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The Evolution of Science & Technology: Latin America and the Caribbean in Comparative Perspective

Thomas Nikolaj Hansen
Natalia Agapitova
Lauritz Holm-Nielsen &
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INTRODUCTION

This study focuses on the evolution of science and technology in Latin America and the Caribbean (LAC). Extensive empirical evidence lends support to the proposition that the ability to innovate, develop new technologies and adapt successfully to existing ones, has become one of the core determinants of economic growth in the past decades. This, in turn, has given rise to concepts like the "knowledge economy" implying that economic growth is no longer a mere reflection of factor endowments; growth is increasingly shaped by the ability to exploit factor endowments in new and more effective ways.[1] Accordingly, the current strength of the US economy is to a large extent due to the country's strong innovative capacity. Likewise, innovation and technology are key for understanding the rapid economic development observed in the East Asian NIC's (Newly Industrializing Countries) since the 1960s. In a European context, countries such as Ireland and Spain also offer interesting examples of economies that have made a change from labor-intensive to capital-intensive production over a short period of time. Hence, there is reason to believe that the "knowledge economy" offers promising perspectives for countries seeking to optimize production and create foundations for sustainable economic growth. This applies to developed and developing countries alike. Thus, India has in recent decades built a strong foundation in engineering, which has helped create a dynamic information and communication technology sector.

Against this backdrop, the question arises, how well the LAC region fares in terms of S&T. This study tries to answer this question by comparing the performance of selected LAC countries to the countries mentioned above. Graph 1 provides a general assessment of the LAC region relative to the G7 and NIC countries. Two of the indicators included in the graph take stock at the overall S&T capacity: The Technology Achievement Index[2] (TAI) and the ratio of high technology exports to total merchandise exports. On both indicators the LAC region appears to lag far behind the levels of the G7 and NIC countries, a clear indication that the LAC region is at a clear disadvantage with regard to science and technology. [3]

The TAI-index is also displayed at the country-level in Graph 2. Argentina, Brazil, Chile, Costa Rica and Mexico rank above the regional average, whereas countries like Colombia and

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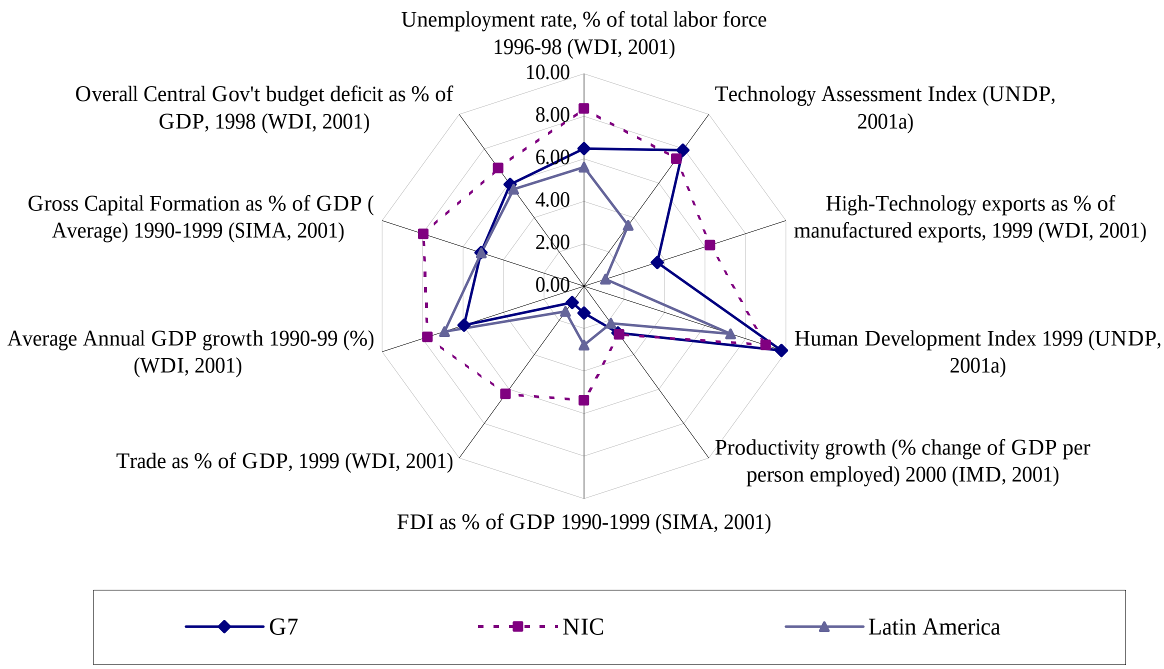
[1] These arguments are elaborated at length in the following publications: OECD, 1997 & 2000a, UNDP, 2001a, Warner, 2000 and World Bank, 1999c.

[2] The Technology Achievement Index focuses on four dimensions of technological capacity: The creation of technology, the diffusion of recent innovation, the diffusion of old innovation and human skills. See UNDP, 2001a for further details.

Bolivia rank in the lower end.[4] Thus, considerable variation exists within the region. The United States is far ahead of every other economy included in the graph. Ireland, Spain and Korea also score better than countries in the LAC region, but have not yet reached the level of the United States. Finally, India receives the lowest ranking of all the countries included in this study.

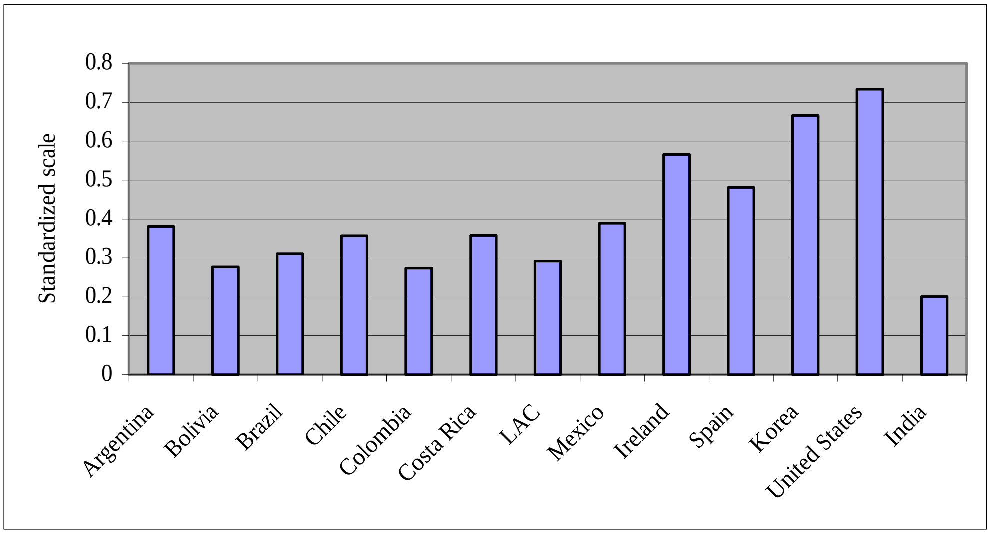
Graph 1 General Indicators



Note: Variables are explained in Annex 1

[3] Brunner finds the TAI-index to be consistent with other indexes of technological capacity, especially the UAI-index computed by the *Universidad Adolfo Ibanez* (2001, p.35).
[4] Thus, Central American states like Nicaragua, EL Salvador and Honduras fare even worse than Bolivia and Colombia on the TAI-index, and countries like Ecuador, Paraguay and Peru also score low in a Latin American context.

Graph 2 The Technology Achievement Index, 2000



Note: The TAI-Index represents eight items, which have been grouped into four main areas: i) Creation of technology: no. of patents granted and royalty and license fees from abroad; ii) Diffusion of recent innovations: no. of internet hosts and share of medium and high-tech exports: iii) Diffusion of old innovations: telephones and electricity consumption; and finally iv) Human skills: years of schooling and tertiary enrolment in science. See UNDP (2001a, Annex 2.1) for further details on the methodology. In the construction of the index, the four areas are weighted equally, as are the different items.
Source: UNDP, 2001a

Thus, the initial assessment suggests that LAC is lagging behind compared to G7 and NIC-countries with regard to S&T. The objective of the present study is to examine the S&T divide up-close and provide an explanation as to why the LAC countries have not been able to upgrade their S&T capacity. First, the key concepts of the paper must be defined.

Key Concepts and Analytical framework

"Knowledge Economy", "Science and Technology" (S&T) and "Research and Development" (R&D) are the key concepts of this study. Yet none of the concepts are easily captured in a single sentence. The "knowledge economy" is a broad complex concept, which has been coined in recent years to indicate that existing ways of perceiving the economy has become obsolete. At its core, the concept stresses the role of knowledge as an increasingly important determinant of economic growth. The increasing importance of knowledge has been further strengthened with the introduction of information and communications technologies. Accordingly, the emergence of the knowledge economy has stimulated interest in the acquisition, creation, dissemination and use of knowledge. The essence and complexity of the concept is captured in the World Bank framework, "the four pillars of the knowledge economy". The assumption is that for a knowledge economy to be successful, the following areas must be in place. i) An efficient institutional framework and strong economic incentives which induce research and development and provide for the necessary financing, ii) a highly developed information and communications infrastructure which reduces the costs of transaction and increases the flow of information, iii) a highly skilled population able to make sense of the rapid changes in the economy and finally iv) an effective innovation system, which can expand the existing frontier of knowledge and adapt innovations successfully to the productive sector.

S&T is intimately linked with the knowledge economy. The fourth pillar of the knowledge economy, the innovation system, is largely constituted by S&T activities, which according to the guidelines of UNESCO[5] includes three activities: i) R&D, ii) S&T-services and iii) S&T-education. The core activity is without doubt R&D, which, in turn, is divided into basic science, applied science and experimental development. Basic science deals with original science undertaken without any particular application in view. This kind of work is normally published as scientific articles. Applied science is also original work, but undertaken with a particular application in view. Experimental Development, on the other hand draws explicitly on existing work, but does so with a view to provide substantial improvements. It goes for all three groups that the knowledge produced must be non-obvious and contribute significantly to the existing stock of knowledge. S&T-services, the second category within S&T activities, include activities which support R&D without being an intrinsic part of the knowledge creation, This, *inter alia,* involves library services, patent offices, standardization and translation services. S&T-education include PhD programs and education of academic staff.[6] Hence, S&T activities go to the heart of the knowledge economy, seeing that they explicitly deal with the generation and diffusion of knowledge in society.

Accordingly, this study will draw extensively on the knowledge economy framework developed by the World Bank. Still, the framework will be adapted to fit the objective of the study. The S&T system will be put at the centre of the analysis and the three remaining pillars will be analysed in terms of their importance for the S&T sector, the assumption being that the analysis of each of these pillars can help illuminate why the LAC region is lagging behind in terms of science and technology capacity.

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[5] These definitions also guide the work of RICyT, whose databases are used extensively in this study (2000, p. 259).

[6] This category is difficult to delimit from R&D, since most PhD projects by definition include the generation of new knowledge. Thus, activities related to PhD programs must necessarily be broken down into courses and supervision of PhD students (S&T-education) and the time devoted to the development of new knowledge within the framework of the PhD-program (for futher details, see RICyT, 2000, p.259 and OECD, 1994).

The study will be divided into five parts. Part I will assess the nature of the critical conditions surrounding the S&T system: the institutional framework, the penetration of ICT technologies and the stock of human capital. Part II, in turn, will target the core of the analysis, the S&T system. Still, the level of technological development is not solely a function of domestic characteristics. Hence, the experience of Japan, and the East Asian NIC's has called attention to the fact that transfer of foreign technologies can play a key role in upgrading domestic S&T capacities. Henceforth, part III will look at the importance of the international stock of knowledge and part IV will sum up the analysis and set forth a number of policy recommendations. However, before moving into the analysis, the methodology and data will be discussed briefly.

Methodology and Data

The study is based on a comparative design involving regional as well as country level data. The regional comparisons include average data for the LAC region, which will be compared to G7 and NIC- countries.[7] These comparisons are intended to provide a rough overview of how the LAC region is faring in comparison to some of the most competitive and significant economies in the world.

In order to account for differences between LAC countries and make the basis for a more thorough investigation where necessary, a selection of LAC and non-LAC countries has been singled out. The following LAC countries have been selected: Argentina, Bolivia Brazil, Chile, Costa Rica, Colombia, Cuba and Mexico.[8] This selection includes some of the most populous countries in the region, but also represents the different sub-regions within the region, including Central America, the Caribbean, The Southern Cone, the Andes Region and the Northern part of South America. It is important to bear in mind, though, that the selection is slightly biased towards the better performing countries in the region in terms of S&T. The bias in intended, though, in order to highlight how some of the countries in the region have succeeded in creating significant S&T capacities within certain sectors. Costa Rica, for example, is not a representative example of the average performing Central American state, but the country has been included because it is an interesting example of how a country can successfully adapt to foreign

[7] G7-countries include: Canada, France Germany, Italy Japan United Kingdom and the United States of America (the United States). NIC-countries include Hong Kong Special Administrative Region, Republic of Korea (Korea), Singapore and Taiwan.

technologies. Furthermore, the bias is made explicit by listing average score for the LAC countries where available and including LAC countries whose overall capacity ranges below the LAC average, notably Bolivia, Colombia and Cuba.[9]

The non-LAC countries included are those mentioned in the introduction: Ireland, Spain, Republic of Korea (Korea), the United States of America (United States) and India. The selection includes examples of developed and developing countries, which all to some extent have succeeded in using S&T as a vehicle for economic growth. Ideally, some of these experiences can be used when formulating policy recommendations for the LAC-region.

The study is based on statistics from various international organizations, including World Bank, OECD and UNESCO databases as well as the RICyT database (*Red de Indicadores de Ciencia y Tecnologia*), which is a rich source of information on S&T in the LAC region (2000 & 2001). Unfortunately, only few sources include data for the full selection of countries included in this analysis. Thus, in some cases comparison is impossible; in other cases comparison is based on different data sources, which means that differences between countries may be due to differences in methods rather than actual differences in performance.[10] Accordingly, this must be taken into account when interpreting data. Apart from quantitative indicators, the study draws extensively on official government web pages as well as information and analyses published by international organizations and academic scholars.

[8] For some of the countries included in the analysis, only limited data is available. This is particularly the case for Cuba, which nevertheless has been included due to its position as one of the most populous countries in the Caribbean and its development strategy, which has put significant emphasis on science and technology.
[9] Average scores have only been included if data is available for a representative sample of LAC countries.
[10] Vukmirovic, 1999 highlights how UNESCO and RICyT data on resident and non-resident patent applications differ significantly.

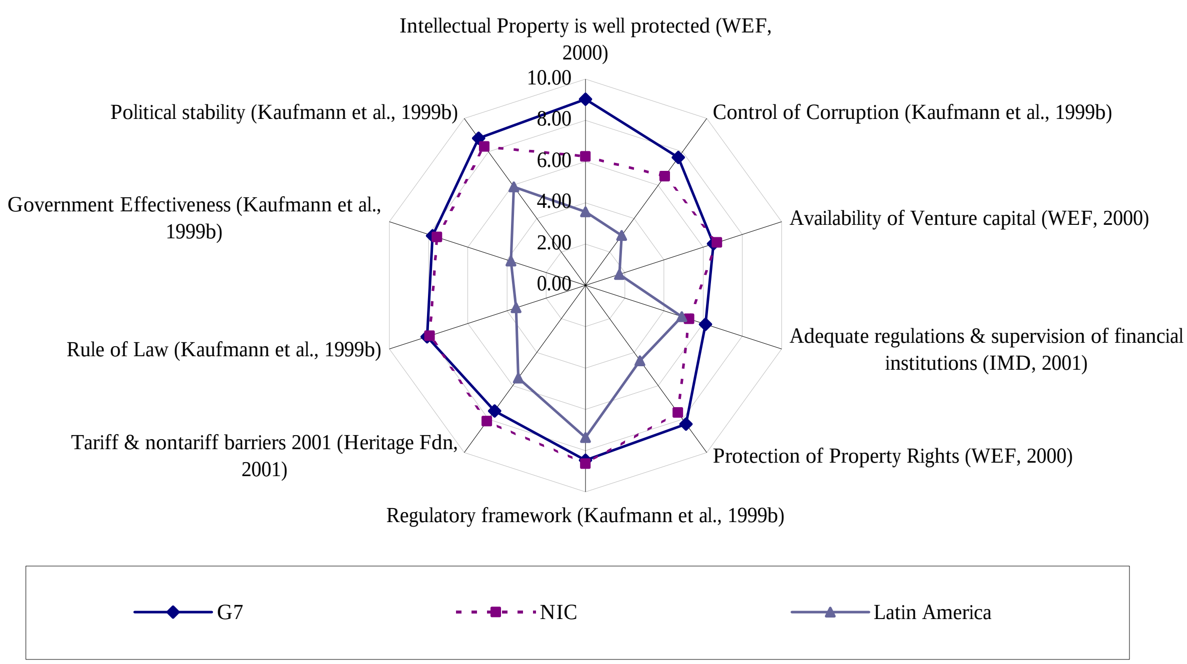
PART I – CONTEXT

For a strong S&T system to develop, a number of preconditions such as a consolidated institutional framework and proper economic incentives, a highly developed ICT-infrastructure and a stock of highly skilled human capital, must be in place. This part of the study will assess the degree to which the LAC region meets these preconditions.

I-1 INSTITUTIONAL FRAMEWORK & ECONOMIC INCENTIVES

The discussion of the institutional framework and economic incentives will touch on the quality of the overall legal framework, the level of competitiveness in the domestic economy and access to investments. Each of these variables are considered vital for the emergence of a strong S&T system, but whereas the question of finance has direct implications for S&T activities, the impact of the other aspects are expected to be less direct.

Graph 3 Institutional Regime and Economic Incentives



Note: Variables are explained in Annex 1

In a snapshot, Graph 3 provides a general overview of the quality of the institutional framework in the LAC region compared to the G7 and NIC countries. A clear trend emerges from this comparison: On almost every dimension included, LAC is significantly lagging behind. The implication is that S&T policies adopted in the LAC region are less likely to have a successful impact due to the poor quality of the institutional framework and weak economic incentives.

This, however, is only a preliminary conclusion based on a selected number of aggregate, quantitative indicators. Thus, the following sections will provide a more detailed analysis and also consider country-level data in order to account for variations across the LAC region.

Legal Framework

A proper legal framework is constituted by the rule of law, absence of corruption and a consolidated property rights regime. In this particular context, special focus will be on the strength of intellectual property rights regimes, which are believed to play a key role in promoting innovation. In general, a proper legal framework is believed to be a core condition for the establishment of a strong knowledge economy. Thus, where the rule of law is fragile, corruption is ubiquitous and property rights remain weak, pay-offs from investments in S&T related fields become unpredictable and subject to sudden policy changes.[11]

Kaufmann et al. (1999a, 1999b & 2002) have computed an indicator to assess whether the "rule of law" is prevailing.[12] Based on this indicator, the rule of law in the LAC region appears to have serious flaws compared to the G7 and NIC countries (Graph 3). However, significant differences exist between the LAC countries. The rule of law seems to be consolidated in Chile, and Costa Rica also displays a stable legal framework. In contrast, Colombia and Cuba receive very low ratings. Variations are also found outside the LAC region. In Ireland, Spain and the United States, rule of law is deeply entrenched. As regards India, the rule of law appears less consolidated than in Chile and Costa Rica, but still more solid than the average LAC country (Graph 4). It should be noted that these patterns are largely reproduced in terms of corruption.[13]

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[11] These aspects are discussed in World Bank 2002a.

