corresponds to the broad definition given in “Brazil and the knowledge economy”, C. Dahlman, A. Adhar-Uitz, J.-E. Aubert, C. Zhen-Wei Qiang, WBI, 2001.
It appears that Colombia has not taken advantage of its strongest innovation indicator—the entrepreneurial ability of its population. Only 6.6% of small firms and 8.7% of medium firms in Colombia are truly innovative, compared to 15.1% of multinational-dominated big enterprises (OCyT, [2001]).

Private investment remains at a low level, discouraged by low confidence in the political system, security problems arising from violent conflicts, high level of crime, and concerns about the fiscal imbalance. Therefore, local competitiveness and financial institutions’ regulation remain poor even at the regional level and notably behind the developed countries. The growing unemployment contributes to further increases in income inequality.

Despite government efforts, the contribution of innovation and technology to the long-term Colombian economic development has been limited, and the country’s innovation system manifests serious gaps. The improvement of the overall capabilities of the country calls for a multi-prolonged effort oriented towards all elements of the NIS.

These elements are strongly interdependent (WBI, 2001). It is not enough just to improve one and expect that the others will readjust automatically. Government action coupled with international assistance is necessary to build a comprehensive development strategy, which would spur economic and social growth.

In order to explain the weaknesses of the Colombian innovation system, we should take a closer look at its key elements:

(i) Institutional framework and economic incentives;
(ii) S&T in the productive sector;
(iii) Factor conditions; and
(iv) Scientific activities.

---

2 The very fact that the innovation rate is higher among big enterprises is not unusual (for example for the OECD countries), but most of Colombian big innovative firms are foreign-owned, and their innovation abilities are strongly dependent on knowledge imports.

3 It’s difficult to compare Colombia to other countries since data sources vary. For example, the OECD divides the firms into two categories: fewer and more than 500 employees, while Colombia statistics classify firms into four categories, the largest category regroups enterprises with more than 200 employees.
3. INSTITUTIONAL FRAMEWORK AND ECONOMIC INCENTIVES

Institutional structure remains one of the weakest points of the Colombian society. Despite the relative constitutional and institutional stability (compared to other Latin American countries), drug trafficking and political corruption are the most destabilizing factors, seriously affecting the political stability and rule of law (Graph 3.1.).

**Graph 3.1. Institutional regime and economic incentives**

![Graph showing institutional regime and economic incentives](image)

**POLITICAL INSTABILITY AND CORRUPTION**

The political exclusion of the poor, marginalized by great social inequality, a highly concentrated pattern of land ownership and an inefficient justice system, created the conditions for the emergence of several violent rebel groups, two of which are still active. Notwithstanding Colombian Government efforts and international support for the current peace process, little progress has been achieved towards peace.

Since the 1980’s, the insecurity brought by guerilla warfare has been further aggravated by drug trafficking. The wealth amassed by the drug cartels through the trading of illegal drugs has fed violence and corruption, distorting the country’s political and social foundations. Through bribery, blackmail and violence, the cartels even succeeded in incorporating a ban on extradition into the 1991 constitution.
**INSTITUTIONAL FRAMEWORK SUPPORTING NIS**

Colombia is among the few Latin American countries that have enjoyed almost uninterrupted constitutional and institutional stability throughout its history. As a result, the institutional structure supporting Colombian innovation system is well developed and includes four levels of interrelated institutions schematically represented in Table 3.1.

**Table 3.1. Institutional framework of NIS in Colombia**

<table>
<thead>
<tr>
<th>Level 1: planning and governance</th>
<th>Level 2: promotion of S&amp;T</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNP (National Department of Planning)</td>
<td>COLOCIENCIAS (1968) (National Council of Science and Technology)</td>
</tr>
<tr>
<td>Ministries</td>
<td>Bureau of strategic planning (1994)</td>
</tr>
<tr>
<td>Ministry of Agriculture</td>
<td>Financial supporting organizations</td>
</tr>
<tr>
<td>CNCT (1958) (National Council of Science and Technology)</td>
<td>Public institutions</td>
</tr>
<tr>
<td>Ministries</td>
<td>Financial supporting organizations</td>
</tr>
<tr>
<td>CONPES (1958) (National Council of Economic and Social Politics)</td>
<td>Public institutions</td>
</tr>
<tr>
<td>Ministry of Agriculture</td>
<td>Public institutions</td>
</tr>
</tbody>
</table>

The largest funding agency is Colciencias – Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnologia, which, in 1997, accounted for over 27% of all government expenditure in S&T.

The higher levels of institutional framework (level 1 and 2 in Table 3.1) are much more developed and better coordinated, whereas the number of research institutes, and in particular those that are privately funded, and the collaboration between the lower levels of institutional framework remain underdeveloped (level 3 and 4 in Table 3.1).
Government laboratories are primarily concerned with meeting public needs, while universities and research institutions focus primarily on generating basic knowledge. Universities typically have a more independent research agenda than government laboratories and are therefore less responsive to public policies. However, considering that the government controls much of the research budget of these institutions, university research has become a relevant instrument for policy makers.

Several government-funded programs, such as the creation of centers of excellence (Box 3.1.), have been implemented to promote S&T and contribute to economic growth, providing indirect support to business R&D.

Box 3.1. Centers of Excellence

In 1995, Colciencias accepted 150 applications from S&T institutes for selection for Centers of Excellence. Four were selected, and classified as excellent: Centro Internacional de Fisica (CIF), Centro Internacional de Entrenamiento e Investigaciones Medicas (CIDEIM), Corporacion para Investigaciones Biologicas (CIB), and Fundacion para la Educacion Superior y el Desarrollo (FEDESARROLLO). They were selected on the basis of their contribution to their respective field of science, for their capacity to train investigators, and for their ability to apply the acquired knowledge toward solving tangible problems.4

The support for these centers of excellence comes from the national budget; in 1996, about $150 million was allocated to the four centers. None of the centers can support itself from the sale of services or from international funding, which makes them reliant upon the government. The four centers of excellence have proceeded to establish the Foundation of Centers of Excellence, which will be charged with funding, supporting, and evaluating the work and results produced by the centers.

Government R&D accommodates public needs (such as defense or health) and serves economic goals when there are market failures associated with R&D. These market failures typically have two causes. First, firms have difficulty fully appropriating the returns to their investment in R&D, so that their private rate of return is lower than the social return. Second, the high risk involved in research may mean that firms hesitate to engage in innovation. This is particularly a problem for small firms with limited access to funding. For the above reasons, the amount firms invest in R&D is likely to be below the socially optimal level (Arrow, 1962).