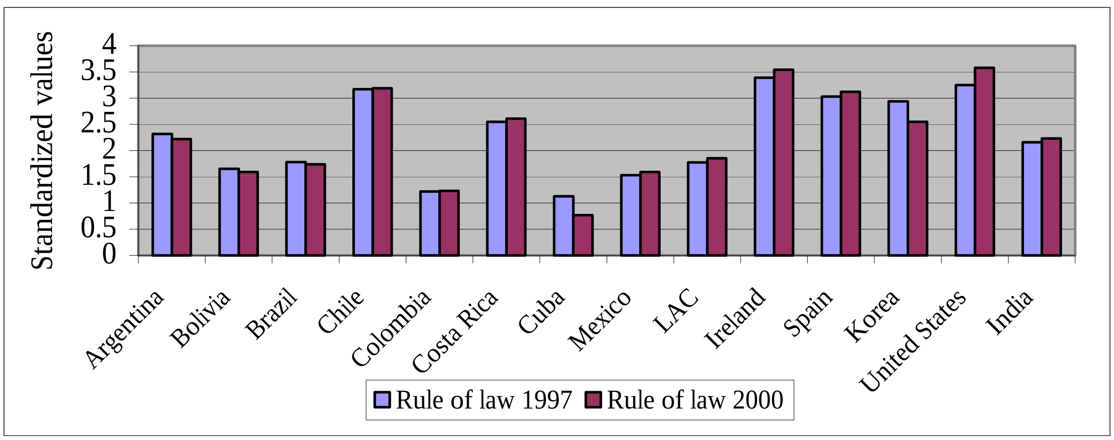
[12] The indicator is in fact a composite index based on numerous polls and surveys from different sources. A detailed explanation is provided in Kaufmann et al. 1999a & 1999b.

[13] Transparency International's Corruption Perception Index (CPI) confirms these findings with regard to the level of corruption in the region. The CPI is an aggregate index based on numerous subjective indicators The index covers approximately 125 countries, hereof 15 LAC-countries. The LAC-countries generally range in the bottom two-thirds of the selection with Chile being the least corrupt in the region, whereas countries like Bolivia, Mexico and Colombia range among the most corrupt in the region. Furthermore, it can be concluded that countries like Argentina have seen corruption become even more prevalent during the last half of the 1990s whereas Brazil has

Thus, in countries where the rule of law is flawed, corruption is by consequence more likely to emerge.

Special attention must be paid to the issue of intellectual property rights (IPRs). IPRs encompass various legal instruments that differ in the extent and kind of protection they offer, ranging from patent rights to innovations and significant technological improvements to copyrights of original works of culture and trademark rights for names or concepts associated with a particular company or product. IPRs provide innovators with exclusive rights to their innovations for a specific period of time, ensuring that innovations cannot legally be copied or used by others without proper authorization. Primo Braga et al. (2000) note that the three main economic effects of IPR regimes include: i) providing incentive for creating new knowledge and information, ii) promoting diffusion of knowledge within and across economics, and iii) affecting market structure and prices.[14] While these effects vary considerably among different industries and countries, there are general trends that can be highlighted.

Graph 4 Rule of Law, 1997 & 2001



Note: The index for rule of law has been constructed by aggregating 42 items (expert polls and resident surveys), which take stock at the prevalence of crime, enforceability of public and private contracts, tax evasion, predictability and independence of the judiciary and the willingness of the citizenry to accept legal means as a way to adjudicate disputes. The items have been aggregated through the adoption of an unobserved components model, a weighted average of appropriately rescaled scores of each item. It should be noted that the exact number of items included in the specific country estimate varies due to variation in the country coverage of the different items. Furthermore, the standard deviations of the estimates are large relative to the units in which governance is measured. By implication, marginal differences are not statistically significant. See Kaufmann et al. (1999a) for further discussion on the methodology. Scale has been changed from –2 – 2 into 0 – 4
Source: Kaufmann et al., 2002

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managed to increase the control of corruption notably. Outside the LAC region, Spain has also succeeded in reducing corruption significantly, whereas a country like Korea continuously struggles with a level of corruption equivalent to that of the better performing LAC countries. Finally, India receives very low rankings reflecting that corruption is prevalent throughout the public administration (Transparency International, 1995, 2000 & 2001).

[14] Primo Braga, C. P., Fink, C., Sepulveda, C., P., 2000

IPRs provide incentives for innovation by providing inventors (or corporations that employ them) with legal title to the end result of their work, thus offering them an exclusive opportunity to derive economic benefit from that work. In return, IPR regimes commit the innovators to disclose their innovations to the public, thereby contributing to the general stock of knowledge and diffusion of that knowledge. In the absence of effective IPR-regimes, innovators have less incentive to invest time and money in R&D activities, since they are not guaranteed exclusive right to the results of their efforts. The implication is that few private investors would invest in R&D activities where everybody benefits and the few carry the costs.[15] Thus, IPR-regimes are believed to contribute significantly to a greater level of R&D activities in a society, and serve as incentives for stimulating innovation.[16] Diffusion of knowledge, both nationally and internationally, is promoted by trade and active licensing efforts, which, in turn, are greatly affected by IPR regimes within a country.

Intellectual property rights do not exist in a vacuum. The strength of IPR regimes is determined not only by laws and regulations adopted by individual countries to establish legal rights and broad protections for all types of IPRs, but also by the existence of effective institutional systems for administering and enforcing IPRs. As the enforceability of IPRs varies greatly from one country to another, it has become clear that laws that seem alike on paper may have substantially different effects in countries with different market structures and enforcement mechanisms.[17] Moreover, the effect of IPRs on innovation and economic activity is determined by the availability and access to high risk investment capital, availability of human capital, the use of protected know-how in production and consumption, and access to large markets open to free trade.[18] These factors contribute to the complexity of studying, assessing and measuring the direct effects IPRs, and devising a single, global policy regarding IPR regimes.

Keeping in mind the difficulty of assessing and measuring IPRs, the great variations between individual countries, and the heterogeneity of effects of IPRs, it might be useful to look at comparative effects of different levels of IPRs. Sherwood defines three levels of protection for intellectual property: First, a non-robust level that leads to random and sporadic innovation.

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[15] It should be noted that other stimulants of research (such as public investments and social benefits from accolades and prestige associated with truly novel discoveries) exist, although such stimulants commonly play a greater role in earlier stage (i.e. discovery versus commercialization) of research.
[16] Kanwar, S., 2001, p. 9
[17] Maskus, K. E., 2000, p.2223
[18] For more detailed discussion, see Primo Braga, C., Fink, C., and Sepulveda, C., P., 2000, and Sherwood, R., M., 2000.

Second, a level that facilitates trade and tends to encourage local innovation in selected circumstances. Finally, a robust level that stimulates local investments in sustained R&D and a high level of inventiveness.[19] Table 1 highlights the effects of different levels of protection on ten different arenas:

Table 1: Levels of IPR-protection

Effects:	Non-Robust IP Systems	Trade-Facilitating Systems (e.g. TRIPS)	Investment-Stimulating Systems
Innovation	Random, sporadic	Achieved in some areas	Planned, constant
Proprietary technology	Little acquired	Some acquired	More acquired
Human skills	Limited development	Some development	Higher skills developed
Agricultural base	Old science	Some new science	Best new science
Private investment in technology	Limited investment	Investment in low technology	Investment in high technology
Industrial base	Sales & distribution & assembly	Some 'pirates' displaced by imports	New high tech industries spring up
Prices of pirated products	Low	Higher	Lower than trade model
Risk capital	Little available	Some available	Optimum risk capital
Technology transfer	Theoretical, unused	Some technology transfer	More technology transfer
Cultural advancement	Impaired	Well stimulated	Fully stimulated

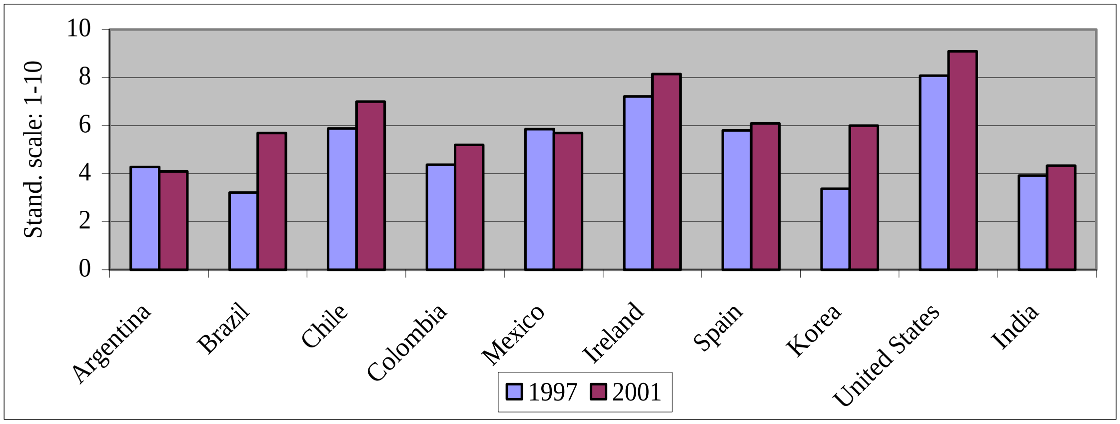
Source: Sherwood, 2000, p. 61

The importance of strong IPR regimes has been questioned in recent years. It has been argued that overly strong patent protection could restrict the process of innovation by discouraging researchers from pursuing the development of a particular technology because of the fear that they might infringe on existing patent rights.[20] While is very difficult to define an optimal level of intellectual property protection that provides adequate incentives without any limitation on further innovation, this fear can be moderated by supporting and enhancing the institutions and systems charged with administering IPRs, which, on a case by case basis, mediate between allowing too broad (excessively restrictive) or too narrow (insufficiently protective) claims. Critics have also been vocal with regards to the effect of strong IPRs on developing countries. In particular, many fear that stronger standards of protection might foster monopolistic behavior from multinational companies, and thus lead to higher prices for particular goods and services,[21] and that the strong novelty requirement for granting patents may preclude many small, adaptive innovations that take place in developing countries from obtaining adequate patent protection and associated benefits.[22] Moreover, it has been argued that strong IPR-regimes could prevent

[19] Sherwood, R., M., 2000, p. 62
[20] Primo Braga, C., Fink, C., and Sepulveda, C., P., 2000, p. 28
[21] ibid. p. 47
[22] ibid. p. 28

developing countries from following the path originally followed by countries such as Korea, which benefited from weak IPR-regimes by "inventing around" existing patents.[23] Many questions remain with regard to setting up appropriate IPR regimes in developing countries, as specific needs and particular circumstances (including the level of technological development, the strength of judicial systems and rule of law, and prevalence of corruption, among others) play a prominent role in a country's ability to effectively implement and benefit from adequate IPR regimes.

Graph 5 Protection of Intellectual Property Rights, 1997& 2001



Note: 1993 data reflect whether "intellectual property is adequately protected in your country". 2001 data reflect the degree to which "patent and copyright protection is enforced in your country".
Source: IMD, 2001; IMD & WEF, 1994

Survey data measuring the strength of IPR regimes reveal that LAC as a whole scores very low compared to G7 and the NIC countries (Graph 3). Looking inside the region, Chile outperforms the rest of the LAC countries, but IPR-regimes in countries such as Brazil and Mexico also receive fairly high rankings seen in a regional context. [24] Furthermore, the quality of IPR-regimes seems to have been stable or improving throughout the LAC region as well as among non-LAC countries in the course of the 1990s. [25] The significant improvements observed in Brazil and Korea are arguably a reflection or recent, sweeping reforms of the regimes carried out in the latter half of the 1990s (Graph 5).[26]

[23] See World Bank, 2002a, p.147.
[24] See World Bank, 2002b for general considerations and Agapitova et al. (forthcoming) with regard to Colombia, which is still in the process of implementing the TRIPS-agreement. See also Country Commercial Guide on Costa Rica, 1999.
[25] It should be noted that the countries included in 0, arguably represents a biased selection of LAC countries, in the sense that are expected to perform above average in a Latin American context. Unfortunately, comparable, valid data are only available for these countries.
[26] See Commercial Guide, 1999 for Brazil and Korea, respectively. For Korea see also EIU, 1999.

The Trade-Related Intellectual Property Rights (TRIPS) agreement has contributed to improving the current standards of IPR protection in the region. The TRIPS agreement was adopted within the framework of World Trade Organization (WTO) Marrakech Agreement of 1994, and while it does not promote a single, global standard of IPRs, it sets forth a number of common minimum standards (such as the minimum protection period of 20 years) and basic enforcement measures, thus establishing the groundwork for the emergence of stronger intellectual property rights protection throughout the world. Developing countries were given until January 2000 to comply with the regime, whereas the least developed countries (LDC's) are given until January 2006. [27] In most cases the TRIPS agreement offer better protection than existing national IPR-legislation in the LAC region. Accordingly, the importance of integrating the TRIPS agreement into national legislation has been mentioned in Brazil and Colombia as driving forces behind recent reforms of IPR-regimes.[28] In the case of Mexico, the NAFTA regime is also believed to lock-in the current IPR regime. Thus, Mexico updated its IPR regime comparatively early in order to accommodate US negotiators who demanded strong protection of US intellectual property in return for the free trade agreement.[29]

In conclusion, the LAC countries have been moving from "non-robust IP systems" towards "trade-facilitating systems", according to the terminology of Sherwood. By implication, LAC countries still need to make further progress if they want their IPR-regimes to stimulate investment and innovation. Simultaneously, LAC countries also need to ensure that current IPR-regimes are properly enforced.

Competition

A competitive market is assumed to stimulate the demand for scientific progress and technological innovations. Thus, if internal and external barriers to competition are broken down or lowered, the demand for science and technology will by implication be strengthened.

As pointed out, the economic environment in the LAC-region has changed significantly in the course of the last decades with the abandonment of the import substitution industrialization (ISI) approach and the subsequent market liberalization. Thus, the majority of the countries have

[27] The only LAC-county with official status as least developed country is Haiti (WTO, 2002).
[28] See Country Commercial Guide, 1999 on Brazil and Agapitova et al. (forthcoming) on Colombia.
[29] See World Bank, 2002b, p.132.

worked determinedly in recent years to deregulate domestic markets and open up their economies to foreign goods, services and investments.[30]

As shown in Graph 3, the general regulatory framework in the LAC region is to some extent comparable to the average values reported for G7 and NIC-countries.[31] However, there is considerable variation between the LAC countries. Chile, Mexico, Costa Rica and Argentina have succeeded in creating a far better environment than countries such as Bolivia, Cuba and to some extent Brazil where the regulatory quality has been deteriorating in recent years.[32] By consequence, the private sector in countries such as Bolivia and Cuba is not likely to thrive unless the quality of the regulatory framework is improved significantly.

In an international comparison it stands out, that markets in Ireland, Spain and the United States are more attractive to investors in terms of regulatory quality than most of the LAC countries with the exception of the countries mentioned above (Graph 6). Ireland for example has taken a number of initiatives to accommodate the private sector and foreign direct investments; initiatives that have paid off significantly.[33]

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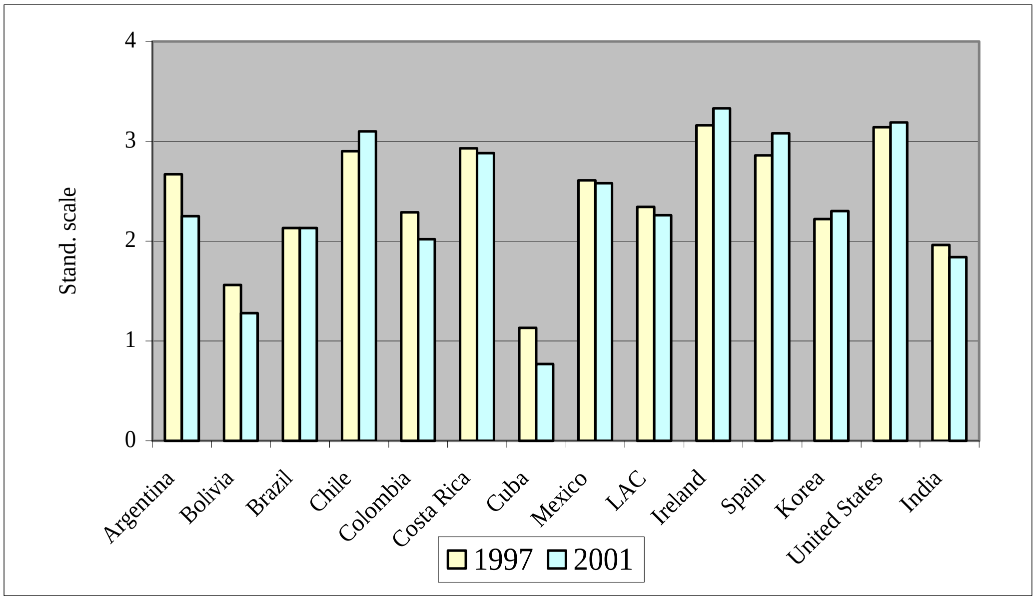
[30] See Erber, 1999

[31] This is based on an indicator developed by Kaufmann et al., which measures the extent to which the government distorts the economy through regulation, including, *inter alia,* the degree to which the government invokes price controls, put restrictions on local business and set up restrictive foreign currency regulations. This indicator can be used as a proxy for the extent to which internal barriers distort the economy. For further details see Kaufmann et al. 1999a.

[32] In 2001, Costa Rica furthermore launched the "IMPULSO-programme" which adapts the regulatory framework to the needs of the private companies (La Nacion, 2001).

[33] See EIU Country Profile, 2001

Graph 6 Regulatory Quality, 1997 & 2001



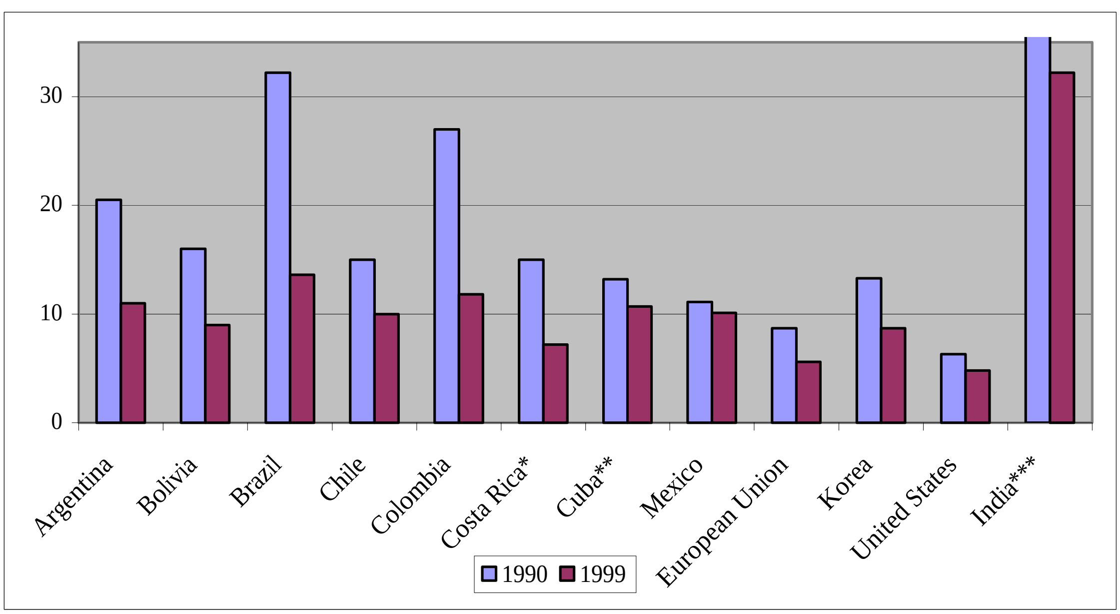
Note: The index has been obtained by aggregating 61 items (expert polls and resident surveys) concerning regulations on business establishment and investments, export tariffs, price controls, foreign trade regulations and the nature of the tax system. See note to Graph 4 for details on aggregation of data. Scale has been changed from –2 – 2 into 0 – 4.
Source: Kaufmann et al., 2002

The state has played a dominant role in the Korean economy. However, this has changed in recent years and the strategy is now to transform the state into a small, efficient and service-minded entity. Extensive deregulation has taken place in most sectors, including the labor market, with the services sector as the sole exception. However, Korea has like a number of LAC countries still a long away to go in terms of improving its regulatory quality. In the case of India, the regulatory quality has decreased slightly in recent years and is generally less supportive of the economy than the average LAC country (Graph 6).

As pointed out above, liberalizing trade and investment regimes also stimulates the competitive environment. From the 1940s into the 1980s the LAC countries largely followed a protectionist approach to economic development. Thus, the intention was to reduce dependency on foreign markets by keeping away foreign imports through high tariffs and developing a strong domestic industrial sector. This clearly damaged the competitive pressure in the domestic economy. Seeing that the ISI path of development proved fiscally unsustainable by the end of the 1970s and the 1980s, numerous efforts were made to open up trade and investment regimes in the region. Thus, average tariffs now range about 13-15% and restrictions on FDI have been lifted in most cases.[34] Likewise, India has broken with a protectionist strategy similar to that of the LAC countries, lowering mean tariff rates from about 80% in 1990 to about 30% by the end of the 1990s. Korea on the other hand, departed from protectionism much earlier, when disappointing results materialized in the late 1950s. In consequence, the Koreans opted for export promoting policies. [35] Still, most of these countries do not compare to the United States and the European Union, where mean tariffs lie in the range of 5-6% (Graph 7).

Still, the recent liberalizations on the LAC region represents a significant change in terms of competitive environment, which in turn has led to an increase in the mortality among SME's incapable of technological upgrading. The causes of this problem arguably have to be detected in the failure of financial and technological markets. Although the opening up of the economy had a particularly negative effect on SME's as a group, the SME's that did survive operated in the economy's faster growing industries showing a tendency to improve their performance with respect to large-scale companies. Conversely, the performance of SME's operating in slow-growth sectors deteriorated. This evidence suggests that the sectoral environment and externalities, rather than forces emerging from the firms themselves, are the main determinants of small, family-run firms' success in improving their performance over time (Katz, 2000).

Graph 7 Mean Tariff Barriers (%), 1990 & 1999



* 1992 & 1999 ** 1993 & 1997 *** Mean tariff rate 1990: 81,8%

Note: External tariffs for European Union have been included instead of country data for Spain and Ireland

Source: World Bank, 2001c

[34] For Costa Rica and Colombia, see their respective Country Commercial Guides, 1999.

[35] See Etzkowitz and Brisolla, 1999; Lall, 2000, p.40; Chang & Cheema, 2001 and World Bank, 1999c, p.32.

In addition to removing entry barriers to the economy, a number of positive measures can also be taken to promote the level of competitiveness. Such measures include the establishment of fair trade and anti-monopoly agencies, which have been established throughout the LAC region since the early 1990s.[36] The introduction of quality standards is also believed to strengthen the competitive environment. They do so by improving the flow of information and increasing the transparency in the market.[37] This is especially the case for international standards such as ISO 9,000 and 14,000.[38] However, caution is warranted since countries frequently set up national quality standards, which discriminate against foreign products and as such act as technical trade barriers. ISO standards are today used throughout the LAC region, but have not yet become an integrated part of SMEs in the region.[39] For this to happen, the mere introduction of standards will not suffice. Demand must also be stimulated. Thus, companies must be made aware of the potentials of adapting to and using ISO standards.[40] The nature of this challenge differs from country to country in the region. Thus, countries such as Argentina have more than 60 years of experience in using quality standards, whereas other countries are still in the initial stages.[41]

Finance

Lack of investment is a major obstacle to the promotion of a competitive S&T sector. As noted in the introduction, the questions of finance is particularly pertinent for the S&T sector, since S&T investments usually do not pay off in the short term and often involve high risks. This in turn warrants government intervention, but for a sustainable S&T-system to emerge other sources of finance must be provided. Accordingly, the development of financial markets is a key condition for the development of a competitive S&T sector. A solid and properly regulated bank sector is a necessity, but far from sufficient. Banks are usually disinclined to run the risk of investing in high-risk S&T areas. Furthermore, experience shows that the banking sector

[36] World Bank, 2002a
[37] World Bank 2002a
[38] See MIF, 1999.
[39] See various Country Commercial Guides, 1999.
[40] Thus, evidence suggests that the adoption of ISO-standards increases productivity by making production methods more effective (World Bank, 1999c).
[41] Another issue of concern to the competitive environment concerns the risks of economic entrepreneurship. If risks are too high and cannot be mitigated trough through insurance schemes and proper bankruptcy legislation, this by itself constitutes a significant entry cost. However, setting up appropriate insurance schemes and bankruptcy laws may not prove sufficient. There is also a major cultural dimension to the issue of failure. In countries such as the United States failure is socially accepted whereas it is associated with social stigmatization in other cultures. Thus,

typically requires lenders to have tangible assets that can serve as collateral, which excludes a number of potential entrepreneurs from credit. This clearly makes a case for promoting alternative sources of funding such as stock markets and "patient" venture capital.[42]

Over the 1990s the penetration of stock markets have increased as measured by the ratio of market capitalization to GDP, but the absolute size of stock markets is still moderate.[43] As is the case for most indicators, considerable variation exists within the LAC region. Thus, the penetration of stock markets is especially high in countries such as Chile, Argentina, Brazil and Mexico, where market capitalization is about 30% of GDP or higher. Chile ranks by far the highest with a market capitalization rate towering around 100%. Bolivia on the other hand displays the weaknesses of some of the lesser-developed countries in the LAC region with a barely existing stock market. Still, the overall increase in capitalization rates is a promising evolution, indicating that finance markets are developing quickly in the region. However, measured in terms of turnover ratio, only Brazil and Mexico rank high in the region, which indicates that transaction costs in most LAC countries are still fairly high.[44] Thus, evidence suggests that high costs of listing have led Argentinean SME's to stay away from stock markets.[45] In Colombia, the merger of the country's stock exchanges in July 2001 led to a drop in listing costs, which is expected to ease smaller companies' access to stock markets. Likewise, the Indian stock exchange decided to ease entry requirements in the 1990s, which accordingly spurred a massive growth in market capitalization. Interestingly, a significant part of this capitalization is constituted by ICT-companies, which obviously are among those who benefit from improved access to stock markets.[46]

Another source of funding, related to traditional stock markets, is venture capital. Small firms and entrepreneurs with innovative ideas and no substantial tangible assets have limited options with regard to accessing capital necessary for the development and commercialization of new products or processes. While capital for innovation is scarce, venture capital funds have emerged

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entrepreneurship cannot simply be created through institutions; it implies a cultural challenge as well (Dahlman & Aubert, 2001).

[42] Even though the implications of banking finance are limited with regard to S&T, a short assessment is warranted: The penetration of the banking sector in the LAC region has increased with approximately 38% in the course of the 1990s as measured by the ratio of quasi-liquid liabilities to GDP. Still, the ratio only represents about 25% of GDP, which is fairly low compared to regions such as East Asia where quasi-liquid liabilities represent about 85% of GDP (WDI, 2001). Nevertheless, the banking sector is clearly on the rise in the LAC region, and a country like Bolivia has seen an astounding increase in quasiliquid liabilities in recent years..

[43] This part draws on World Bank, 1999.

[44] WDI, 2001

[45] EIU Country Profile, 2001

[46] Oxford Analytica (2000)

as an important intermediary in financial markets, providing an efficient and effective source of high-risk capital to entrepreneurs and young companies.

Venture capital refers to equity investments in young companies that have high-growth potential, where investors take an equity position and often assume an active role in the company by serving on the Board of Directors, relying on their professional expertise and experience to provide advice and guidance to the company's senior management team. The managerial expertise and discipline institutional investors bring has often proven just as valuable as the capital infusion for the long-term value creation. Gompers and Lerner note that "the evidence suggests that the early participation of venture firms—including their guidance, monitoring, shaping of management teams and boards, networking, and credibility—helps innovators sustain their success long after their company issues an IPO."[47] Venture capital is a source of patient capital, as investors expect their investments to remain illiquid for a period of 3-7 years. Upon successful exit from the investment, often achieved through an initial public offering or an acquisition by a well-established player in the industry, venture capitalists realize capital gains.

The macroeconomic environment, institutional framework, and cultural factors affect the supply and demand of venture capital. Adequate legal protections, robust financial infrastructure (including the existence of viable secondary markets), well-developed educational infrastructure, palpable culture of innovation and entrepreneurship, adequate intellectual property protections, tax incentives, availability and demand of capital, and adequate regulatory environment are some of the elements that need to be in place or developed in parallel to allow for the emergence of a successful venture capital industry.

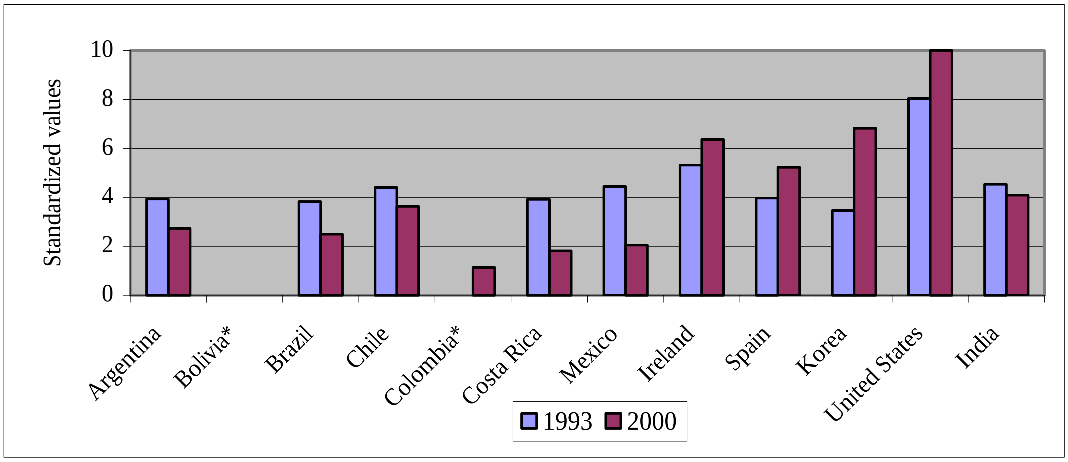
Survey data from World Economic Forum reveals a stark difference between the LAC region on the one side and the G7 and NIC countries on the other side with regard to availability of venture capital (Graph 3). Thus, LAC is trailing far behind and country level data show that this is the case for most LAC countries, with Chile being the regional leader and Bolivia and Colombia in the lower end (Graph 8). The data does not suggest that the availability of capital has increased in the LAC region over the last decade, but seeing that the survey data does not refer to the same question in 1993 and 2000, respectively, no conclusions can be drawn.

The large supply of venture capital in the United States has had wide implications for the country's ability to create and sustain growth in the high-tech sector (see Box 1). In Europe, on the other hand, the venture capital industry only recently started to emerge.[48] There are numerous

[47] Gompers & Lerner, 2001, p. 64
[48] See OECD (2000b)

indications that the availability of VC is starting to spread outside of the United States. In Spain and Korea, smaller stock markets (Ibex Nuevo Mercado & KOSDQ) with more flexible administration have been set up to meet the demand driven by the number and growth of venture-backed firms.[49] In India, the competitive ICT-sector has also managed to attract large sums of venture capital; by the end of 2000, venture capital funds amounted to US$2,5 billion in the Indian economy. In consequence, India is ranked higher than all the LAC countries with regard to availability of venture capital (Graph 8).[50]

Graph 8 Availability of Venture Capital, 1993 & 2001



*No data available for 1993, Bolivia's rating for 2001 is 0.
Note: 1993 data are originally measured on a scale 1-10, whereas 2000 data have been standardized. 1993 data reflect whether "venture capital is readily available for business development. 2000 data reflect whether "entrepreneurs with innovative but risky projects can generally find venture capital in your country".
Source, WEF, 2000; IMD & WEF, 1994

The lack of venture capital in the LAC countries largely reflects lack of involvement by the private sector. Most of the venture capital schemes set up in the in the region have been established by the public sector (see section on public policies). The lack of private sector involvement has several reasons, but the absence of an investment friendly environment stands out as one of the main problems. Accordingly, improvement of IPR-regimes, and the general rule of law could be expected to facilitate the growth of venture capital.

Still, some private initiatives have emerged over the 1990s, which can be regarded as a positive response to improved IPR-regimes. Yet, most of these initiatives originate in the US and include a recent decision to set up a venture fund in support of Internet and software companies

[49] Secondary stock markets affect the venture capital industry by offering a venue for achieving liquidity, enabling venture capitalists to return investment funds and capital gains to their limited partners, and for providing individual portfolio companies with access/opportunity to raise further capital and continue their growth. For information on the secondary stock markets in Spain and Korea, see EIU, 2001.

in the LAC region. Likewise, the US based Advent International have been successful in supplying small, innovative firms in the Americas with essential capital infusions.[51] The growth of US venture capital in the region draws attention to the fact that a culture of entrepreneurship is another necessity for stimulating venture capital. Hence, it is far from certain that mere changes to the formal institutional framework will cause private investors in the region to engage in high-risk ventures. This reservation notwithstanding, LAC countries should do anything in their power to foster venture capital markets realizing that it is a *sine qua non* condition for the advancement of innovative entrepreneurs, small and medium enterprises and the private sector in general.

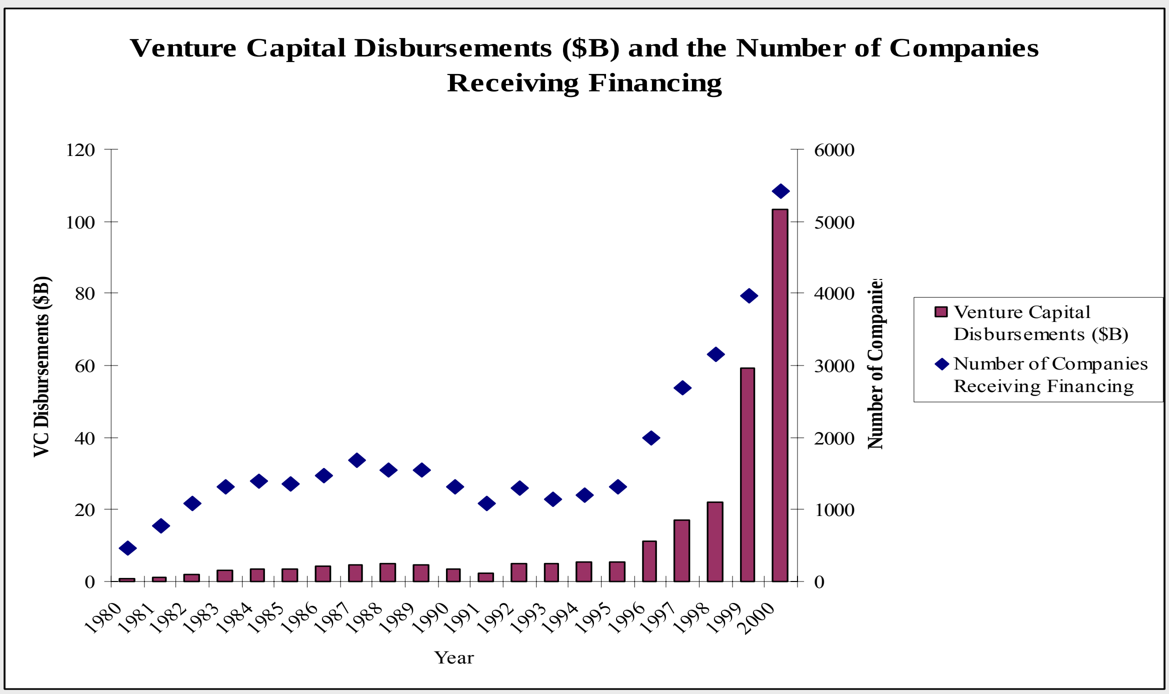
[50] EIU Country Profile India (2001) and Oxford Analytica (2000)
[51] See Barham, 2001, which describes the current status of capital venture investments in the LAC region.

Box 1: Impact of Venture Capital on the US Economy

The US venture capital (VC) industry has enjoyed extraordinary growth over the past decade. Spurred by the emergence and evolution of new technologies and in turn stimulating an unprecedented rate of innovation and technological change, the venture capital industry contributed considerably to the economic growth and prosperity in the US.[52] While it is difficult to extrapolate from the US data to the rest of the world, the impact venture capital has had in the US on the economy and the national innovation system is astounding, and merits a brief overview.

In 2000, close to 700 VC firms had US$209.8 billion under management, a six-fold increase from 1990 when 375 firms managed US$32.0 billion, and an almost seventy-fold increase from 1980, when 87 VC firms managed US$3.0 billion. In 2000, US$103.5 billion was disbursed by venture capital funds in the United States, up from US$3.3 billion in 1990 (Graph 9). Of that amount, over 91% was invested in high-technology companies, and close to a quarter (23%) was invested in early stage companies. Over the past two decades, the number of companies receiving financing has grown more than ten-fold— from 472 in 1980, to 5,412 in 2000.[53]

Graph 9 Venture Capital Disbursements, 1980-2000



Source: NVCA 2001a

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[52] Venture backed companies contribute to the economy through employment creation, payment of above average wages, technology advancement, greater rate of patenting (innovation), transfer of knowledge and skilled worker training, , and the development of high tech hubs that often become vibrant economic centers.

[53] NVCA, 2001b, p. 32. All of the above statistics are taken from the NVCA 2001b.