Government Policy for the S&T Development

The Colombian government adopted a linear approach to the S&T development based mainly on scientific research funding.

The effect of public spending may differ depending on the policy instrument used. Government action typically falls into three categories:

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4 Presentacion, Asociacion de Centros de Investigacion y Desarrollo, 1999
Direct funding, including
a) public expenditures on S&T, social services (like health and education) and public (government or university) research, and
b) direct government funding of business-performed R&D;

Indirect incentives, including tax exemption, tax deduction or other tax benefits;
Participation in international programs.

The three policy tools are likely to interact and the effectiveness of one depends on the others. Unfortunately, Colombian government predominantly allocated research resources to the public sector, which could be partly responsible for the lack of university-industry cooperation and a low level of business R&D activities.

Recent OECD studies (OECD, 2000, 2001) show that both fiscal incentives and direct funding stimulate business-funded R&D, whereas research performed by government and universities appears to crowd-out the privately funded research. This suggests that if governments wish to increase business-funded R&D, direct funding is more effective than the indirect supply of knowledge. However, only the latter has been available in Colombia so far.

Public R&D expenditures and incentives for private firms innovative activities should be complementary: public research gains in effectiveness when government funding of R&D increases, thereby increasing the capacity of firms to digest the knowledge generated through public research.

**Direct Funding**

Funding for science and technology in Colombia comes predominantly from the government. In 1993/94, 77% of investments came from public funds, with the remaining 23% coming from the private sector (but only 13% from business enterprises). In 1997, Colombia invested US$632 million, or 0.65% of its GDP in S&T, of which US$398 million was spent in R&D. The gross domestic expenditure on R&D has been relatively consistent since 1994, ranging from 0.62 to 0.70%. While, this level of investment, as percentage of GDP, roughly equals the average for Latin American countries (0.63%), it is noticeably less than the investment of 2.37% of GDP for the North American Free Trade Agreement countries, 1.85% for European Union, or 0.78% for the Mercosur average.

While Colombia spends a similar percentage of GDP for science and technology as other Latin American countries, the net amount of investment does not rival that of Brazil or Argentina. Colombia accounted for 4.4% of the total of US$14.3 billion expenditure on science and technology in Latin America, while Brazil and Argentina accounted for 64.3% and 10.3%, respectively.

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5 World Science Report, 1998
Public S&T expenditures have been highly concentrated in the Capital District. Until 1996, the Capital District received all of the public S&T expenditures. Since then, investment slightly increased in other regions, but Bogotá still receives at least 80% of government financing (DNP, OCyT, [2000]).

The three largest government recipients for R&D funding – Colciencias, Ministry of Agriculture and National University – accounted for almost two thirds of total government expenditures for S&T in 1995-1997, whilst the aggregated investments of the top ten institutions amounted to more than 80% of the total expenditures (Table 3.2).

Table 3.2. Government Investments in S&T, by Institution
(millions of US$, converted from Colombian pesos at the 1996 exchange rate of US$ 1= 1,036.7 pesos).

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US$ (mil.)</td>
<td>% total</td>
<td>US$ (mil.)</td>
<td>% total</td>
<td>US$ (mil.)</td>
<td>% total</td>
</tr>
<tr>
<td>COLCIENCIAS</td>
<td>38.50</td>
<td>23.32</td>
<td>58.96</td>
<td>27.37</td>
<td>47.03</td>
<td>27.24</td>
</tr>
<tr>
<td>MINAGRIC-DS</td>
<td>38.91</td>
<td>23.57</td>
<td>47.13</td>
<td>21.88</td>
<td>44.86</td>
<td>25.97</td>
</tr>
<tr>
<td>UNACIONAL</td>
<td>20.21</td>
<td>12.24</td>
<td>21.91</td>
<td>10.17</td>
<td>21.52</td>
<td>12.46</td>
</tr>
<tr>
<td>INGEOMINAS</td>
<td>3.71</td>
<td>2.25</td>
<td>3.79</td>
<td>1.76</td>
<td>4.37</td>
<td>2.53</td>
</tr>
<tr>
<td>INPA</td>
<td>4.53</td>
<td>2.74</td>
<td>4.31</td>
<td>2.00</td>
<td>3.91</td>
<td>2.27</td>
</tr>
<tr>
<td>FONDANE</td>
<td>6.25</td>
<td>3.79</td>
<td>1.88</td>
<td>0.87</td>
<td>3.69</td>
<td>2.14</td>
</tr>
<tr>
<td>MINSALUD-DS</td>
<td>9.18</td>
<td>5.56</td>
<td>6.93</td>
<td>3.22</td>
<td>3.50</td>
<td>2.03</td>
</tr>
<tr>
<td>IGAC</td>
<td>4.60</td>
<td>2.79</td>
<td>4.44</td>
<td>2.06</td>
<td>3.43</td>
<td>1.99</td>
</tr>
<tr>
<td>MINDESA-DS</td>
<td>4.26</td>
<td>2.58</td>
<td>5.71</td>
<td>2.65</td>
<td>3.29</td>
<td>1.91</td>
</tr>
<tr>
<td>INS</td>
<td>1.69</td>
<td>1.02</td>
<td>2.64</td>
<td>1.23</td>
<td>2.30</td>
<td>1.33</td>
</tr>
<tr>
<td>MINTRANS-DS</td>
<td>1.93</td>
<td>1.17</td>
<td>3.95</td>
<td>1.83</td>
<td>2.17</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Source: Departamento Nacional de Planeacion- Colciencias, 1994-1998

The Government investment can be further broken down by sector and by type of investment, as in Table 3.3. Such a breakdown shows that ‘strengthening the S&T capacity’ and ‘R&D projects’ were the government’s priority, receiving the largest fraction of the allocations: on average 53% for 1995-1999. Growing part was allocated to the ‘innovation, competitiveness and technological development’.

In 1999, the share of expenditures in basic science slightly increased (2.5% of total S&T investment compared to 0.002% in the average for 1994-1998), whereas experimental development received only 4.1% of investments. Applied and combined research clearly were priority sectors, regrouping 57.5% of the overall expenditures, followed by infrastructure with 28.4%. The rest was allocated to diffusion activities and databases, but their shares diminished to 6.4% and 1.1% respectively (compared to 24.2% and 5.8% in 1995).