The US$273.3 billion of venture capital invested between 1970 and 2000 in the United States created 7.6 million jobs and more than US$1.3 trillion in revenue as of the end of 2000, accounting for 13.1% of the US GDP in 2000.[54] In 2000, venture backed firms that had gone public accounted for over 20% of all publicly traded firms, and over 32% (US$2.7 trillion of US$8.25 trillion) of the total market value of public firms.[55]

It should be emphasized that the record numbers reached in 2000 are not likely to be sustained, as the investment pace has already slowed down and capital commitments to venture funds have decreased in 2001, largely as a result of the extraordinary fall in value of publicly traded equities and the effective closing of the initial public offering window in the United States. Yet, the venture capital industry is showing resilience, as 2001 investments totaling nearly US$38 billion amount to the third most active year in the US history (after 1999 and 2000).[56]

Venture capital firms provide financial resources to further develop and commercialize inventors' ideas and discoveries, effectively becoming a tool for funding and stimulating innovation. Samuel Kortum and Josh Lerner find that increases in venture capital activity are associated with significantly higher patenting rates; on average, "a dollar of venture capital appears to be about three times more potent in stimulating patenting than a dollar of traditional corporate R&D."[57] The authors further find that these patents are of high quality, as they are more frequently cited by other patents, and are more aggressively litigated by license assignees.[58]

[54] NVCA, 2001b
[55] Gompers & Lerner, 2001, p. 67
[56] NVCA, 2002
[57] Kortum & Lerner, 2000, p. 674-692; p. 675
[58] Kortum, & Lerner., 2000, p. 675

I-2 INFORMATION AND COMMUNICATIONS TECHNOLOGIES

ICT-technologies include traditional devices such as radio, television and telephones, but over the last decades ICT-technologies have been revolutionized with the advent of computers, the Internet and wireless communication. As stated in the introduction, a high penetration of ICT technologies reduces transaction costs significantly, and increases access to information. By consequence, a high penetration of ICT-technologies greatly supports the S&T system.[59]

Latin America is a latecomer to the information technology revolution; a fact which is clearly confirmed by the ranking of the LAC countries on the information society index (Graph 10).[60] Whereas the G7 and NIC countries seem to have fully embraced the ICT-technologies, the LAC countries still have a long way to go. The divide seems to be greatest with regard to the application of the newest technologies. It is estimated that only 0,5% of Latin Americans had access to the Internet in 1999 compared to 30% of the residents of the United States. Electronic commerce is also in its infancy in Latin America: US$459 million in 1999 compared with a GDP of about US$2 trillion (World Bank, 2000a). More traditional devices such as TV's and radios, on the other hand, seem to have a far higher penetration. It should be noted, though, that the lack of telecommunications services is especially rampant in rural areas. Finally, the penetration of cellular phones is increasing dramatically in the region.

The low penetration of modern ICT-technologies is confirmed with regard to the number of Internet hosts and personal computers in the region. On both indicators there is a big gap between Latin America and the industrial world. Whereas the number of Internet hosts is 811 (per 10,000 people) for industrial countries, the corresponding figure for Latin America is 23 (per 10,000 people). Similarly, while the number of personal computers (per 1,000 people) in industrial countries is 353, such a number is barely 44 in Latin America. (Graph 11 and ITU, 2000).

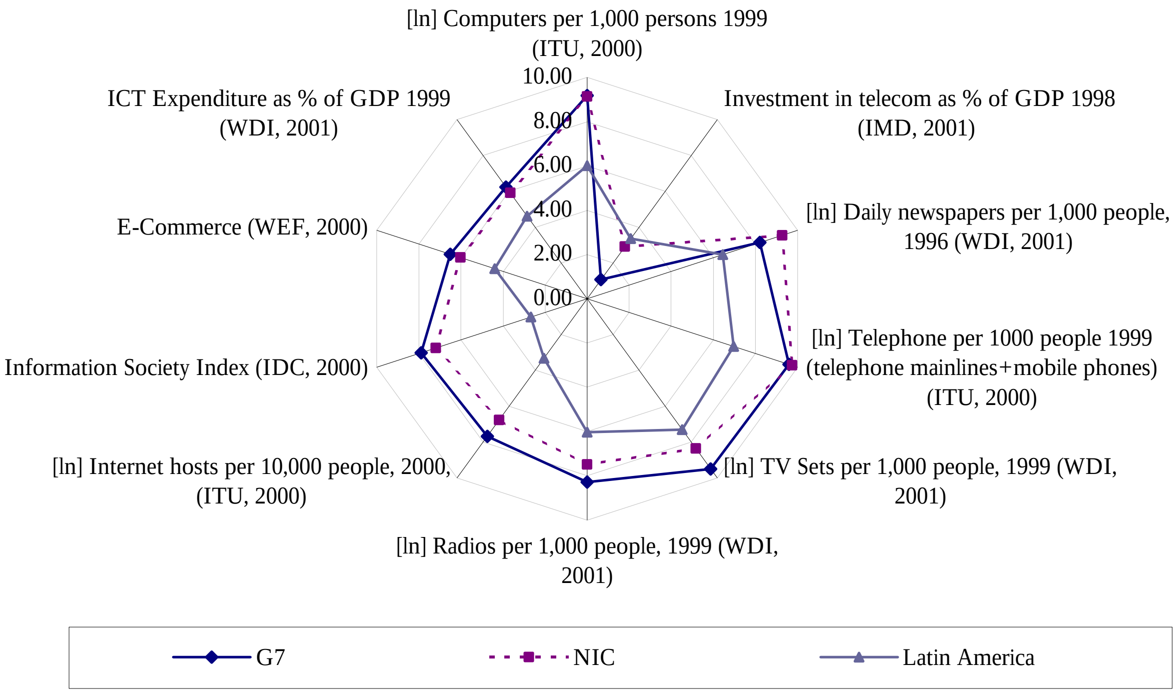
A closer look at the numbers shows that there is wide disparity among Latin American countries (Graph 11). A county like Costa Rica today features one the highest penetrations of computers in the region (approx. 100 per 1,000 people), whereas the penetration is only 10 per 1,000 people in countries like Cuba and Bolivia. With regard to the number of Internet hosts Argentina, Chile and Mexico feature between 40 and 50 hosts per 10,000 people, a rate that is

[59] See The Economist, 1999 and World Bank, 1999c

[60] The index is an aggregate indicator based on more than 20 different items, measuring how well information is adapted and disseminated throughout society For further details on the methodology of the index, see IDC, 2000.

clearly among the highest in the region. At the other extreme, countries such as Cuba and Bolivia have at most one Internet host per 10,000 people.

Graph 10 Information and Communications Infrastructure

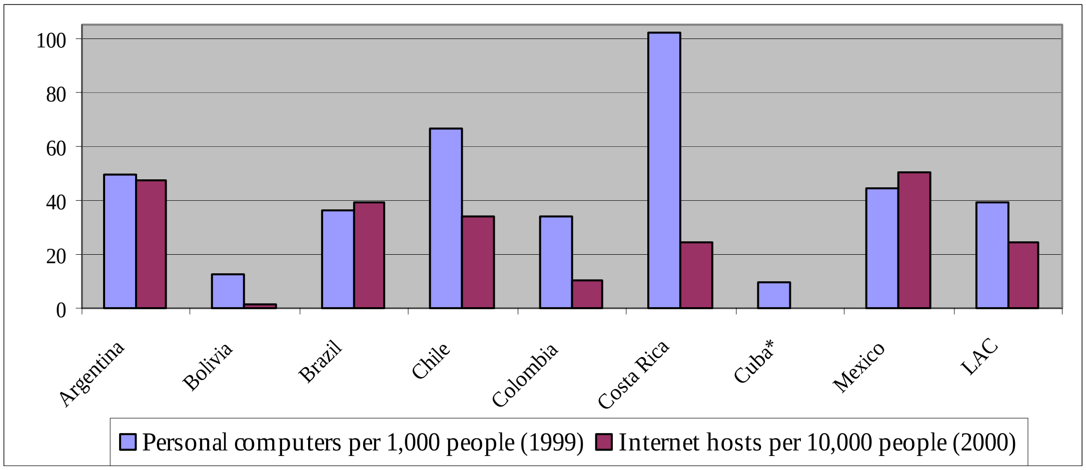


Note: Variables are explained in Annex 1

For the sake of comparison, a country like the United States features more than 500 PC's per 1,000 people and almost 2,500 Internet hosts per 10,000 people. India, in contrast, is significantly behind, even compared to most LAC countries with 3.3 PC's per 1,000 people and 0.32 Internet hosts per 10,000 people. Countries like Ireland, Spain and Korea, on the other hand, clearly outstrip the levels of the LAC countries and India, but have not yet reached the level observed in the United States.[61]

[61] See ITU, 2000.

Graph 11 Penetration of Computers (1999) and Internet Hosts (2000)



* 0.33 Internet hosts per 10,000 people
Source: ITU, 2000

The low Internet access in the LAC region is due to numerous factors, including a low PC penetration. Of far greater influence has been the fact that Internet services require greater bandwidth for data transmission and the vast majority of consumers and businesses continue to rely on Internet access via fixed telephone lines. Thus, in many Latin American countries Internet access is still controlled by private telecommunication monopolies not willing to bring down prices, let alone improve services. Likewise, inadequate capital markets and lack of support for local businesses also explain why the penetration of the Internet is still lagging behind the levels of G7 and NIC countries.

However, Internet access is growing throughout the region and LAC economies are currently investing 8% of GDP in telecommunications, hardware and software.[62] This figure differs substantially across the region, however, ranging from almost 16% in Colombia to less than 4% in Mexico. Moreover, innovative solutions in the region have demonstrated that there are ways of bringing down the costs of telecommunications.[63] Likewise, a number of public funding initiatives have been created in Latin America to improve access to the Internet and IT education in the less industrialized parts of the region. In Brazil, for example, local governments have been leveraging technology to improve their delivery of services: In consequence, the number of people filing on-line tax returns increased with 1230% in a two-year period.

Still, the ability to assimilate new technologies is not just a matter of infrastructure. For example, although Portugal's per capita GDP is very close to Argentina's, its rates for cellular

[62] Data on ICT investment is available for Argentina, Brazil, Chile, Colombia and Mexico (IMD, 2001).

phone and Internet penetration are vastly greater than most countries in Latin America. It is critical that the region's poorest citizens cannot only afford but also see the utility and benefits of these new Internet based services. This, once again, brings the question of human capital to the foreground.

Wireless technology would ultimately provide the necessary low cost Internet access that is critical for developing a competitive knowledge economy. Growth in cellular communication will probably continue to outpace fixed line usage in the region as third generation wireless technology and increased market competition lower costs and lead to new applications. In addition to the wireless option, companies in the region are already utilizing the Internet for voice transmission and long distance communication while cable and other utility companies are investing in fiber optic infrastructure that will dramatically lower the cost of data transmission. Regulatory authorities still have a critical role to play in fostering a technology boom by forcing formerly state-owned, but now privately held, telecommunication monopolies to compete fairly in the market place and by ensuring that future bandwidth auctions remain corruption free. So, once again, the need for effective and transparent governance is pertinent.

I-3 HUMAN CAPITAL

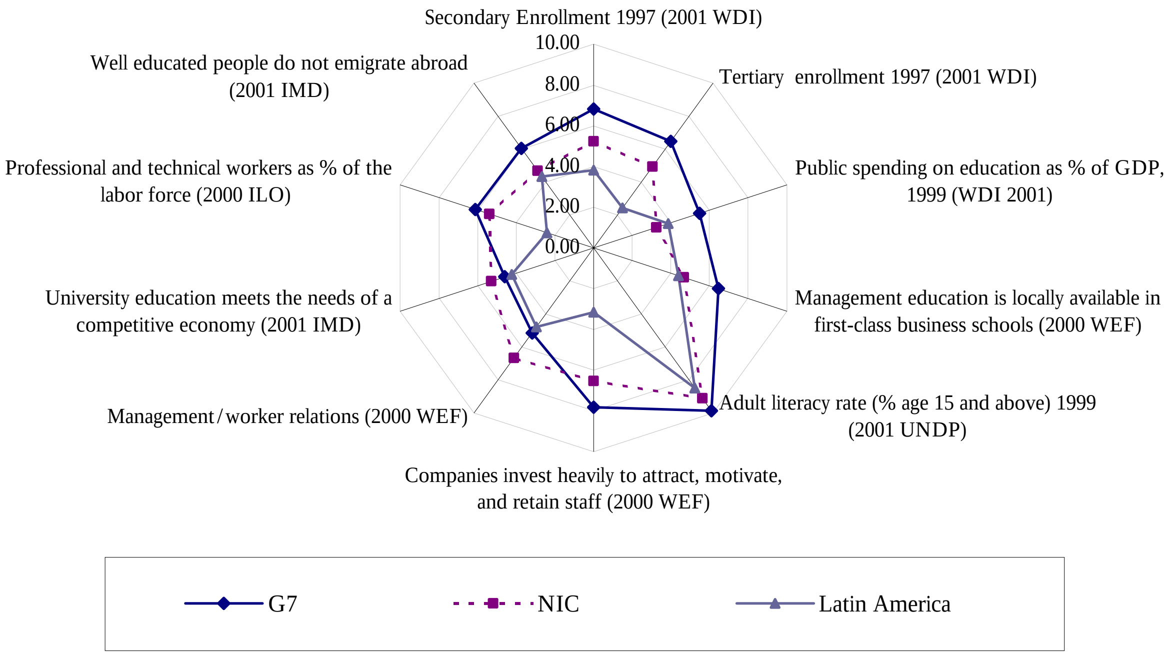
Human capital is truly a core ingredient in the development of a competitive S&T system. Thus, most efforts to fund a strong S&T sector and upgrade the technical infrastructure will be in vain if these activities are not supported by a sufficient stock of human capital. In other words, any effort to establish a viable development strategy should take the stock of human capital into account. This basically applies to all levels of education, but clearly the development of higher education is of particular importance, since most R&D activities rest upon the inputs of highly skilled researchers.

The level of human capital can be measured in a number of ways and at various levels. Graph 12 includes a number of indicators, which highlight different aspects, spanning from the basic level of literacy and public spending on education to more specific indicators such as the level of tertiary enrollment and flexibility of work force. Generally, the graph shows that LAC as a region matches the G7 and NIC countries on basic indicators, such as the overall literacy rate. However, with regard to higher levels of education and specialization within technical fields, LAC is at a disadvantage. Thus, the LAC economies do have a basic level of human capital to

[63] Consumers who opted for more affordable wireless services circumvented the problem of basic telephone access

build on, but in order to be competitive the countries still have a long way to go in terms of upgrading and specializing its stock of human capital.

Graph 12   Human Capital Indicators



Note: Variables are explained in Annex 1

General Indicators

The impression that LAC as a region can compare in terms of the basic, general level of education is to some extent confirmed by Graph 13. The graph shows that countries like Argentina and Chile outstrip Spain and almost equal Ireland with regard to average years of education.[64] However, in comparison to Korea and especially the United States it becomes evident that LAC still has some way to go in terms of extending education. This is especially the case for Brazil and Colombia, which display rates one or two years below the regional average. India likewise compares disfavorably on education.

With regard to the development over time, the graph shows that all LAC countries have managed to increase the average level of schooling over the last decade. This development, however, is not specific to LAC, but is reflecting a global trend, which is equally representative to other developing countries such as India.

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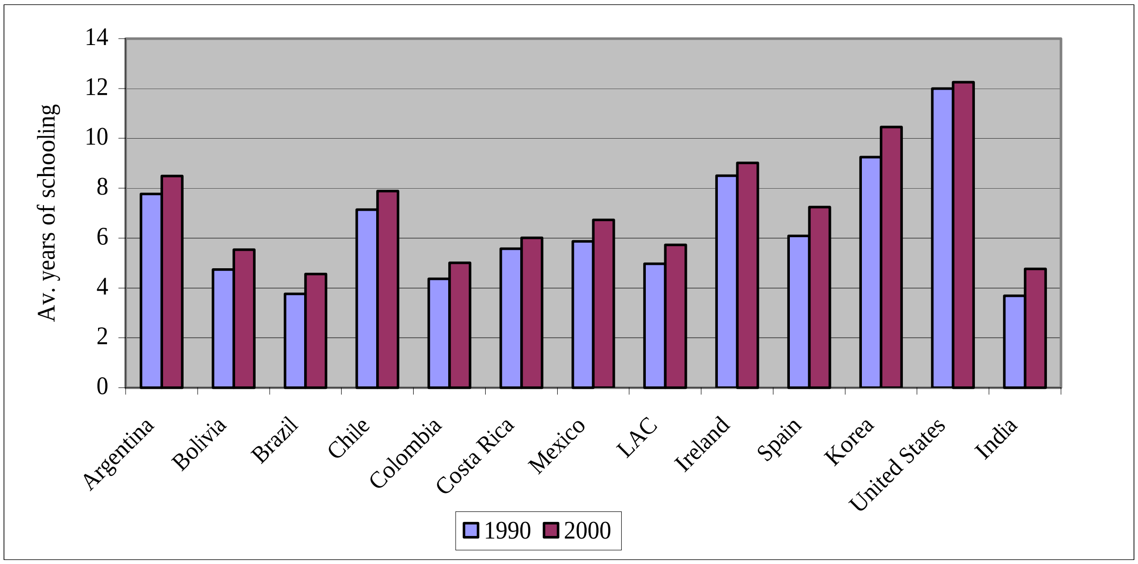
in Rio.

[64] However, it should be kept in mind that the return to education generally increases with the level of education (Blom et al, 2001).

Graph 13 Educational Attainment: Average Years of Schooling, 1990 & 2000



Note: Data for population over 25 years of age.
Source: Barro & Lee, 2000

Focusing on expenditure on education, the LAC and NIC countries seem to be spending a similar amount on education. However, both regions seriously backtrack the G7 countries (Graph 12). It should be noted, though, that this indicator only includes spending by the public sector and thus neglects the role of the private sector in education, which in some countries is quite substantial.[65] Thus, when accounting for total educational expenditures the similarities disappear: Korea spends close to 13% of GDP on education when all expenses are accounted for.[66] Based on this information it is not surprising that a country like Korea have managed to outstrip the LAC countries with regard to the average number of years of education.

This, in turn also implies that the rate of public expenditures cannot be used as a valid indicator for the amount of total expenditures flowing to the education sector. Still, the level of public expenditures does to some extent reflect the commitment of the government to education. Cuba outstrips LAC and non-LAC countries alike with regard to public expenditure on education as a percentage of GDP. Nonetheless, Brazil, Costa Rica and Chile also spend a significant proportion of GDP on education, similar to spending ratios observed in Ireland, Spain, Korea, and the United States.[67]

[65] Public spending includes subsidies to the private sector, though (WDI, 2001).
[66] World Bank, 2000b
[67] See UNESCO, 2002 and WDI, 2001.

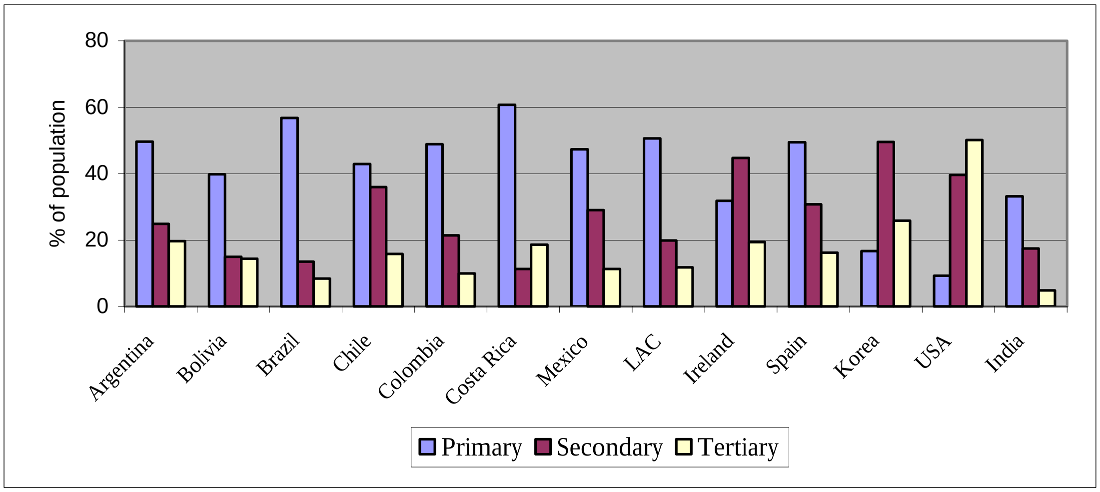
However, the relationship between input and output is far from straightforward. Thus, in countries featuring relatively high government effectiveness, such as the United States, Chile, Spain and Ireland, an extra dollar spent on education is likely to yield a stronger effect, than in countries with low government effectiveness, including LAC countries such as Brazil, Bolivia, Colombia and Cuba. Accordingly, the effect of the high spending rates on education in Cuba is likely to be reduced due to low government effectiveness.

Composition of Human Capital

In order to take effectively part in the development of the knowledge economy, countries need to develop specialized skills at secondary, tertiary and postgraduate levels.[68] The composition of education in the LAC countries is still skewed towards primary education (Graph 14). Thus, 40-50% of the population reach primary school but never surpass it. 20% make it to the secondary level, a trend that is broken in Chile and Mexico where the proportion of the population that attained secondary education as the highest level increased to 30-40%. Finally, only 10% of the Latin Americans attain some extent of tertiary education. Costa Rica and Argentina are among the regional leaders, where approximately 20% of the population reach the level of tertiary education; a level which is equivalent to that of Ireland and Spain. The United States, on the other hand, is characterized by having close to 50% of its population reaching tertiary education. This is a strong indication that the United States counts on a far stronger stock of capital than the LAC countries, and essentially all the other countries included in the analysis. A country like Korea, though, could be expected to move in the direction of the United States, with a fairly high share of students attaining tertiary education and secondary education becoming almost universal. A similar trend can be noted in the case of Ireland, whereas Spain still has some way to go in extending secondary and tertiary education. Finally, the composition of education in India is also heavily skewed towards primary education, and accordingly only a very small proportion of the population attains some amount of tertiary education.

[68] See World Bank, 1999c, chapter 2.

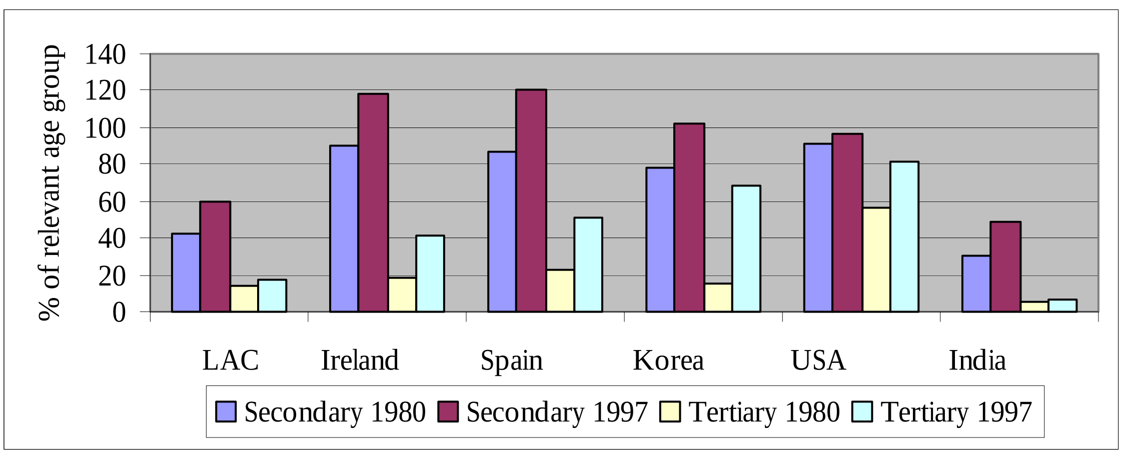
Graph 14 Educational Attainment, Highest Level Attained, 2000



Note: Data includes dropouts.
Source: Barro & Lee, 2000

Graph 15 and Graph 16 describe how the composition of the capital stock has changed over the last two decades. The graphs only include gross enrollment rates for secondary and tertiary education, realizing that these levels are of immense importance for the development of a strong knowledge economy.[69]

Graph 15 Gross Enrollment Ratio: LAC in Comparison, 1980 & 1997

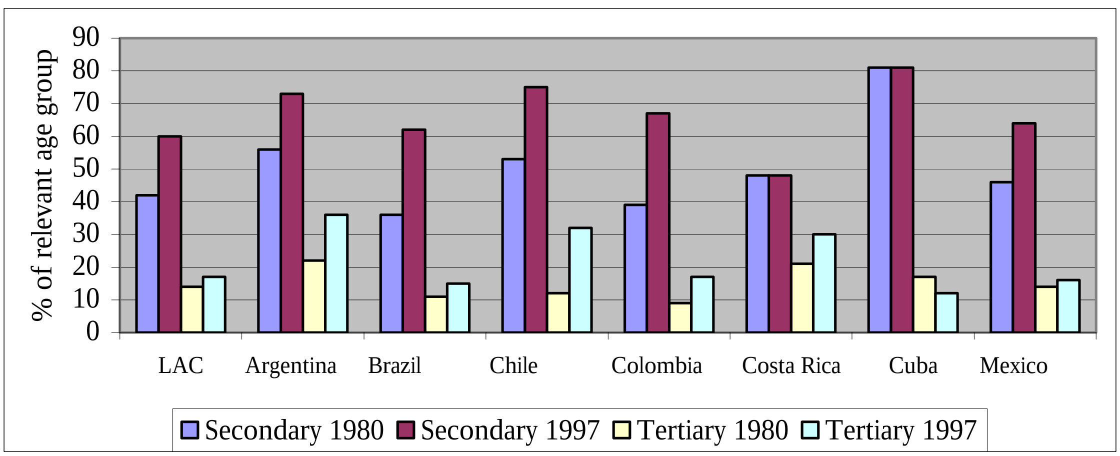


Source: WDI, 2001

Aggregate data for the LAC countries show that secondary education has become increasingly popular with an approximate 50% rise in the gross enrollment rate. Tertiary education, on the other hand, has only increased marginally. Interestingly, Ireland, Spain and Korea, who all featured tertiary gross enrollment rates similar to that of the LAC region in 1980, have managed to increase these rates two-, three- or even fourfold over the last two decades while the level has stagnated in the LAC region. This reflects the fact that tertiary education to some extent has been neglected in the LAC region compared to countries such as Ireland and Korea. The latter have put a lot of focus on tertiary education, which is reflected in comparatively high public and private spending on tertiary education.[70]

Looking inside the LAC region it appears that some of the countries, notably Chile, Costa Rica and Argentina have distinguished themselves by increasing tertiary gross enrolment rates by proportions similar to those experienced outside the region, but the general picture nevertheless remains one of stagnation, a trend which is confirmed by the experiences of Mexico, where higher education continues to be in scarcity. It should be noted that Cuba, in turn, features a very high level of secondary enrolment, a fact that arguably reflects the level of public expenditures spent on education in Cuba.

Graph 16 Gross Enrollment Rate, Selected LAC Countries, 1980 & 1997



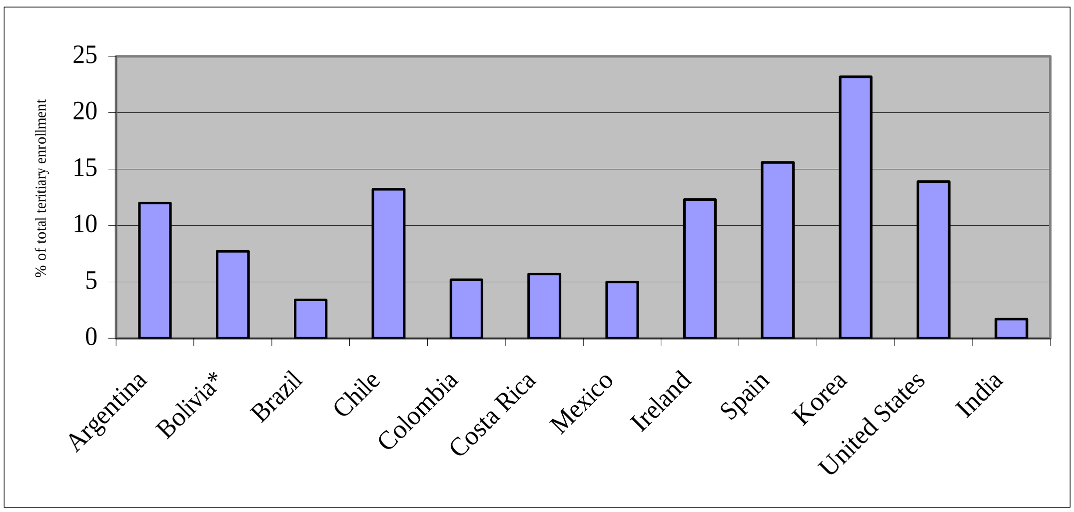
Source: WDI, 2001

Tertiary education can furthermore be broken down into different fields of science. With the significant exceptions of Argentina and Chile, the countries in the LAC region generally score very low in terms of science enrollment, but all of the LAC countries nevertheless feature higher

[69] Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown (WDI, 2001, p.89)
[70] Based on UNESCO statistics extracted from SIMA, 2001.

rates than India (Graph 17).[71] Thus, the data show that countries like Spain, the United States and specifically Korea, have a large competitive advantage compared to most LAC countries in terms of highly educated people specialized within the fields of S&T. The high rates observed in Korea is partly due to the government's education policies which have explicitly targeted S&T at the expense of other fields. This included the establishment of a technological university modeled over the acclaimed Massachusetts Institute of Technology (MIT).[72] The low S&T specialization in the LAC region, on the other hand, has not only negative implications for their ability to expand the frontier of knowledge themselves, but also impacts upon their ability to adapt to technologies imported from other countries.

Graph 17 Tertiary Science Enrollment, 2000



* Data is based on preliminary UNESCO estimations and refer to most recent year available during period 1989-1994.
Note: See endnote 71 for further details
Source: UNDP, 2001a

Quality of Education

None of the indicators above target the question of quality in education. However a number of cross-country studies have been carried out in recent years to estimate the science and education skills of students at the primary and secondary level. Unfortunately, none of the studies include more than a few LAC countries.[73] Hence, the 1995 and 1999 TIMSS assessment of science and mathematics skills only included Colombia (1995) and Chile (1999). Colombia was ranked among the poorest countries in 1995, and Chile also emerged among the weakest countries in the

[71] This is based on data estimating the ratio of tertiary enrollment in S&T related fields such as science, mathematics and engineering to total tertiary enrollment (UNDP, 2001a).
[72] See Etzkowitz and Brisolla, 1999, p.340
[73] See IAEP/ETS, 1991 and TIMSS, 2002

1999 assessment (8th grade level), far behind the level of Korea and most other OECD countries.[74]

Moreover, a number of proxies can be used to assess the quality of education in the LAC countries. One possibility is to use survey data from IMD, which measures the degree to which business executives perceive educational output as "meeting the demands of a competitive economy" (2001).[75] Based on this data, the quality of education in the LAC region is slightly lower than that of the G7 and NIC countries. Looking at country level data (Graph 18) Chile emerges as the regional leader, whereas the rest of the LAC countries display comparatively low ratings. Still, as pointed out by the TIMSS-study, even Chile performs badly in an international context.[76] Part of the reason why the quality of education is low in the LAC region has to do with the contents of curriculum, which is less relevant to private sector needs . Hence, as pointed out by Arellano, science has been neglected in the case of Chile compared to some of the non-LAC countries that did well in the test. As a consequence, the Chilean government has reformed the curriculum in order to strengthen the quality, and new programs will be effective overall from 2002 (Arellano, 2002).

Outside the LAC region, Korea receives a very low rating in terms of the fit between supply and demand; a fact which is inconsistent with the scores afforded to Korean students in the TIMSS assessment, where they rank among the world's best performing students.[77] A possible explanation is that business leaders increasingly perceive the Korean curriculum as being too focused on memorization and thus neglecting to foster creativity and flexibility. As pointed out in a recent OECD/World Bank study of Korea, the educational sector is also heavily regulated and still has a long way to go in terms of diversification, flexibility and social skills, something that is in increasing demand in the knowledge economy.[78]

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[74] See http://timss.bc.edu.

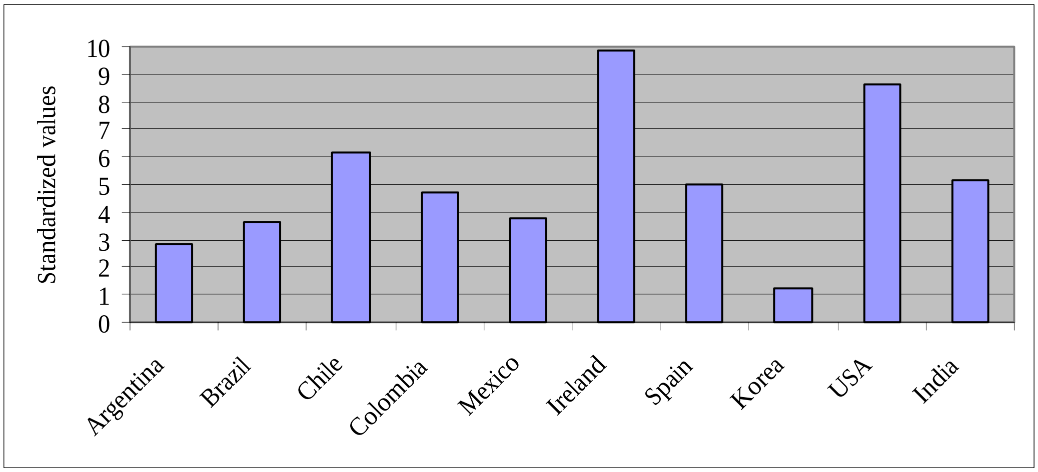
[75] Reservation should be made, since the data is based on surveys of business executives, whose perception of a competitive economy may differ substantially between countries.

[76] World Bank, 2001b

[77] TIMSS, 2001

[78] Another sign of discontent with the quality o education is the large sums spend on private tuition, which is intended to make up for the shortcomings of the education sector World Bank (2000a, p.38ff) provides an in-depth analysis of the current challenges of the education sector (developed in cooperation with OECD).

Graph 18 Supply meeting demand? 2000



Note: Data reflect the degree to which executive business leaders agree that “university education [is] meeting the need of a competitive economy”
Source: IMD, 2001

Ireland, on the other hand, is a positive outlier, receiving the maximum rating with regard to the fit between supply and demand. Again this excellent ranking is arguably due to determined efforts on behalf of the public sector to build up a competitive and highly skilled human capital and thereby strengthening the economy.[79] India also receives a high rating with respect to the fit between human capital and the demand for labor in the economy. Thus, efforts by the Indian government to build capacity within engineering have paid off, and the country now features one of the most competitive pools of scientific and technical personnel in the world; personnel which is employed with great success in the Indian ICT-sector.[80] However, it should be kept in mind that India still have a long a way to go in terms of extending tertiary education and science enrollment, notwithstanding the strengths of the engineering sector. Another proxy for the quality of education measures whether business executives perceive that “management education is locally available in first class business schools”.[81] The LAC countries are also ranked in the lower end of the scale on this indicator. Thus, the LAC countries’ position on various indicators indicates that the current supply of tertiary education in the LAC region does not fulfill the demands of a modern economy.

[79] Green, 2000
[80] Country Commercial Guide, 1999
[81] See WEF, various years.

Brain Drain

One of the challenges currently faced by the LAC countries is how to counteract migration of highly skilled workers (brain drain). Thus, efforts to build up a competitive stock of human capital may not prove sufficient all the while, highly educated people perceive it as more attractive to live and work abroad. The United States, but also Europe to some degree, acts as the main pole of attraction.

Survey data clearly illustrates that migration of "well educated people" is a serious problem for the LAC region (Graph 12). This obviously creates a challenge for LAC countries since its human capital stock is continuously eroded. It is a highly complex problem, which is due to a multitude of factors. Survey data suggest that the private sector apparently does too little in order to attract and retain qualified staff (Graph 12). Obviously, governments also play a large role. Accordingly, tax regimes perceived as excessively unjust have been stressed as one of the major factors inducing skilled workers and researchers to leave their countries. [82]

However, experience shows, that the decision to leave or stay abroad is not only influenced by economic incentives; another highly important factor is the work environment. Thus highly skilled researchers prefer to work among equally skilled researchers in order to profit from an inspiring environment and be part of a peer community. Therefore, LAC countries should work to establish and retain a critical mass of researchers; the question is how to surpass the critical point?

According to Cervantes & Guellec (2002) only a small number of countries, notably Korea, Taiwan, and Ireland, have been successful in luring back highly skilled nationals. The keys to their success have been market liberalization, significant S&T investments and the creation of national centers of excellence, where highly skilled researchers can benefit from research autonomy and a stimulating academic environment. Thus, Korea increased the share of returning scholars with two thirds following the upgrading of the *Korean Institute of Science and Technology* (KIST). Still, countries can also benefit from highly trained nationals even though they remain abroad after completion of their degrees. India is case in point, where parts of the highly skilled Diaspora have set up networks with Indian companies and have invested significant amounts in Indian enterprises.[83]

[82] See The Economist, 2002.