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It is unclear whether the investment through the National University is a real S&T investment or rather a higher education subsidy.
### Table 3.3. Government Investment in S&T

<table>
<thead>
<tr>
<th>By Sector</th>
<th>1995 (%)</th>
<th>1996 (%)</th>
<th>1997 (%)</th>
<th>1998 (%)</th>
<th>1999 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strengthening S&amp;T capacity</strong></td>
<td>47.76</td>
<td>50.60</td>
<td>51.48</td>
<td>54.18</td>
<td>51.98</td>
</tr>
<tr>
<td>Innovation, Competitiveness and technological development</td>
<td>29.35</td>
<td>28.54</td>
<td>25.68</td>
<td>24.14</td>
<td>34.09</td>
</tr>
<tr>
<td><strong>Science and Social Development</strong></td>
<td>3.25</td>
<td>3.65</td>
<td>2.70</td>
<td>4.93</td>
<td>5.48</td>
</tr>
<tr>
<td>Environment</td>
<td>7.30</td>
<td>6.71</td>
<td>9.25</td>
<td>7.62</td>
<td>1.69</td>
</tr>
<tr>
<td>Integration of S&amp;T into society</td>
<td>12.16</td>
<td>10.50</td>
<td>10.89</td>
<td>9.14</td>
<td>6.77</td>
</tr>
<tr>
<td><strong>By Type of Investment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D Projects</td>
<td>46.49</td>
<td>43.82</td>
<td>57.39</td>
<td>61.84</td>
<td>64.08</td>
</tr>
<tr>
<td>Institutional infrastructure</td>
<td>11.55</td>
<td>16.59</td>
<td>14.22</td>
<td>10.69</td>
<td>8.73</td>
</tr>
<tr>
<td>Human Capacity Building</td>
<td>6.58</td>
<td>4.53</td>
<td>8.48</td>
<td>7.90</td>
<td>15.73</td>
</tr>
<tr>
<td>Diffusion of S&amp;T knowledge and support for acquisition of new technologies</td>
<td>26.27</td>
<td>25.01</td>
<td>7.49</td>
<td>7.92</td>
<td>6.68</td>
</tr>
<tr>
<td>Information Systems</td>
<td>9.11</td>
<td>10.04</td>
<td>12.42</td>
<td>11.66</td>
<td>4.77</td>
</tr>
<tr>
<td><strong>TOTAL: (In millions of 1995 Pesos)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>151 703</td>
<td>196 268</td>
<td>173 835</td>
<td>118 240</td>
<td>117 491</td>
</tr>
<tr>
<td><strong>TOTAL: (In millions of US$)¹⁰</strong></td>
<td>166.18</td>
<td>214.99</td>
<td>190.42</td>
<td>129.52</td>
<td>128.70</td>
</tr>
</tbody>
</table>

*Source: Unidad de Inversion Publica, BPIN, DNP-SENA, Observatorio de Ciencia y Tecnologia*

In total, the government allocated US$829.81 million in 1995-1999 to S&T, of which 24% was allocated to the agricultural science, 20% to engineering, 8% to natural science, 7% and 5% to social and medical science respectively, and 36% to the combination of sectors.

![Government S&T expenditures by science field in 1995-1999, %](chart.png)

*Source: Unidad de Inversion Publica, BPIN, DNP-SENA*

¹⁰ Exchange rate in 1995: US$ 1 = 912.9 pesos, as quoted in CIA World Fact Book.
**Indirect Incentives**

Considering that governments are less likely than market forces to allocate resources efficiently, the allocation of resources between fields of research may be distorted, as may competition between firms, if some are supported at the expense of others.

The drawback of tax benefits is the opposite of those of targeted funding. Tax breaks discriminate less, so that firms can use public money for any goal, whatever its social rate of return. This may be regarded as an advantage, since it does not distort the research agenda created by market forces.

Pursuant to articles 70 and 71 of the Colombian Constitution the government has the duty to promote not only scientific and technological knowledge, but also the entities or persons that are dedicated to these activities. In this regards, Law 29 of 1990 provides guidelines for promoting these activities (i.e. tax exemptions, tax deductions or other tax benefits). This law conditions the granting of the exemptions, tax deductions and other tax benefits to the technological and scientific activities that are recognized by law, with previous approval from Colciencias (MONDAQ, 02/08/01).

Although, according to the law, all organizations can enjoy tax deduction, the public sector, including technical service centers (mostly public), government agencies and public universities, benefits the most, accounting, on average, for 73.7% of tax deduction in 1995-1999 (Graph 3.3).

R&D tax breaks are generally regarded as only weakly discriminatory. However, tax subsidies to private firms are still the exception in Colombia (less than 2% on average).

In addition, tax incentives have discriminatory features, as they are not accessible to firms that are not taxed, e.g. young firms where investment exceeds sales. Such companies may, however, be among the most innovative and may also be the most in need of capital, especially
considering that venture capital remains largely unavailable for small firms and new enterprises in Colombia (Graph 2.2)

**International Collaboration**

Colombia, together with Mexico and Venezuela, belongs to the Group of Three, a sub-regional cooperation program that provides additional financial support to the S&T sector. Colombia has received a number of loans in support of R&D and innovative projects that were both initiated and generated by the industry. One of the most recent projects is the IDB-Colciencias III, which totals US$200 million.

The World Bank is currently providing funds for strengthening the primary and secondary education projects in Colombia. No higher education projects have been implemented to date.

**Protection of Intellectual Property**

Colombia does not yet provide adequate and effective intellectual property (IP) protection. As a result, Colombia has been on the “Watch List” under the Special 301 provision of the 1988 Trade Act every year since 1991. An out-of-cycle review in mid-1999 placed Colombia once again in the same “Watch List” category. Colombia has ratified, but not fully implemented, the provisions of the World Trade Organization (WTO) agreement on Trade Related Aspects of Intellectual Property (TRIPS). A major intellectual property rights issue has been the Colombian Government’s failure to license legitimate pay television operators and pursue pirate operators.

The weakness of Colombian’s IP protection laws is one of the main factors accounting for weak business R&D funding. Private firms are concerned with a financial return on R&D investment, and will rarely fund the research that results in discoveries that benefit the society at large, without giving the firm an opportunity to realize gains on investment. The enterprises thus have to be assured that they will at least have an exclusive opportunity to commercialize the results of R&D.

Nevertheless, serious improvements in IP protection were achieved in several areas. Colombia, which is a WTO member, has ratified the Uruguay Round implementing legislation. It is a member of the World Intellectual Property Organization (WIPO) and has negotiated to join the Paris Convention for the Protection of Industrial Property, the Patent Cooperation Treaty and the Union for the Protection of New Plant Varieties.

**Patent and Trademarks**

Colombia is a member of the Inter-American Convention for Trademark and Commercial Protection. Colombia requires registration and use of a trademark in Colombia to exercise trademark protection. Trademark registration has a 10-year duration and may be renewed for 11 World Science Report, 1998

12 This paragraph is largely based on the U.S. Department of State country report (2001).
successive 10-year periods. Thus, the Colombian law provides 20-year protection for patents and reversal of burden of proof in cases of alleged patent infringement.

Andean Community Decision 486, which came into force on December 1, 2000, provides improved protection to patents, trademarks, industrial inventions, rules of origin and unlawful competition related to industrial property. This decision, approved after the pharmaceutical industry, which has been particularly affected by inadequate protection of confidential data, requested that Decision 344 be amended to ensure compliance with WTO requirements. Decision 486, eliminates previous restrictions on biotechnology inventions, increases protection of industrial designs from eight to ten years, and protects integrated circuits (microchips) designs. However, Decision 486 appears to have shortcomings with respect to protection of data confidentiality and protection for second-use patents. Enforcement of trademark legislation in Colombia is showing some progress, but contraband and counterfeiting are widespread.

The Superintendency of Industry and Commerce acts as the local patent and trademark office in Colombia. This agency suffers greatly from inadequate financing and a backlog of trademark and patent applications exceeding 25,000, although new applications are now generally reviewed within nine months.

**COPYRIGHTS**

Colombia’s 1993 Copyright Law increased penalties for copyright piracy. In April 1999 President Pastrana issued a directive to all government and educational institutions to respect copyrights and avoid the use or purchase of pirated printed works, software and audio/video material. Enforcement problems consistently arise not only with inadequate police activity, but also in the judicial system, where there have been complaints about the lack of respect for preservation of evidence and frequent perjury.

**NEW TECHNOLOGIES**

Colombia has a modern copyright law which gives protection for computer software for 50 years and defines computer software as copyrightable subject matter but does not classify it as a literary work. Semiconductor design layouts are not protected under Colombian law.

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13 However, the recent data from the International Intellectual Property Alliance (IIPA) suggests that U.S. industries, for example, continue to lose substantial ($163.2 million in 1999) revenue from piracy. The IIPA estimates that in Colombia videocassette piracy represents approximately 55% of the video market; sound recording piracy 60% of the market; business software piracy 56% of the market; and entertainment software piracy 75% of the market.
4. **S&T IN THE PRODUCTIVE SECTOR**

Colombian economic structure, shown in the Table 4.1, resembles that of other developing countries: it includes a substantial agricultural production, followed by a developing services sector and a robust industry sector.

<table>
<thead>
<tr>
<th>Table 4.1. Economic structure, as % of GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colombia</strong></td>
</tr>
<tr>
<td>Agriculture</td>
</tr>
<tr>
<td>Industry</td>
</tr>
<tr>
<td>Services</td>
</tr>
<tr>
<td><strong>Latin American Countries</strong></td>
</tr>
<tr>
<td>Agriculture</td>
</tr>
<tr>
<td>Industry</td>
</tr>
<tr>
<td>Services</td>
</tr>
<tr>
<td><strong>G7</strong></td>
</tr>
<tr>
<td>Agriculture</td>
</tr>
<tr>
<td>Industry</td>
</tr>
<tr>
<td>Services</td>
</tr>
</tbody>
</table>

* At the basis of eight countries: Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru and Venezuela.

Source: The World Bank regional database, OECD.

**SERVICES**

The share of services increased from 47.6% of GDP in 1980 to 55% of GDP in 2000, dominated by community, social and personal services (14% of GDP), retail sale (11%) and telecommunications (7%).

Knowledge-intensive services, such as finance, insurance, communications, health and education, which are intensive users of high technology, demand a relatively highly skilled workforce and help to promote technological innovation. Unfortunately, Colombian statistics are not rich enough to draw a precise picture. Nevertheless, telecommunications and healthcare seem to be the most dynamic knowledge-intensive services.

The services sector plays an important role in the innovation process. For example, the well functioning telecommunications infrastructure affects the development of social and economic networks, necessary for knowledge diffusion throughout the economy. Furthermore, the surveys carried out by the OECD Focus Group indicate that manufacturing firms increasingly interact with knowledge-intensive service firms, establishing co-operative links with consultancies, technological firms or other service firms.

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14 In 2000, public spending on healthcare amounted at 3.9% of GDP (EUI, [2001]).
Agriculture

The importance of agriculture, which has been particularly hard hit by Colombia's economic liberalization, diminished over the past 10 years, but, with 13.8% of GDP, it remains one of the most significant economic sectors. Together with the food processing industry (11.2% of GDP), it accounts for 25% of GDP.

Agriculture benefits from absorption agreements, which require domestic food processors to purchase the total production of certain domestic crops at higher than "normal" prices. During 1997, important competitiveness agreements between the private sector and the government resulted in a new policy to improve commercialization of agricultural products by eliminating the Institute of Agricultural Marketing ("Idema") and providing direct compensation to producers instead. In addition, public expenditures for the scientific development of agriculture were higher than in other sectors – 24% of all S&T expenditure, but the high share is insufficient or ineffectual to upgrade the quality of agricultural products. Therefore, the sector continues to lose market shares to foreign competitors. Lack of credit, unqualified labor and the presence of large landholders aggravate the situation.

Industry

Worldwide, industrial enterprises remain the primary institutions for designing and developing new technological artifacts and for applying them in the search for competitive advantage. They also have a major impact on the development of skills and tacit knowledge. All industries are to some extent dependent on knowledge inputs, but some much more than others. The term ‘knowledge-based industries’ refers to those industries that are relatively intensive in their input of technology and/or human capital (OECD, 1997).

OECD “Classification of industries based on technology” (OECD, 1999, p.106) uses the International Statistic Industrial Classification, second revision with four digits, but only three-digit classification is available for Colombia. Nevertheless, since only tree digits are used to classify low and medium-low technology industries and the fourth digit helps to distinguish between high and medium-high-technology industries, we have regrouped the last two categories into ‘knowledge-based industries’ for the case of Colombia.