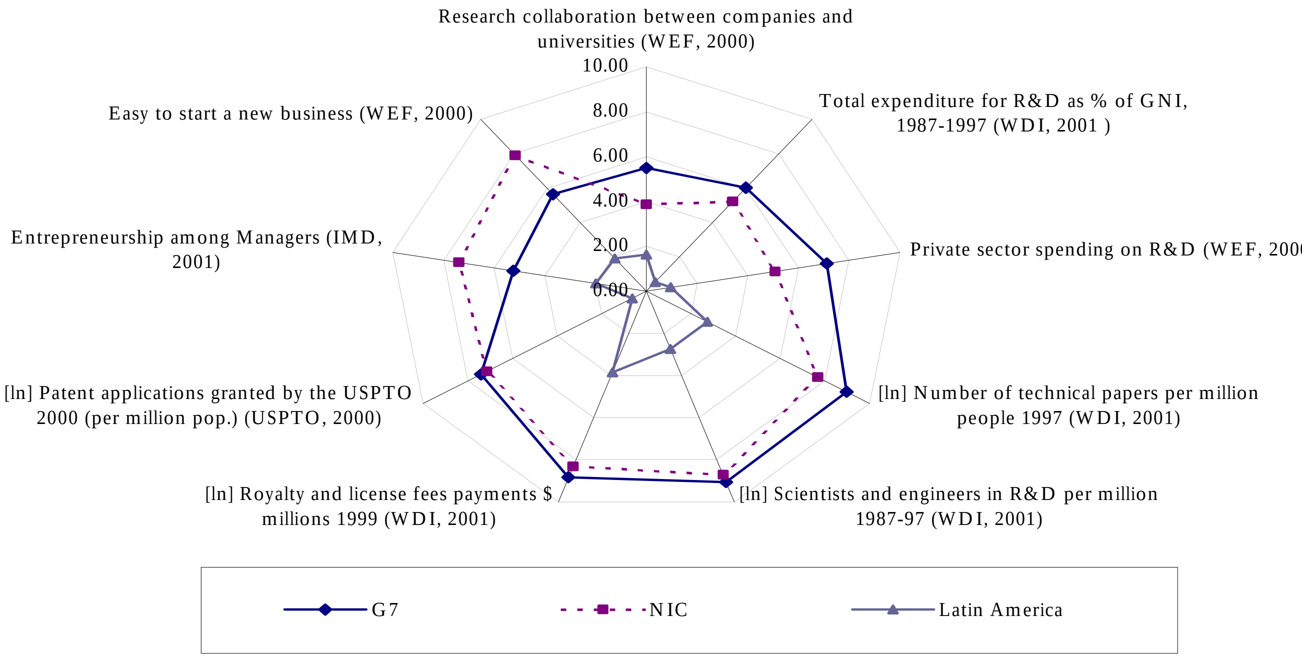
[83] UNDP, 2001a: 91ff

Drawing on these experiences, the Colombian National Council of S&T (Colciencias) moved in 1995 to establish Centers of Excellence in order to stop migration and lure back highly skilled nationals. Out of a total selection of 150 applicants, four centers were selected on the basis of their contribution to their respective field of science and for their capacity to train researchers: *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). Given the successful outcome of similar policies outside the LAC region, such an initiative is expected to reduce the current brain drain in Colombia. Still, the extent of brain drain in countries such as Colombia is alarming, and any policy to revert the current wave must also target more fundamental issues such as political and economic stability. As long as these issues remain unresolved, S&T policies are unlikely to suffice.

PART II: S&T SYSTEM

This part will open by benchmarking the overall performance of the S&T system in the LAC region. The two following sections will assess the amount of resources invested in S&T and the specific policies adopted to advance science and technology. The final section will benchmark the LAC countries with regard to a number of indicators commonly used to assess the output S&T activities.

Graph 19 S&T System



Note: Variables are explained in Annex 1

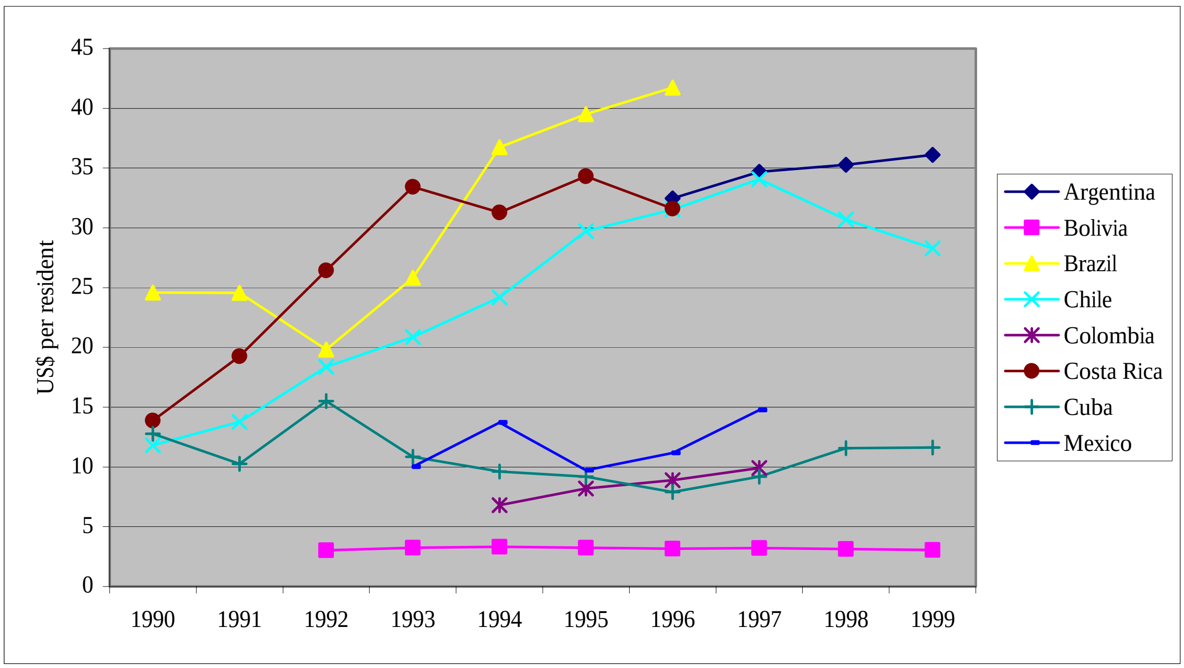
Graph 19 provides an overall picture of the relative strengths and weaknesses of the S&T system in the LAC countries compared to G7 and NIC-countries. The LAC countries lag far behind with regard to R&D investments and the number of scientists and engineers engaged in R&D. Furthermore, there are large structural differences between the LAC region and the G7 and NIC regions. The private sector is the main sponsor of R&D in the G7 and NIC countries, a trend that is completely inversed in the LAC countries where the public sector is the main sponsor. The LAC region also lags behind with regard to output factors: Thus, the contribution of LAC countries is limited in terms of publications of technical papers as well as number of patent applications.

II-1 INPUT FACTORS

Overall Expenditure

The commitment to innovation is partly reflected in the human and financial resources devoted to R&D.[84] Most Latin American countries have increased their allocation of resources to S&T related activities over the last decade (Graph 20). Thus, during the last decade, total investments in the LAC region increased from US$10.1 billion in 1990 to US$15.4 billion in 1999.[85] The spending increases have been especially large in Brazil, Costa Rica and Chile (measured in relation to number of residents), whereas expenditures have remained stable over the 1990s in Bolivia and Cuba (Graph 20).[86]

Graph 20 R&D Expenditures per Resident, 1990-1999



Source: RICyT (2000).

Notwithstanding overall increases, some of the countries have experienced a number of kinks on their spending curve during the 1990s. This, *inter alia,* applies to Cuba, Chile, Mexico and Costa Rica, which in one or consecutive years have decreased their level of R&D funding (in

[84] R&D has various sources of financing. Only direct transfers of resources used to carry out R&D are measured; other government provisions to encourage R&D (tax concessions, the payment of bonuses for R&D, exemption from taxes and tariffs on R&D equipment, etc.) are excluded.
[85] RICyT, 2001
[86] In absolute terms, the level of R&D spending doubled from 1990 to 1996 in Brazil and a similar rise took place in Mexico and Costa Rica. See Hill, 2000.

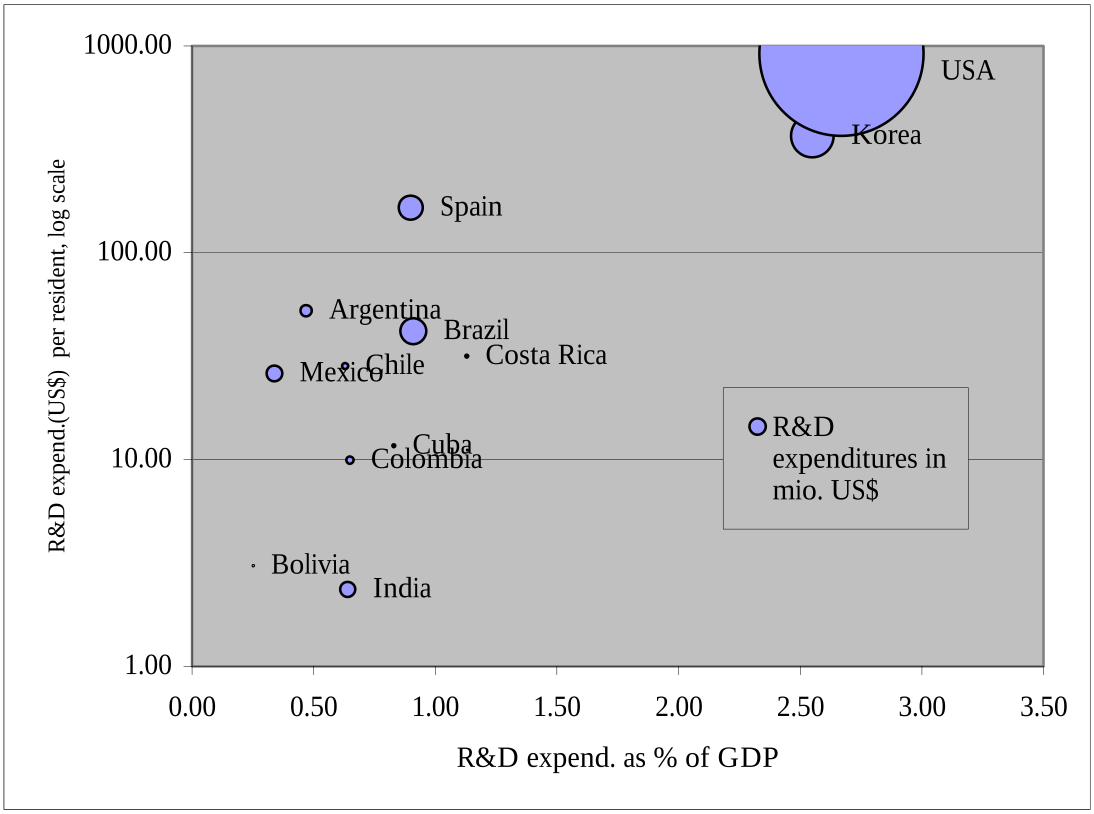
absolute terms and relative to no. of residents). In Cuba, for example, the level of R&D expenditures decreased from a level of US$169 millions in 1992 to US$87 millions in 1996 (RICyT, 2000). Likewise, the Mexican R&D expenditures fell from a level of US$1,235 millions in 1994 to US$886 the following year. These fluctuations questions the commitment of the government to S&T, which at worst can have detrimental consequences for the overall performance of the system: If the commitment of the government is cast into doubt, the propensity of research personnel to engage in R&D activities will likewise be low.[87] Further, it is important to note that fluctuations in funding usually first influence critical activities such as hiring of young researchers purchase of new equipment and information collaboration, areas that are decisive for an S&T system's competitiveness.

The absolute volume of R&D expenditures also differs enormously between the LAC countries.[88] Brazil is by far the frontrunner in terms of government support for S&T development, both in terms of economic investment and institutional experience. In 1997, Brazil spent US$9.2 billion on S&T and accounted for 62% of total LAC expenditure on S&T, followed at a considerable distance by Mexico (11%) and Argentina (about 10%). However, Brazil also ranks among the biggest spenders in the region when the level of R&D expenditures is seen in relation to the number of residents. However, countries like Costa Rica, Chile and Argentina also spend fairly large sums on R&D seen in relation to number of residents, whereas Bolivia, Colombia and Cuba rank in the lower end (Graph 21).

[87] See Park (2002: 25) and OECD (2001b, 64) who both argue that firms will only adjust to spending increases if they are perceived as permanent. This is particularly the case for tax incentives.

[88] The absolute volume of R&D is important, since it reflects the country's role in world scientific and technological progress. Even a highly R&D-intensive small country is unlikely to make a large contribution to overall technological progress. Small countries may be important for specific fields, however, as their efforts are often more focused (OECD, 2000).

Graph 21 R&D Expenditures, 1999*



* Or closest year available
Source: RICyT, 2001and WDI, 2001

The LAC countries still lag the levels of the more developed countries (Graph 21). Korea alone invests more than all the LAC countries, and the United States spent around US$250 billion in 1999, which is 20 times as much as all LAC expenditures.

Measured in relative numbers the differences between LAC and economies such as Korea, the United States and Spain are equally astounding. The ratio of R&D expenditures to GDP is less than 0.8% in most LAC countries, with the exception of Costa Rica (1,1%), Brazil (0.91%) and Cuba (0.83%). In contrast, Korea and the United States spend about 2.5% to 3% of GDP on R&D. Likewise, while the average level of R&D expenditures per resident in the LAC region exceeds the level of India (US$2.3 per resident), it does not rival that of Spain, Korea and, not to mention, the United States, where expenditures amount to almost US$1,000 per resident. Thus a significant gap exists between the LAC countries and the G7 and NIC countries no matter how spending on R&D is measured. Compared to India, on the other hand, the spending in the LAC countries does not seem to lag behind, especially when R&D expenditures are seen in relation to number of residents.

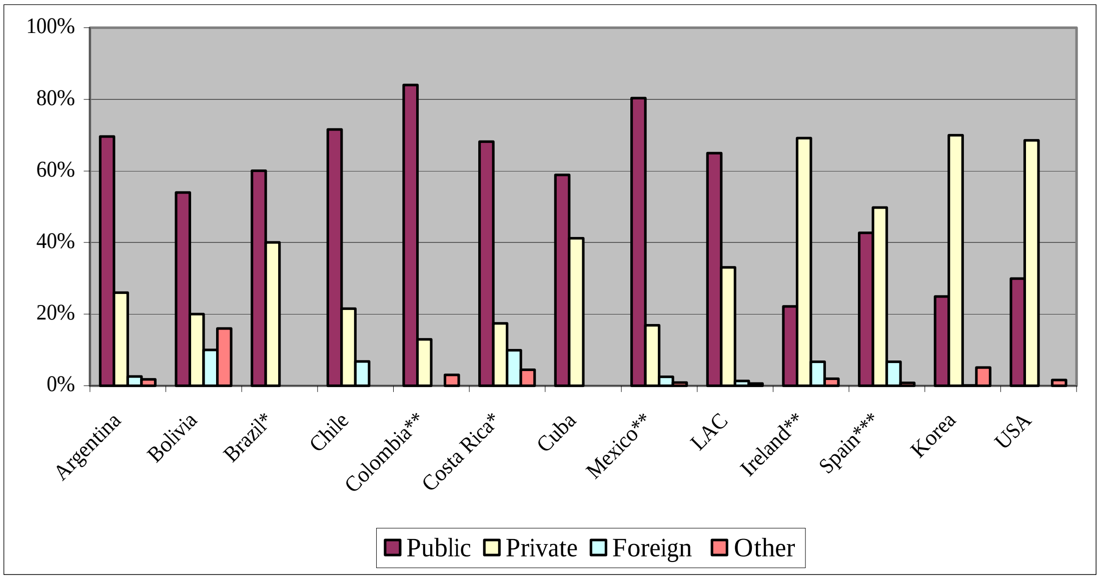
Interestingly, the levels of R&D investment were similar in Korea and the LAC countries in the 1970s as a ratio to GDP. Why then, has R&D investments increased significantly in Korea but stagnated in the LAC countries? One reason is differences in the level of competition. Korean companies were competing on foreign markets and therefore had a strong incentive to increase their level of technological development to remain competitive. This, naturally created a strong demand for R&D. Furthermore, the large "chaebols" of Korea could afford to invest heavily in R&D. By comparison, the private sector in LAC, which consisted mainly of SME's, could not afford such activities, and as pointed out above, finance markets were (and still are) underdeveloped.[89]

Breakdown of Expenditures

During the ISI-period, the public sector played a crucial role in determining the level and direction of knowledge creation (in terms of R&D efforts) in the region.[90] In spite of attempts in recent year to diminish its influence, the public sector is still largely in charge of R&D financing in Latin America. Almost 70% of R&D funding was provided by the public sector in LAC during 1994-1998: 54% came from government and 13% from higher education (Graph 22). In comparison, the public sector finances less than one-third of total R&D expenditures in Korea, the United States, and Ireland. In Spain, on the other hand, the public sector still plays a significant role more or less equivalent to that of the private sector.

[89] See Dahlman , 1999, p.560 and Etzkowitz & Brisolla, 1999, p.341.
[90] Almost 80% of S&T expenditures were publicly funded and only about 20% of were funded and carried out by private agents.

Graph 22 Origin of R&D Expenditures, 1999



*1996, ** 1997, ***1998

Note: For purpose of international comparison, public general university funds (GUF) are included under "public". They are the funds, which higher education establishments allocate to R&D from the general grant they receive from the Ministry of Education or from the corresponding provincial or local authorities in support of their overall research/teaching activities. "Other" includes funds from the private non-profit sector (PNP).

Source: RICyT, 2001; OECD, 2002

The public sector's share of total R&D expenditures may even be underestimated because "public expenditures" in some cases exclude expenditures of publicly owned firms. This appears to be the case in Brazil, where public enterprises provided one third of industrial funding in 1998. Accordingly, if R&D financing by public firms was counted as part of the public sector, the public sector's share in Brazil would be an estimated 75% in 1998, compared to the official figure of 61%.

Private sector participation has historically been limited to three main groups: i) Local subsidiaries of transnational corporations, ii) SME's (Small and Medium Enterprises, typically family owned), and finally iii) Large domestic conglomerates.

The efforts in R&D and human capital training made by local subsidiaries of transnational corporations were mainly aimed at adapting product designs and organization technologies to local conditions. The target was not to create new products (or processes) but to adapt those already developed in the country of origin to the local environment. This strategy appeared to be inevitable in order to operate in highly idiosyncratic production and institutional environments such as those offered by LAC countries. Nonetheless, this approach had a significant impact upon the local industrial fabric. As a result, many subsidiaries acted as national focal points for the diffusion of technology.

A completely different approach to innovation was followed by most of the SME's. The distorted environment created by the high level of tariffs on imports acted as a break to innovation. Hence, the SMEs main concern was to produce domestic substitutes for imports in virtually monopolistic conditions at the expenses of productivity and efficiency. In most cases, the innovation efforts went no further than imitating foreign products and processes, which by the time were already below the productivity frontier.

Many of the large domestic conglomerates specialized in processing raw material, producing mainly standardized commodities such as pulp and paper, iron and steel, vegetable oil, etc. Therefore, they remained at the most elementary stage of the processing sequence, without undertaking significant efforts in developing *in-house* engineering and R&D. [91]

The division of labor between the public and private sector has been relatively stable over the last decade, but there are indications that the private sector is slowly increasing its R&D activities. Thus, the private sector in the LAC region increased its level of activities from 20.9% in 1990 to 36.5% measured as the ratio of total R&D expenses.[92] This trend applies to most of the countries in the region. However, Brazil appears to the only country in the LAC region where the business sector plays a significant role, but, as pointed out, the data could be misleading, since state owned enterprises are included in this category. Even if industry R&D has increased its share of total R&D performed in the LAC region, it is still significantly behind the level of developed countries.

The unequal relationship between the public and private sector has wide implications for the overall level of R&D funding in the LAC region. As discussed in Park, public funding could be crowding out private sector investments in the LAC region (2002). In his empirical analysis based on a wide sample of countries, he finds an overall positive relationship between the level of public funding and private R&D investments. Still, this does not apply to the LAC region, which in turn suggests that public funding may have reached a level where it no longer maximizes social benefits.[93] At worst, public funding may even have a negative effect on private sector R&D expenditure.

[91] This paragraph is largely based on Katz, 2000 & 2001.
[92] RICyT, 2000
[93] Park, 2002. p.50f.