Low technology industries, dominated by food processing (34.5%) and textile (7.1%), stand for the largest part of industrial output. Since trade liberalization, low-technology industries have faced strong competition from Asia, and have become the main receptors of government support – soft credit lines, import subsidies and management assistance. These sectors face new challenge of competitiveness, but their technological development primarily depends on acquired technology and modernization of production tools.

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15 The only exception is for transport equipment (Shipbuilding and repairing (3841) – medium-low-technology industry, Aircraft (3845) – high-technology industry, and the rest – motor vehicles and other transport equipment – medium-high-technology industries). Colombian main transportation production is automotive, categorized in medium-high-technology industries.
16 As shown for other countries in OECD studies (OECD, 1998, 2000, 2001).
Table 4.2. Structural composition of Colombian industry according to the knowledge intensity, % of industrial output

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-technology industries</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood products &amp; furniture</td>
<td>33</td>
<td>1,09</td>
<td>1,01</td>
</tr>
<tr>
<td>Food, beverages &amp; tobacco</td>
<td>31</td>
<td>33,69</td>
<td>32,83</td>
</tr>
<tr>
<td>Textiles, apparel &amp; leather</td>
<td>32</td>
<td>15,55</td>
<td>12,63</td>
</tr>
<tr>
<td>Paper, paper products &amp; printing</td>
<td>34</td>
<td>6,24</td>
<td>6,61</td>
</tr>
<tr>
<td><strong>Medium-low-technology industries</strong></td>
<td>21,59</td>
<td>22,36</td>
<td>24,05</td>
</tr>
<tr>
<td>Ferrous metals</td>
<td>371</td>
<td>2,64</td>
<td>3,17</td>
</tr>
<tr>
<td>Petroleum refineries &amp; products</td>
<td>353+354</td>
<td>5,52</td>
<td>4,90</td>
</tr>
<tr>
<td>Metal products</td>
<td>381</td>
<td>3,75</td>
<td>3,26</td>
</tr>
<tr>
<td>Non-metallic mineral products</td>
<td>36</td>
<td>4,33</td>
<td>4,90</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>372</td>
<td>0,58</td>
<td>0,56</td>
</tr>
<tr>
<td>Rubber &amp; plastic products</td>
<td>355+356</td>
<td>3,95</td>
<td>4,75</td>
</tr>
<tr>
<td>Other manufactures</td>
<td>39</td>
<td>0,81</td>
<td>0,82</td>
</tr>
<tr>
<td><strong>Knowledge-based industries</strong></td>
<td>21,83</td>
<td>24,56</td>
<td>23,08</td>
</tr>
<tr>
<td>Non-electrical machinery</td>
<td>382</td>
<td>1,90</td>
<td>1,70</td>
</tr>
<tr>
<td>Transport equipment</td>
<td>384</td>
<td>5,21</td>
<td>5,52</td>
</tr>
<tr>
<td>Chemicals</td>
<td>351+352</td>
<td>11,65</td>
<td>13,82</td>
</tr>
<tr>
<td>Electrical machines</td>
<td>383</td>
<td>2,80</td>
<td>3,01</td>
</tr>
<tr>
<td>Professional goods</td>
<td>385</td>
<td>0,28</td>
<td>0,52</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

* Adapted to the three-digit classification.

** High and medium high technology industries, including shipbuilding.

Source: DANE-EAM, 2001; OECD, 1999

The production of medium-low technology industries is generally for domestic consumption, except petrochemicals and plastic products. These two industries, interrelated with the chemical industry, rely on imported technologies, because their innovation capacity is limited by low labor qualifications, as shown by national industrial survey in 1996 (Table 4.3.).

Table 4.3. Limitations to innovation, % of firms perceiving the obstacle

<table>
<thead>
<tr>
<th></th>
<th>Research capacity</th>
<th>Economic &amp; financial</th>
<th>Human capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrochemicals</td>
<td>29,2</td>
<td>31,3</td>
<td>91,0</td>
</tr>
<tr>
<td>Plastic products</td>
<td>49,8</td>
<td>55,3</td>
<td>62,2</td>
</tr>
<tr>
<td>National average</td>
<td>50,2</td>
<td>50,9</td>
<td>55,3</td>
</tr>
</tbody>
</table>

Source: Colciencias and DNP, [1996]; OCyT, [2001]

In several case studies, the importance of technology-based activities has been approximated by the share of high-technology industries in manufacturing\(^\text{17}\).

\(^{17}\) Especially by OECD studies, but also by European Commission.
**High and medium-high-technology industries** in Colombia represented a surprisingly large part of national output in 1987-1996, compared to others LAC countries and even world benchmarking economies\(^{18}\) (Table 4.4.). However, the share of high and medium-high-technology industries shrunk significantly after the liberalization of the economy, achieving a record low of 5.8% of GDP in 1999.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colombia</strong></td>
<td>9.0%</td>
<td>6.7%</td>
</tr>
<tr>
<td><strong>Mexico</strong></td>
<td>8.2%</td>
<td></td>
</tr>
<tr>
<td><strong>USA</strong></td>
<td>9.1%</td>
<td></td>
</tr>
<tr>
<td><strong>Korea</strong></td>
<td>13.8%</td>
<td></td>
</tr>
<tr>
<td><strong>France</strong></td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td><strong>Spain</strong></td>
<td>8.8%</td>
<td></td>
</tr>
<tr>
<td><strong>OECD</strong></td>
<td>9.8%</td>
<td></td>
</tr>
</tbody>
</table>

*Source: DNP, OECD.*

The evolution of real value added of knowledge-based industries reflect the fragility of Colombian competitive advantage. Continuously increasing in the 1980’s, the output of knowledge-based industries first broke down just after the trade liberalization, but then recovered after the inflow of foreign investment in this sector. Nevertheless, the investors were discouraged by poor factor conditions, especially of human capital and political instability, and the sector is at loss of productive capacities compared to its 1987 level (Table 4.4). The only exception is chemical production (including pharmaceuticals). Being one of the most dynamic industries, it accounts for slightly more than half of the production of knowledge-intensive industries, and despite the 1999 crisis, the output reached 113% of 1987 volume.

Box 4.1. Possible clustering in chemical industry

The chemicals industry (including pharmaceuticals) is the second largest manufacturing sub-sector in terms of value added—at around 15%—and has grown steadily. The industry, dominated by multinational companies, exports 38% of total production; foreign sales reached US$1.7bn in 2000, a considerable increase on the US$235m registered in 1990. The industry has been one of the main beneficiaries of the lowering of trade barriers, which reduced the cost of imported inputs, while easing technology transfer through increased flexibility of foreign investment and currency regulations.

Producing pharmaceuticals, fertilizers, insecticides, acids and alkalis, cosmetics, detergents and paint, chemical industry has important spillovers into most important domestic sectors, such as agriculture, food production and textile. Altogether, with less knowledge-intensive petrochemicals (7%) and plastic products (5%), chemical production accounts for 27% of industrial output.

Under favorable conditions, chemical industry could serve as a basis of a highly technologically developed cluster having multiple beneficial effects on the rest of the economy.


BUSINESS R&D FUNDING

The R&D funding by business enterprises is inadequate in Colombia; while it slightly rose in mid 1990's (from 8% in 1994 to 13% in 1997), it dropped after the financial crisis in 1999 (Table 4.5). Whereas the share of business funds in R&D is close to 60% of overall investment in the developed countries, it remains around 30% in the most dynamic developing countries. Collaborations between universities and industry are still nascent.

Table 4.5. Share of business enterprise’s participation in funding of R&D in 1993-1997*, %

<table>
<thead>
<tr>
<th></th>
<th>Colombia</th>
<th>Mexico</th>
<th>USA</th>
<th>Korea</th>
<th>Turkey</th>
<th>Spain</th>
<th>OECD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993-97*</td>
<td>10,6%</td>
<td>16,0%</td>
<td>61,0%</td>
<td>74,4%</td>
<td>33,8%</td>
<td>43,4%</td>
<td>60,4%</td>
</tr>
</tbody>
</table>

Source: RICyT, OECD.

Research Activities by Size Classes of Firms

Not surprisingly, large enterprises innovate more than small and medium enterprises (SME) in Colombia, especially with regards to the in-house research. They benefit from better investment capacities and more qualified labor than small Colombian firms: 47,3% of employees have professional qualification in large firms, compared to only 6,2% for small firms and 25,1% for medium-size firms (OCyT, [2001]). Unfortunately, international comparison is impossible due to methodological differences in Colombian and OECD studies.
Inter-firm Co-operation

Several studies show that the co-ordination of an innovative endeavor almost always requires a network of independent organizations with different competencies. To a large extent, innovation is the result of inputs from co-operative systems, networks of firms and knowledge-based organizations. However, co-operation agreements are embryonic among Colombian firms, especially smaller ones.

The nature and potential benefits of network co-operation are not always well known in small firms. New business models are more difficult for them to consider due to the lack of highly skilled employees. Furthermore, their managers may be afraid to lose competitive advantages to prospective partners. The recent programs of the Colombian government and business associations (Centros de Desarrollo Tecnologico, Centros Regionales de Productividad, Incubadoras de Empresas de Base Tecnologica) try to promote firms’ awareness of networking, but no statistical evidence can attest to the success of these policies.

FOREIGN DIRECT INVESTMENT

Trade and foreign direct investment (FDI) remain significant sources of innovative ideas and concepts and may take on greater importance as the complexity of innovation at the

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19 The Community Innovation Surveys (CIS) as well as the CATI surveys carried out in the OECD Focus Group show that firms rarely innovate alone. The CATI survey showed that 61% of the product-innovating firms in Austria collaborated with one or more partners, 83% in Spain and as high as 97% in Denmark.
technological frontier makes it increasingly difficult for individual firms and countries to engage in innovation.

In Colombia, foreign investment grew by an annual average of 55% between 1991 and 1997, compared with 15% in the 1980s. However, FDI fell sharply in 1998, owing to a marked slowdown in privatizations and flagging investor confidence. The total stock of foreign investment in Colombia was close to US$2bn in 2000. Although the US continues to hold the largest share, this country’s participation declined throughout the 1990s in favor of Latin American countries and the EU.

High-technology industries have experienced the greatest increase in international trade during the early 1990s. The telecommunications, manufacturing and finance sectors have increased their share of the FDI stock in recent years, whereas the share of mining has declined. Besides its positive effect on national S&T capacities, investment in knowledge-based industries proved to be much more persistent than investment in other sectors. Foreign investment in high and medium-high-technology industries and services was the only to remain at the same level during the economic recession, whereas it fell down in all others (Graph 4.3).

The structural composition of FDI reflects the attractive growth of services, especially telecommunications and finance sector, for foreign investors. However, the decreasing share of FDI in knowledge-based manufacturing reflects the low level of Colombian competitive advantages in this area (Graph 4.4).

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20 Including portfolio and oil.
THE EXTERNAL SECTOR

The share of manufactured exports is still low, and Colombia is heavily dependent on raw material exports accounting for 43.8% of the export in 2001 (primary oil - 34.8%, and carbon - 6.6% (DANE, 2001)). However, the export of knowledge-based industrial products increased not only in volume (from US$0.4 billion to US$2.1 billion), but as share of non-traditional export: from 14% in 1990 to 32% in 2000 (as shown at the graphs 4.5a and 4.5b).

Although capital goods, raw materials and other inputs for the industry are by far the largest categories of imports, imports of consumer goods have also risen steadily. As a proportion of total imports, consumer goods increased from 12% in 1991 to 19% in 2000, while the share of capital goods fluctuated between 30% and 40%.

Scientific instrument represent only 3.55% of all exported goods, whereas all high-technology goods comprised 6.74%. This implies that Colombia does not take full advantage of international trade, since high-technology goods account for approximately 20% of trade in OECD countries, and more than 60% together when combined with medium-high technology industries (35.79% for Colombia).
5. FACTOR CONDITIONS

Colombia is a country of outstanding natural resources, but with the third largest population in the Latin America, its most valuable possession is, without any doubt, human capital. Although living conditions improved considerably over the last decades, regional and social disparities remain pronounced. The population is overwhelmingly urban (74% according to DNP), with approximately 30% of people living in four biggest cities.

Whereas Colombia is making progress with respect to providing better healthcare and living conditions, the professional skills of its labor force need considerable improvements (Graph 5.1.). On average, 55.3% of Colombian industrial firms indicated low qualified labor as one of the most important obstacles to innovation, and this share is even higher in selected industries, like steel or glass production (66%), and petrochemicals (91%) (OCyT, [2001]). The competitive edge of the country’s economy is and will be determined by its people ability to create, acquire, share and use knowledge effectively (WDI Study, [2001]).