Accordingly, the challenge consists in stimulating private sector funding. This challenge, in turn, can be met through the establishment of an environment conducive to private sector investment. Some of the core areas include strengthening of the IPR-regime, bureaucratic efficiency, investment opportunities and the establishment of a competitive environment, which gives the private sector an incentive to engage in R&D activities (see section I-1 for a discussion on these issues). Moreover, the introduction of matching grants tax credits may be another venue for policy action (these questions are further examined below). Still, the role of the private sector cannot simply be stimulated through the establishment of institutional and financial incentives. A change in mind-set is also needed seeing that most firms in the region still do not consider S&T activities as a strategic variable in their business plan.[94]

Other sponsors of R&D activities include foreign sources, notably multi- and bilateral development agencies, and private nonprofit organizations. During the 1990s these sources provided funding for R&D in countries like Argentina, Chile, Colombia, and Mexico (around 5% of R&D investment) and a much bigger part for poorer LAC countries such as Bolivia (31% of total R&D expenditures). In particular, the World Bank and the Inter-American Development Bank (IDB) provided substantial resources to support science and technology activities in the region. For example, the World Bank and IDB recently approved almost US$600 million in multi-year science and technology loans for Argentina, Brazil, and Mexico. Counterpart financing by the governments and private industry will provide an additional US$700 million, totaling US$1.3 billion.[95]

Personnel

Another reason, why the LAC countries face difficulties in catching up has to do with the lack of researchers capable of performing high quality research. By 1999, the LAC region featured 0.79 researchers for every 1,000 economically active people. The difference to countries like Spain and the United States is tremendous, where the relative amount of researchers is ten to 15 times higher. However, it should be noted that countries such as Costa Rica and especially Argentina compare fairly well. This, in turn, reflects the efforts undertaken in education in these countries. Argentina, for example, features high levels of gross tertiary enrollment ratios and

[94] Mercosur, 2001

[95] Information on the IDB's activities is available at http://www.iadb.org/exr/PRENSA/prsctec.htm . Information on World Bank loans is available at http://wbln0018.worldbank.org/external/lac/lac.nsf. See also *Nature,* 1998, p. 317.

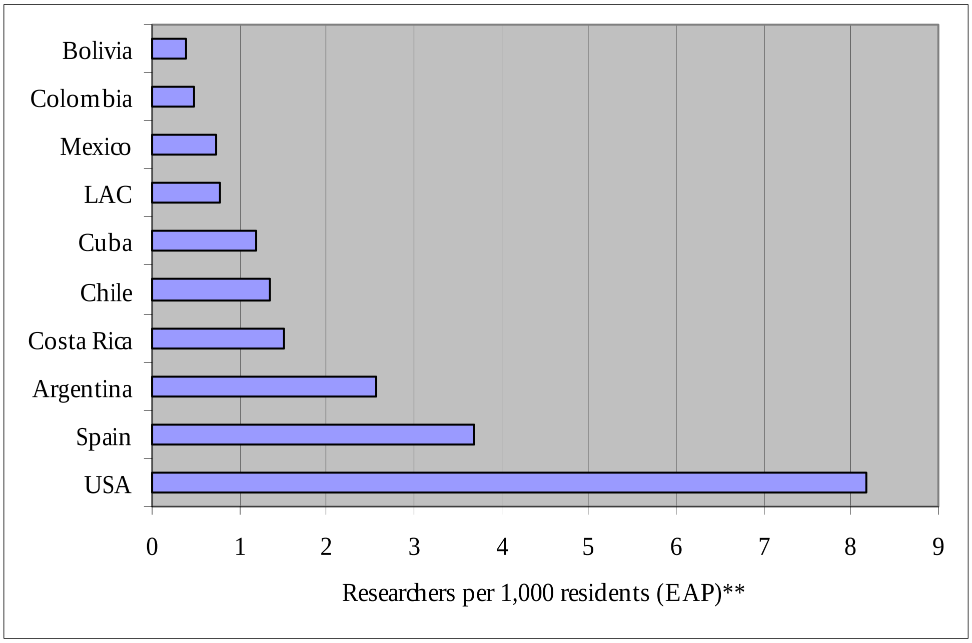
high levels of enrollment in science related fields, and it is therefore not surprising that the country ends up having a comparative advantage in terms of R&D personnel compared to countries with lower enrollment in tertiary education. Still, even a country such as Argentina is significantly behind the North American and European benchmarks.

One of the barriers to extending the stock of researchers in the Latin American is lack of career opportunities. This, for example, has been the case in Chile, where many of the universities have developed in isolation, neglecting the needs of the economy. In consequence, PhD programs are not seen as a step stone to a private sector career, but are mostly associated with academic careers.[96] In sum, LAC countries face an important challenge in making PhD programs more attractive. Research programs could be brought in better agreement with the needs of the economy. This would make PhD candidates more attractive to the enterprise sector, which in turn would increase the incentive to enroll in PhD programs.

Furthermore, the levels of R&D funding and the number of researchers should be considered together. Thus a high number of researchers combined with a low level of R&D funding does not augur well for the chances of achieving a high output per researcher. Whereas the average spending per researcher in Argentina, Brazil and Mexico is close to US$50,000, Spain, on the other hand, spends around US$100,000 per researcher and the United States is approaching US$200,000.

[96] See Mullin et al. 2000, p.86ff.

Graph 23 Researchers, 1999*



* Or latest year available; ** Economically active population
Source: RICyT (2001).

II-2 PUBLIC POLICIES

The question of government intervention in S&T is highly contested, but has traditionally been justified with the assumption that R&D activities are hampered by market failure. This follows from the assumption of the non-excludability of ideas, which implies that private actors face weak incentives to engage in research and development. Hence, government can provide incentives to stimulate private R&D efforts by setting up strong IPR-regimes as discussed in earlier sections. Moreover, governments can also promote S&T development by creating an investment friendly environment. Still, all these activities only target the context of the S&T system. The question remains whether governments should engage directly in S&T activities.

As the following sections will make clear, governments throughout the world have developed a long tradition for intervening in the S&T system in various ways. First of all, many governments have taken on the role as overall coordinator of S&T activities. This entails that governments analyze the economy and on that basis coordinate policy programs with a view to maximize social returns. Moreover, governments try to correct market failures by supplying funds, direct and indirectly, to public and private agents alike. Finally governments have also undertaken in recent years to correct so-called systemic failures by setting up cooperation schemes designed to promote joint R&D efforts and improve the dissemination of information in society.

Coordination and Evaluation

S&T differ from more traditional policy areas in a number of ways. S&T policies have, or should have, implications for most other policy areas. Thus the promotion of S&T activities is equally important for environmental control, health services, agriculture, energy, water, environment and economic growth and productivity.[97] Accordingly, coordination of S&T policies can be an effective tool to promote network externalities between sectors and, in relation to this, rule out any potential overlaps.[98] The objective of coordination is also to formulate priorities between sectors in order to maximize social returns form public R&D funding.

Problems of policy coordination have been prevalent throughout the LAC region. In Mexico, Chile and Argentina lack of coordination has been stressed as one of the major reasons why these countries have faced difficulties in improving their S&T capacities.[99] The legacy of the ISI-period is considered to be one of the reasons why coordination has been insufficient, or even absent, in the region. During the ISI period the innovation systems were mainly based on public enterprises. Minor efforts were made to adapt imported technologies to the local environment by subsidiaries of large multi-national corporations (MNC). At the same time, limited efforts were made by privately owned SME's to develop and adjust technology. These different groups of firms developed a fragmented and uncoordinated innovation system, which lacked in purposes and sense of direction. The major exception to this trend was Brazil where S&T played a key role in the national development strategy for decades, but even Brazil suffered setbacks in the 1980s where the Ministry for S&T was closed down temporarily. Another exception is Cuba, where a cohesive public sector and high-level political support has created broad support for the activities of the Ministry for Science, Technology and the Environment.[100] Still, the general picture in the LAC region has been one of fragmented policies, which have failed in stimulating a proactive technological culture in most of the region.[101]

[97] As pointed out in the draft World Bank strategy paper for science and technology (World Bank, 2002e).
[98] On the need for coordination, see Dahlmann, 2001 and Change & Cheema, 2001.
[99] See World Bank, 1999a; CONACYT, 200; and Katz and Berkovich, 1993.
[100] The Cuban Ministry for Science, Technology and the Environment has launched various sector program, which have created significant results within the sugar industry, pharmaceuticals and biotechnology. (Cetto & Vessuri, 1998, p.62)
[101] See Katz, 2001 and Cetto & Vessuri, 1998. p.66.

In an effort to break with the past, a number of countries, notably Argentina, Mexico and Costa Rica, have launched long-term policy plans for the S&T sector.[102] Generally, these strategy plans are accompanied by the establishment or upgrading of interministerial S&T councils or ministries.[103] Still, there is little empirical evidence in support of such initiatives, especially if they are designed top-down. It is therefore of paramount importance that the formulation of strategies is based on partnership with the market and civil society. The United Kingdom has been a pioneer in this field with its "Technology Forecast"-system, where a number of expert panels consisting of scientist and industrialists identify needs in their respective sectors and subsequently report to a steering committee, which synthesizes the findings and sets forth national priorities.[104] The partnership trend is also broadening in the LAC region, but the development of public-private partnerships is still in the initial phases and should be put at the center of national policy strategies. Otherwise, national S&T programs may evolve into documents with little relevance or importance.

With regard to the setting-up of new policy bodies, policymakers in the LAC region should seek to eliminate heavy bureaucracy and government inefficiency. Unfortunately, these traits have been ubiquitous in the LAC region, even in relatively efficient systems such as Chile.[105] The United States, Spain and Ireland, by contrast, benefit from much higher government effectiveness. At a first glance the government effectiveness of India is also fairly low, but this belies the way in which the country's S&T sector has been managed in the late 1990s. Thus, in a highly non-bureaucratic way, an 18-member task force with representatives from the private sector was commissioned to suggest how the country's capacity in information technology could be improved. The task force operated with no strings attached since no major government bodies regulated the area. The task force also benefited from direct access to the PM, who himself supported the task force. This approach led to the formulation of numerous innovative proposals, including public Internet-booths throughout the country, which subsequently were adopted in the

[102] CONACYT, 2001 outlines the current Mexican strategy, whereas the current strategies for Argentina and Costa Rica are described in SETCIP, 2001 and MICIT, 1999.

[103] GACTEC, a inter-ministerial council, was created to improve coordination in Argentina (SETCIP, 2001). The Venezuelan Ministry for S&T was established in 1989 to improve coordination of S&T activities (World Bank, 2000c). In

[104] See UNDP, 2001a, p.79f.

[105] This general assessment is based on the "government effectiveness" index (Kaufmann et al. 1999a & b), which consists of 31 items (expert polls and resident surveys), which target the efficiency and quality of public services as well as the skills of the bureaucrats and the political independence of the bureaucracy. See note to Graph 4 for details on aggregation of data. With regard to Chile, accusations of inefficiency have been directed towards CONICYT, the body responsible for implementing S&T policies (World Bank, 1999a).
Source: Kaufmann et al, 2002

legislation.[106] Hence, the success of the Indian task force stresses that the organization of the S&T sector is highly important. This is not to endorse the specific way of organization chosen in the Indian context, but the example draws attention to the fact that innovative reforms of the public sector can have a major bearing on the output and impact of the government's policies.

Government efficiency and red tape notwithstanding, the creation of policy bodies and new strategic plans could have a symbolic effect and boost confidence and commitment in the private sector. The creation of the Korean Ministry of Science and Technology in the 1960s was a clear signal to the market and civil society that S&T was to form the backbone of the Korean development strategy.[107] Political leadership can have a similar effect. Hence, the statement by Pandit Jawaharlal Nehru in the late 1950s that science was to become a national priority and "an instrument for emancipation" induced wide parts of the economy to commit to S&T strategies.[108]

Related to the question of governance and coordination is the issue of policy evaluation. In order to continuously improve S&T policies, the policies and programs must necessarily be subject to frequent and appropriate evaluations. Ultimately, S&T policies are expected to increase productivity and competitiveness and thus sustainable growth. However, evaluations have typically focused on immediate and tangible output factors, neglecting the long-term development objectives.[109] A related problem concerns the availability of indicators and access to proper methodologies. If no relevant data is available or methodologies are insufficient, most efforts to evaluate policies will be in vain. Therefore, if policy evaluations have to be more than a mere formality, but actually a helpful tool for policymakers, efforts should be made to broaden the scope of evaluations and increase the range of indicators and methodologies available. The RICYT initiative mentioned above represents one of the most significant initiatives in the region to increase the amount and quality of S&T policy indicators. Being a regional database it allows easy comparison of policy programs throughout LAC. Still, most governments in the region need to collect supplementary data and improve the reliability of existing data. This, for example, has implications for the quality of science education, which cannot be properly assessed due to lack of valid data.

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[106] Nicholson (1998)
[107] This is explained in Sikka, 1998, p49.
[108] See Mashelkar, 2001.
[109] See OECD. 1998, p.137ff.

Direct Subsidies

Government R&D funding can be executed by the government proper (including public research institutes, mission contracts and public procurement) or allocated to universities, the private enterprise sector and private non-profit institutions.

Government bodies and higher education institutions execute the bulk of R&D budgets in the LAC region.[110] Government R&D has been especially dominant in areas related to the strategic sectors of the economy (e.g. energy, transportation, telecommunications, urban sanitation services, iron, steel, petrochemicals and aluminum production). In line with this Keynesian approach the 'public sector undertook responsibility for establishing R&D institutes and laboratories, providing them with equipment, trained personnel and research budgets'.[111] Moreover, a vast array of state-owned public utilities started developing domestic R&D laboratories in order to better exploit the available natural resources and to better satisfy the specificity of the local demand. In this manner, a large number of state-controlled research centers emerged, representing the core of the innovation system of the post-war period.

Another important source of investment in research and development came from a large number of public financial agencies, which were created to finance specific large-scale projects either connected with the heavy industry or in the field of public services (such as energy, telecommunications, water and sanitation). Considerable progress was made in boosting research, promoting human capital development and creating large-scale production facilities in several fields. Still, there is little evidence in support of promoting large-scale projects. On the contrary, a recent OECD publication (1998) criticized the economic rationale of such large-scale projects and stressed that too many projects had been planned in a strictly top-down manner without due consideration of their social benefits. Most of these projects have taken up vast amounts of government resources and have rarely been effective in diffusing results to other parts of the economy. The Brazilian producer of aircrafts, Embraer, is a case in point.[112] Embraer, originally a state-owned company, is today among the biggest producers of aircrafts in the world and is in many ways considered a commercial success. Even though it is difficult to assess the proper costs and benefits associated with Embraer, it remains without doubt that its commercial success has come at a considerable cost to the Brazilian government in the form of export subsidies, institutional support from the Air Force, mission contracts and various tax

[110] See Park, 2002, p.50 and RICYT, 2000.
[111] Katz, 2001
[112] See Utz, 2001.

exemptions.[113] Moreover, Embraer has been of little value to the rest of the Brazilian economy, seeing that most of the supplies are imported. In conclusion, top-down style, large-scale projects do not seem to be a fruitful venue for action. Instead governments should promote a bottom-up policy style and make sure that projects address socially relevant needs. This in turn would also increase public interest and facilitate technology diffusion.

The higher education sector also plays a significant role in the LAC region in terms of the allocated funding for research and development. This is particularly the case in Colombia (more than 70% of total R&D expenditure), but universities in countries like Chile, Brazil and Bolivia also play a very significant role. There seems to be a rough positive correlation between the dominance of the university sector and the proportion of R&D expenditures spent on basic research. Hence, basic research accounts for approximately 60% in Chile and 50% in Bolivia (no data available for Brazil). In the United States, where higher education amounts to 15 % of total R&D expenditure, basic research accounts for approximately 16% of total R&D spending.[114]

The question is whether LAC countries such as Chile and Bolivia invest too heavily in basic research. As pointed out by the OECD (1998), there can be no doubt that basic research generates substantial social benefits. Still, if universities only focus on basic research with no consideration for the wider needs of the economy, the overall contribution of university research may be negligible. This scenario has been prevalent in Mexico, for example, where the academic community traditionally has been relatively inward oriented.

Accordingly, there is a need to change the orientation of the research community, and policy intervention may be warranted. As pointed out by Lundvall (2002) the orientation of the academia is to large extent guided by reward structures. Hence, the experience from Mexico suggests that the inward orientation of the academia to a large extent follows from the rules guiding promotion, which puts extensive stress on academic performance of little relevance for society at large.[115] Hence, policymakers should target the institutional framework of universities and public research institutions with a view to establish incentives with a more outward orientation. As will be discussed in the section on R&D collaboration (below), this has been done successfully in the United States with the adoption of the 1980 Bayh-Dole Act.

The criteria guiding allocation of research funds could be another venue for action. Evidence from Chile and other LAC countries suggests that allocations has been guided by criteria of

[113] See World Bank, 2002c, p.90ff.
[114] See RICyT, 2000, p.50.
[115] See OECD, 1998, p.162 and Lundvall, 2002.

seniority rather than academic merits. Recently, a number of initiatives backed by the World Bank ("Millennium Science Initiative") have introduced more competitive allocation criteria in the S&T systems of Venezuela, Brazil, Colombia, Chile and Mexico. So far, the shift in allocation procedures has led to a significant rise in the production of PhD's and a rise in quality. Despite these positive developments, inefficient allocation procedures still influence large parts of the region and a change in the mindsets of politicians and researchers alike is arguably needed.[116]

Direct financial support to the private sector mainly takes place through grants and loans extended through funds, many of which are open to public and private sector beneficiaries alike. Some funds promote the development of generic technologies irrespective of sectors whereas other have a specific sector focus, such as agriculture, manufacturing etc. Several funds have also been developed with a view to support SME's. Accordingly, most LAC countries operate a complex system of funds, which supply funding to public and private agents alike.

In Brazil FINEP (*Financiadora de Estudos e Projetos)* is among the key agencies supporting private sector R&D. Support is operated through various mechanisms, but in some cases support is conditional on co-funding by the private sector agent. This should promote a sense of ownership on behalf of the private agent and reduce, as pointed out by Park (2002), the possibility that public funding crowds out private sector investment.

In the case of Chile, government support for the private sector is extended through, *inter alia*, FONDECYT (*Fondo Nacional de Desarrollo Científica y Tecnológica*), FONDEF (*Fondo de Fomento al Desarrollo Científico y Tecnológico*) and FONTEC (*Fondo Nacional de Desarrollo Tecnológico y Productivo*) and several sector specific programs including FIM (*Fondo de Investigaciones Mineras*), FIP (*Fondo de Investigaciones Pesquera*) and FIA (*Fundación para la Innovación Agraria*).[117] Unfortunately, government inefficiency and red tape have not allowed such systems to fully meet their objectives. Accounts of CONICYT, the Chilean government body responsible for administration of FONDECYT and several other funds, point out that decision-making procedures have been "centralized and lacking in flexibility".[118] Accordingly, a recent OECD report (2001b) suggests that funding agencies should be more flexible and engage in private partnerships with the purpose of identifying the needs of the private sector.

[116] See World Bank, 2002e, p.20.
[117] See Mullin et al., 2000
[118] See World Bank, 1999a

In response to the need for nurturing venture capital, a number of LAC government have experimented with venture capital funds. For example, the Mexican KIP-project included an initiative to establish a pilot venture capital fund.[119] The outcome of this project has not been finally evaluated, but a 1999 evaluation paper indicated that the question of financing in the Mexican S&T sector remained vulnerable.[120] Likewise a subsidiary of the Brazilian development bank, BNDESPAR, have set up a venture capital scheme. However, according to BNDESPAR the return rates of this have not been satisfactorily.[121] This begs the question whether governments are the right manager of venture funds.