Although the information economy is accompanied by an increasing codification of knowledge, much knowledge remains tacit, embodied in people’s skills, experience and education. Human capital is therefore crucial to the innovation process, and surveys point to the lack of skilled personnel as one of the greatest barriers to innovation in Colombia.

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21 Average life expectancy in 2000 was 72 years, compared with 57 years in 1960 (EIU country study, [2001]).
EDUCATION SYSTEM

Public spending on education was equivalent to 3.6% of GDP in 2000, compared with just 2.5% at the end of the 1980s. While this percentage spending exceeded that of Chile or Peru, it remains below the regional average (Graph 5.1). The average years of schooling attained by the population was estimated at 6.7 years in 1997, and the government has set the target of an average of 9 years by 2007 in the 7 largest cities, and by 2017 in the rest of the country. The rising real per-capita spending on education over the past 20 years has led to a wider coverage for both secondary and higher education (of 65% and 16%, respectively, in 1999), as well as to notable improvements in basic literacy, which, at over 90%, is the second highest in Latin America.

The higher education and training systems does not match qualifications needed by technologically intensive industries and those of the labour force. Shortages of specific categories of highly skilled personnel, such as ICT workers and scientists and engineers, became flagrant in recent years, a potential sign of specific rigidities in these areas. The share of students in natural science and engineering is considerably lower than on the regional average and in the United States (Graph 5.2).

![Graph 5.2. Composition of university students in 1996, %](image)

*Source: RICyT, [2000]*

The number of higher education institutions rose from 225 in 1985 to 269 in 1997 and the number of students registered in postgraduate studies increased by six fold over the same period. However, the tertiary enrollment is only 16% and qualitative improvements have been modest. The educational system is extremely centralized and teachers remain poorly qualified, particularly in rural zones. Secondary education does not provide vocational skills, and industrial and services employers complain of shortages of skilled labour.
INFORMATION INFRASTRUCTURE

The most developed element of the Colombian NIS is its information infrastructure, which, according to several indicators, is approaching the G7 level (Graph 5.3.).

Telecommunications, liberalized in the 1990s, is one of the most dynamic sectors of the Colombian economy and now accounts for around 7% of GDP. Turnover for the sector passed US$2bn in 2000. The telecommunication system is well-developed compared with other countries in Latin America. Colombia ranked third in terms of telephone coverage in the region, with 16 lines per 100 inhabitants, behind Argentina and Chile, which have 20 and 17 lines per 100 inhabitants, respectively.

The Internet remains outside the reach of most people, but lately improved considerably, and the e-commerce is at the level of the most developed countries.
6. SCIENTIFIC ACTIVITIES

Colombian contribution to basic scientific research is limited. The total number of articles published by Colombian researchers in international journals is much less than either Argentina’s or Brazil’s—both of which spend a smaller fraction of their gross national product on research and development than Colombia (Graph 6.1.).

![Graph 6.1. Publications in Science Citation Index, as % of total](image)

Source: RICyT, [2000]

The agricultural science and biology, privileged by government subsidies as mentioned in the previous chapters, provided more articles than other science fields. The number of publications in chemical and physical sciences is slightly increasing, which is probably one of the spillovers of the development of chemical industry (Graph 6.2.).

![Graph 6.2. Evolution of Colombian contribution in specialized scientific databases](image)

Source: RICyT, [2000]

Furthermore, scientific output, as measured by the number of patent applications, is lower than that of other countries with similar, or even smaller GNP. In 1998, Colombia had dis-

---

22 Patent applications are just a proxy (albeit possibly the best one we have) for measuring innovation, as incentives to patent may play a large role as to whether people actually expend the effort to patent their inventions. The incentives to patent may be reduced by weak IP protection, low entrepreneurial culture in innovation activities, and others.
proportionally fewer resident patent applications (0.018 per 10,000 people) than the United States (5.01) or Canada (1.60), and noticeably less than Argentina (0.24) and Chile (0.29)\textsuperscript{23}. While the total number of applications has grown during the last decade, Colombian self-sufficiency rate – 0.04 – is still very low compared to that of Chile – 0.15 – or Argentina – 0.14\textsuperscript{24}. Most patent applications are (i) product innovation followed by (ii) industrial design and (iii) process innovation (Graph 6.3).

![Graph 6.3. Number of total patent applications in Colombia](image)

Source: RICyT, [2000]

The classification of patent applications by science field reflects the importance of chemical science for Colombian NIS, especially for scientific research (Graph 6.4.). In 1999, over 70% of patent applications were in the field of chemical sciences: chemistry (11.8%), chemical engineering (24.2%) or pharmaceuticals (38.7%).

![Graph 6.4. Number of patent application in innovation, by science field](image)

Source: RICyT, [2000]

\textsuperscript{23} Two sources of data was used in this paper: RICyT 2000, data available for invention patent publications in 1991-1998, ranged in two groups – residents and non residents; OCyT 2001 data available for 1995-1999 for all patent applications, including process innovation and industrial design, ranged by science field.

\textsuperscript{24} The self-sufficiency rate is calculated as ratio of residents’ patent applications to the non-residents patent application.
7. CONCLUSIONS

On the whole, the major elements of innovation system are present, but underdeveloped due to a series of constraints: lack of investment and limited critical mass, inadequate scientific and educational infrastructure, and limited access to skilled labor. Despite several fundamental advantages and recent improvements, the Colombian NIS appears to be dysfunctional, characterized by limited information sharing and general weak links between actors (Table 7.1 summarizes the study’s main findings).

Table 7.1. Strengths and weaknesses of Colombian NIS

<table>
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<th>Strengths</th>
<th>Weaknesses</th>
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<tr>
<td><strong>Institutional framework</strong></td>
<td></td>
</tr>
<tr>
<td>− Institutional stability</td>
<td>− Political instability and violent conflicts</td>
</tr>
<tr>
<td>− Developed higher levels of institutional framework (as described in chapter 3)</td>
<td>− Unbalances public expenditures</td>
</tr>
<tr>
<td></td>
<td>− Poor coordination between lower levels of institutional framework</td>
</tr>
<tr>
<td></td>
<td>− Poor regulation of IP protection</td>
</tr>
<tr>
<td><strong>Productive system</strong></td>
<td></td>
</tr>
<tr>
<td>− Dynamic chemical industry</td>
<td>− Underdeveloped knowledge-based industry</td>
</tr>
<tr>
<td>− Rising FDI investment in knowledge-based industries and services</td>
<td>− Competitive advantages are related to the exchange rate rather that products quality and cost-efficiency</td>
</tr>
<tr>
<td></td>
<td>− Nascent business participation in R&amp;T activities</td>
</tr>
<tr>
<td></td>
<td>− Low level of high-technology products in trade</td>
</tr>
<tr>
<td><strong>Factor conditions</strong></td>
<td></td>
</tr>
<tr>
<td>− Well developed information infrastructure</td>
<td>− Limited access to skilled labor</td>
</tr>
<tr>
<td>− Dynamic telecommunication sector</td>
<td>− Unbalanced education structure (natural science studies are underdeveloped compared to social sciences)</td>
</tr>
<tr>
<td>− High level of entrepreneurship</td>
<td></td>
</tr>
<tr>
<td>− Flexibility of population</td>
<td></td>
</tr>
<tr>
<td><strong>Scientific research and experimental development</strong></td>
<td></td>
</tr>
<tr>
<td>− Positive spillovers from chemical industry</td>
<td>− General low level of research activities among residents</td>
</tr>
<tr>
<td>− Relatively high level of research in agricultural science</td>
<td>− Nascent collaboration between industry and universities</td>
</tr>
<tr>
<td></td>
<td>− High dependency rate</td>
</tr>
<tr>
<td></td>
<td>− Low share of business-funded research</td>
</tr>
</tbody>
</table>

Studies on technological development recognize State intervention as one of the key elements leading to technological catch-up, (Poti and Basile, 2000). In Colombia, as in other developing countries, the underdevelopment of S&T arises as a consequence of several shortcomings: institutional shortcomings25, inadequate provision of infrastructure, market failures, under-investments in human capital and transition failures26. The following section suggests general initiatives that could be taken to improve scientific and technological capacities in Colombia.

25 For instance, poor regulation of property rights in Columbia and political instability.
26 Transition failures are failures to pursue new technological opportunities and markets, (Poti and Basile, 2000).
**INSTITUTIONAL SHORTCOMINGS**

*Upgrading institutional regime and innovation incentives*

**Assure a proper political and legislative framework**

In order to develop sustainable growth, attract foreign investment and promote innovation in everyday life, Colombia needs, first and foremost, to assure *political stability* and an adequate *rule of law*. Income and regional inequalities further contribute to the growing social tensions and any knowledge strategy needs to take full account of this factor.

**Long-term consistent S&T development policies**

Any type of government support for business R&D is more likely to be effective if it is integrated within a long-term framework, thus reducing the uncertainty that firms face. Moreover, the various policy instruments should be consistent; this implies co-ordination among the administrative departments involved in design and management.

**Provide tax incentives for private sector R&D**

Tax incentives are a powerful government instrument that leaves the allocation of R&D resources to the market forces.

**Strengthen IP protection**

Assuring adequate and effective intellectual property (IP) protection is one of the main conditions for the development of business R&D investment and private innovation activities.

**INADEQUATE PROVISION OF INFRASTRUCTURE**

*Promote FDI in knowledge-based sectors*

Foreign investment in high technology industries appears least influenced by economic fluctuations.

**Taking advantage of information infrastructure**

Being one of the most dynamic sectors, telecommunications is not only a tool to diffuse knowledge, but also a highly knowledge intensive and rapidly expanding sector, which could be at the basis of other knowledge-based cluster. It could also encourage international collaboration and facilitate the access to the world knowledge.

**MARKET FAILURES**

*Promoting entrepreneurship and knowledge-based industries*

**Promote SME development**

Reduce bureaucracy and regulatory hurdles to establish new enterprises and provide access to finance, business skills, technical and marketing innovation. Furthermore, create a more even playing field for the development of small and medium size enterprises across all economic sectors. In emerging areas where demand patterns are unclear, risks are large and technology has not yet been worked out, small firms have an advantage over large established firms. They can
be more flexible and more specialized and may also be better than large firms at channeling creativity and providing the right incentives for their employees. New mechanisms such as venture capital and the associated entrepreneurial expertise, may allow these firms to grow rapidly.

*Develop knowledge-based industries*

The positive spillovers of the chemical industry attest to the benefits of creating a favorable environment for the emergence and development of knowledge-based industry.

*Promote trade of technology-intensive products*

Trade promotes innovation, technology transfer and knowledge sharing.

**UNDER-INVESTMENT IN HUMAN CAPITAL:**

*Upgrading education and learning systems*

*Promote higher education*

A solid education and general entrepreneurship are necessary factors to enable Colombia to catch-up with the scientific level of developed countries. Promoting and concentrating graduate science education (and other key disciplines) in centers of excellence would further improve the NIS.

*Tailor education to meet the needs of the industry*

To increase the number of tertiary students and qualified personnel, create incentives for life-long learning. The number of people who graduate with a degree in natural sciences and engineering seems to be disproportionately low compared to the number of people graduating with a degree in social science.

**TRANSITION FAILURES:**

*Improving research and development capacities*

*Promote basic research*

The gap between private and social returns is likely to be the highest in basic research, which is the main reason behind strong government involvement in this area.

*Stimulate the performance of R&D by business*

Government may either reduce the private cost of R&D or help firms understand the technological opportunities available, thus reducing both the cost and uncertainty of research. If such policies are effective, public and private funding may be complementary to each other, benefiting both. Government (targeted) funding of business R&D can also reduce barriers to the transfer of knowledge from universities.

*Focus on the needs of the industry, especially knowledge-based sectors*
An accelerated development of Colombia’s economic and scientific achievements is best achieved through a prioritization of the country’s existing technology-intensive industries, the chemical industry and pharmaceuticals.

Furthermore, policy intervention on linkages, competence-enhancing activities, and public procurement seems to be more important determinants of industrial innovation than financial incentives and market structure. Therefore, the main focus should be put on:

*Developing industry-university collaboration*

The development of industry-science relationships requires innovation in the financing of public/private partnerships, including equity investments by the public sector, cost- and risk-sharing arrangements and third-party involvement. Furthermore, indirect incentives reflecting the needs of private firms could be a powerful government policy tool to promote industry-university collaboration and business R&D investment.

*Develop industrial clusters and promote inter-firm collaboration*

Inter-firm collaboration has in the past proved to be one of the most successful ways to promote knowledge diffusion throughout the economy.
References


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