Fiscal Incentives

Fiscal incentives imply that private enterprises and other bodies involved in R&D efforts can deduct their expenses from taxable income. By implication, tax incentives leave decision of where to invest relatively open. The specifics of tax regimes differ significantly between countries. For example, some countries allow enterprises to carry their expenses back- and forward a specific time period. Such flexibility is of great importance for companies whose income varies significantly. Tax incentives are widely used among the OECD countries, but LAC countries such as Brazil, Mexico, Argentina and Columbia have also launched initiatives of tax relieve for R&D activities.[122] The Brazilian regime, for example, features five different schemes, with the most significant (in terms of revenue foregone) applying strictly to the computer industry.

The effect of tax incentives in terms of generated R&D expenses is somewhat contested in the literature. Hall and Van Reenen (2000) presents a review of the available evidence which mainly focuses on the US and a number of studies on Australia, Canada, France, Japan and Sweden. Most of the older analyses conclude that the response elasticity to tax incentives are less than unity, which implies that a dollar foregone in tax revenue will generate less than a dollar in private R&D spending. Still, more recent evidence has estimated the response elasticity to be approximately one with some cross-country variation. Hence, Mani's (2001) empirical analysis of Brazil finds the responsiveness to be less than unity. Notwithstanding the actual level of response elasticity and cost-benefit ratio, most studies agree that the effects of tax incentives are larger in the long than in the short run.[123]

[119] See World Bank, 1998
[120] See Crawford, 2001, which reviews current and past World Bank lending to S&T related projects.
[121] See Mani, 2001, p.43
[122] See Mercosur, 2001 and US Department of Commerce, 2002
[123] See for example Hall & Van Reenen, 2000 and Bloom, Griffith and Van Reenen, 2000.

Econometric evidence further suggests that direct subsidies and fiscal incentives are substitutes for each other,[124] and countries should therefore coordinate their policies internally. Moreover, the evidence reviewed by Hall and Van Reenen (2000) finds tax incentives to have a cost-benefit ratio around one or higher, which implies that tax credits are equally or even more cost-effective ways of promoting R&D than direct subsidies.

Based on this rather inconclusive evidence drawing mostly on OECD experience, it is difficult to assess whether tax incentives are a feasible policy instrument for the LAC region. At first glance they seem an obvious choice considering that they are created to maximize private sector participation, something that should be high on the policy agenda in the LAC region. Still, evidence from Colombia shows that tax exemptions in force through the latter part of the 1990s were unsuccessful in promoting private sector participation.[125] Likewise, Parks's (2002) cross-country analysis of LAC countries finds tax incentives to have a modest effect on private R&D when controlling for direct funding and IPR-regimes.

Moreover, tax incentives are not effective in promoting R&D in small emerging enterprises, which rarely features a sizable taxable income. Of course they can benefit from carry-forward provisions but that may not be sufficient if agents are myopic. This is unfortunate, seeing that the LAC region suffers from a lack of high-tech based SME's. Instead, as pointed out in a recent OECD report (2001), tax incentives are primarily effective in expanding R&D activities at the margin. That is, firms who already have developed a tradition for doing R&D may be inclined to scale up their efforts by tax incentives, but tax incentives are not likely to induce companies with no R&D tradition to engage in such activities. Moreover, as pointed out by Park (2002), attention should be paid to the quality of the overall tax regime. If tax regimes are unfavorable to the business sector and/or lacking in enforcement, the effect of introducing tax incentives may be negligible. Hence, any effort to set-up tax regimes should take the overall tax regimes and the need for reform into account.

Finally, opting for tax regimes may reduce the government's direct influence on funding decisions. As long as support is extended through public funds, governments may remain in control unless funds have been conferred autonomy. Tax incentives, on the other hand, leave the decision of where and whom to support with the private sector. Still, as exemplified by Brazil, tax regimes can be manipulated to target specific areas according to the Government's priorities.

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[124] See OECD, 2001b, p.61ff.
[125] See Agapitova et al., forthcoming.

R&D Collaboration

Innovation no longer depends solely on how firms, universities, and research institutes perform independently but increasingly on how they co-operate.[126] Coordination and co-operation can optimize the results of R&D activities in various ways. Thus, cooperation between the public and private sector gives the public sector an incentive to increase the commercial value of the research carried out in public research institutes. The private sector, in turn benefits from the large reservoir of knowledge embedded in public research institutions and universities.

Experience from the United States shows that public policies can play a large role in facilitating such cooperation. The passage of the 1980 Patents and Trademark Amendments Act (the Bayh-Dole Act) allowed academic research institutions to retain title to (and thus patent and license) inventions made with government funding, ensuring that a particular institution had the incentive to seek licensing opportunities. After the passage of the Bayh-Dole Act, technology transfer offices at universities became an important vehicle for ensuring that university research results reached the marketplace.[127] The level of sophistication of technology transfer offices varies greatly from one institution to another, but examples from the United States clearly document that such institutions can have tremendous success.[128] Moreover, the availability of venture capital plays a key role in enabling technology transfer from universities to the private sector.

Governments have likewise championed science parks in order to promote industry-university collaboration. Science parks establish formal cooperation links between universities, research institutions and high-tech enterprises. If successful, they are expected to develop into technology

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[126] Co-operation between business and non-business entities is one aspect of a growing trend in co-operation among actors in innovation systems that takes various forms. Firms seek access to the fundamental knowledge necessary for their research; universities seek links to commercialize their research and obtain funding; governments look to alliances that ensure that the economy benefits from public research (OECD, 2001a).

[127] Sherwood, R. M., (2000) notes, for example, that MIT asserts that it seeks to license its research primarily in order to ensure that the resulting technology reaches the marketplace and contributes to national wealth (p. 70). See also Park, who argues, based on the available analyses, that the effects of the Bayh-Dole act are somewhat ambiguous (2002: 35).

[128] Two examples here would be Stanford University and MIT. In 1997, Stanford University earned an income of $52 million from licenses, handled 248 invention disclosures, filed 128 new patents, licensed 15 start-up companies, managed 272 licensed technologies that yielded income, and reported over 1,044 active technology licenses (Rogers et al, 2000, p.57). That same year, MIT handled 360 invention disclosures, filed 200 new patents, licensed 17 start-up companies, managed 255 licenses that yielded income, and earned $21.2 million in technology license income. (Rogers et al., 2000, p. 57). It is estimated that MIT's 205 active patent licenses as of 1993 were associated with close to $1 billion of investment, and created 2,000 jobs (Pressman et al., 1995).

regions, characterized by a high proportion of high-tech firms,[129] which encourages co-operation between the different parts of the R&D system, attracts investors and creates positive spillovers on the rest of the economy. Silicon Valley, for example, is an offspring of the Stanford Technological Park.[130]

Unfortunately, little data is available to describe patterns of cooperation and coordination in the LAC region. Generally, Graph 19 pictures the amount of research collaboration between companies and universities in the LAC region to be negligible compared to G7 and the NIC countries.[131] Still, several initiatives have been launched in the region over the last decade, notably in the forms of science parks in Brazil (Table 2). Science parks are a long-term strategy, where benefits, notably increasing flows of knowledge sharing, may be difficult to measure. Consequently, science parks are difficult to evaluate, especially in the short term. No conclusive studies have yet been made available in relation to any of the initiatives mentioned in the table below. Still, more general evidence does not speak in favor science parks, especially not when they are planned top-down which is often the case in the LAC region.[132] Thus, science parks should be designed bottom-up in order to meet the demand of the business sector and promote ownership.

Table 2: Examples of R&D Collaboration in the LAC region

	Activity/Organisation
Argentina	Virtual business incubator in Support to technology-based firms
	Parque Tecnológico del Litoral (S&T park)
	Polo Tecnológico Constituyentes (S&T park)
Brazil	Establishment of thirteen technological innovation nuclei (S&T parks)
	Program for Implementation of Science Parks: Support to university-industry technology transfer and creation of high-technology parks and incubators
	National Association of Science Parks (Anprotec): Support to science parks, incubators and dissemination of information
	Fifth World Conference of Science Parks, Rio de Janeiro, 1996: Evaluation/Promotion of science parks,
Chile	PROFO (*Proyecto de Fomento)*: Business-to-business collaboration

[129] With reference to less developed countries showing a very low overall average it should be added: above the high-tech average in industrial countries.
[130] Gibson et al., 1999.
[131] This is based on the statistical score of a large sample group in a particular country responding to the question of whether "companies collaborate closely with local universities in research and development activities" in their country. (WEF, 2000)
[132] World Bank (2002, p.15) and OECD (1998, p.153f.) both report that empirical experiences with science parks have been very mixed and that top-down planning rarely has been successful in "picking the winners".

Costa Rica	Incubation Center launched 1994 by the Department of Business Administration of the Technology Institute of Costa Rica with backing from Grupo Zeta-Parque Industrial of Cartago, the Ministry of Science and Technology and the Foundation for Popular Economics.
Mexico	Establishment of science parks, currently 15 in operation, with support from CONACYT, AMIEPAT (Association of Incubators and Technological Parks) and various private organizations.

Source: Gibson et al., 1999

Further, science parks are unlikely to succeed if the do not benefit from a proper framework conditions. The establishment of Silicon Valley, for example, was not was not created through top-down planning, but rather a result of a consolidated legal framework, strong IPR regimes, a highly developed financial system, an open economy and an entrepreneurial business culture.[133] The recent market opening in the LAC region is in this sense a positive factor, which should stimulate private sector demand for R&D collaboration.

The business sector's demand for science parks is also heavily dependent on the quality of universities and research institutions. As noted earlier, LAC business leaders do not generally consider higher education to "meet the needs of the economy". If this perception prevails, it is difficult to see fruitful public-private research partnerships emerge. Moreover, econometric evidence suggests that research institutions may be even less effective than universities.[134] Accordingly, LAC governments cannot expect to set up successful science parks without explicitly addressing the quality of universities and research institutions.

Finally, it should be noted that science parks are becoming increasingly virtual. The advent of ICT-technologies has made it possible for companies and universities to establish R&D collaboration with relevant partners irrespective of distance. This clearly offers new opportunities for the LAC region in terms of R&D collaboration as well as knowledge diffusion.

Diffusion Policies

Another group of policies are commonly referred to as diffusion policies. These policies are guided by the common objective of facilitating information and knowledge flows.

Research and development has generally evolved in a highly fragmented way in the LAC region and little knowledge sharing has been taking place. For example, Mexico features a limited number of knowledge poles, which remain highly isolated preventing spillover effects

[133] See Economist, 2001
[134] See OECD, 2001b, p.70.

into local SME's.[135] In order to address this problem fully, a change in mind-set is arguably needed. Still a number of policies can be launched in order to promote diffusion.

Several of the activities mentioned earlier implicitly address the need for diffusion. Science parks, for example, are to a large extent based on the promotion of knowledge flows. Moreover, ICT-policies play a key role in fostering diffusion policies.

Another important policy instrument is technology institutions (TI). Based on a study of six different industries in eight economies (including Korea, India and Mexico), Goldman and Ergas conclude that TI's have made a remarkable effort in diffusing cutting edge technologies to the industrial sector. Still, TI's can only be expected to be efficient when the economy in question faces a competitive pressure, which induces the private sector to look for technologies. Hence, TI's in Korea were considerably more successful than Indian ones, which traditionally have operated in a protective environment. Accordingly, recent liberalization in the LAC region has increased the possibility that TI's can be successful in diffusing technology throughout the economy.

Still, TI's may not be the proper policy instrument for economies featuring small, unsophisticated firms. Based on the Goldman & Ergas study, TI's mostly target larger, sophisticated firms leaving the needs of startups and SME's unaddressed. So far Japan and Taiwan are the only countries in their sample, which have targeted SME's explicitly. Hence, Japan has developed a number of county-level TI's whose primary purpose is to support small-scale industry. These bodies have even had regional specializations seeing that Japanese small-scale industry has developed in clusters. Goldman & Ergas consider this model to be relevant in other geographical settings and the LAC region could very well be a venue for future replication.

Notwithstanding the specific scope of TI's, it is important to keep in mind that they should be designed carefully in order to make them responsive the needs of the industry. Hence, Goldman & Ergas recommends that they be separated from governments in order to increase their operational and financial autonomy. Moreover, TI's should also be modeled around the public-private partnership philosophy.

Knowledge and information sharing should also be promoted on an international level. Econometric evidence has demonstrated that international transfer of knowledge contributes significantly to boosting economic growth, especially in smaller countries. This, in turn, can be facilitated through the lowering of trade and investment barriers (to be further discussed in Part

[135] See OECD, 1998, p.205

III). International diffusion can also be promoted through the subscription to international standardization bodies such as ISO, which provides access to a large reservoir of state-of-the-art knowledge.[136] Multi- and bilateral donor support is another option. Funding from the German government allowed companies affiliated with the Colombian association for plastics producers, Acoplastico, to receive cutting edge training from German companies. The European Union funds similar initiatives targeting the LAC region under the AL-Invest and ALFA programs.

Several regional initiatives have been launched to strengthen knowledge sharing between LAC countries. The RICYT-initiative, *Red de Indicadores de Ciencia y Tecnologia,* is an important initiative on the regional level. RICYT was originally launched by CYTED, *Programa Iberoamericano de Ciencia y Tecnologia para el Desarrollo.* RICYT works to collect and disseminate S&T information throughout the region.[137] The Organization for American States (OAS) supports the RICYT-initiative but also maintains a number of other activities to promote coordination and cooperation within S&T fields throughout the Americas. For example, the OAS has facilitated the Cartagena Declaration (1996), where the member states express need and willingness to further develop coordination and cooperation within S&T fields.[138] CYTED, *Ciencia y Tecnología para el Desarrollo*, is yet another regional S&T initiative, which also includes Spain and Portugal. The program is based on joint funding but enjoys strong financial support from Spain, and has since its creation in 1984 facilitated more than 75 networks and more than 250 S&T related projects in the LAC region.[139] On the subregional level, the RECyT-initiative has been formulated within the framework of Mercosur. The RECyT program implies specialized S&T meetings among Mercosur's founding members, including the associated members Chile and Bolivia. RECyT is partly set up to promote the collection of data on research projects in the region, which subsequently is published in databases accessible through the Internet. This information is expected to make ground for improved regional coordination.[140] So far, one of the outcomes has been an increase in the amount of S&T information shared between Argentina and Brazil.[141] In the northern part of Latin America, The Group of Three (G3), comprising Colombia, Mexico and Venezuela, recently (March 2001) adopted the Declaration of

[136] See ISO, 2002.
[137] See RICyT 2000.
[138] See www.redhucyt.oas.org for information on OAS related S&T activities.
[139] For more information on CYTED see www.cyted.org. Another example of regional cooperation on S&T is the Latin American Commission for Science and Technology, COLCYT, set up by SELA, Sistema Económica Latinoamericano (Cetto & Vessuri, 1998, p.70f).
[140] See Mercosur, 2001b
[141] See Erber, 1999 and Mercosur, 2001a

Caracas, in which the countries, among other things, agree to strengthen cooperation in the fields of science and technology.[142]

It is difficult to assess the impact of these regional and subregional initiatives, but one should keep in mind that S&T deeply affects the competitiveness of the involved economies.[143] This, in turn implies that countries may be more focused on relative than absolute advantages and consequently they may be more interested in receiving than giving.

II-3 OUTPUT FACTORS

The measurement of patent applications and publications of scientific work are two common ways of assessing the success of science and technology activities.

Scientific Publications

With regard to the validity of scientific publications, it should be kept in mind that most journals are published in English. Consequently, there may be a slight bias towards Spanish-speaking countries. Nevertheless, the indicator can be used as a rough indicator of scientific output.

Latin America contribution to scientific research is limited. [144] Even if the total number of articles published by LAC researchers in international journals doubled during the 1990s, it only reached 2,5% of total publications in the world in 1999 (Graph 24). The four biggest Latin American economies provided almost 90% of all the publication in the region: Brazil (43%), Argentina and Mexico (19% each), and Chile (8%). In 1998, some of the highest publication rates were observed in countries like Chile and Argentina (between 11% and 16% per 100,000 people) but Costa Rica, Brazil, Cuba and Mexico also performed well in a regional context (between 4,5% and 6,5% per 100,000 people). The contribution of other LAC countries is negligible.[145]

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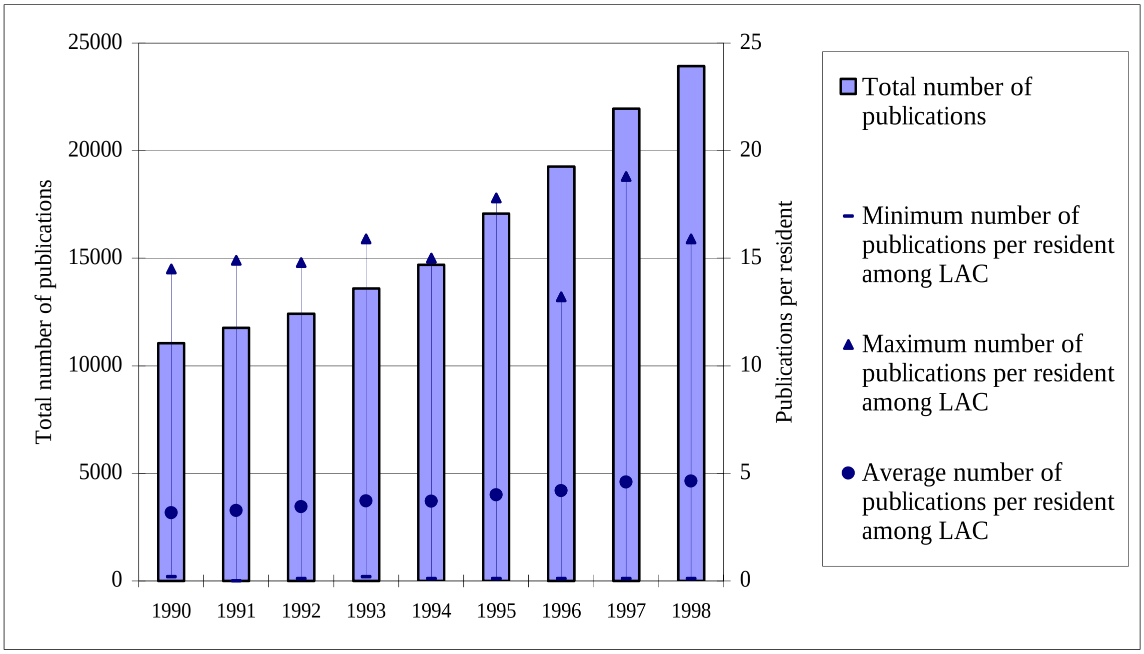
[142] See SELA, 2001

[143] See European Commission, 2002 and Financial Times, 2002.

[144] The output of scientific research is varied: it includes improvement of skills (especially for doctorates and post-doctorates), new scientific instruments and intermediate products, new methods, prototypes and publications. The last is the major output in that it partly captures the others and, in addition, contains the abstract knowledge which is the essential form of most discoveries (e.g. formula, proof of scientific facts) (OECD, 1999).

[145] Controlling for the possible language bias, the analysis has also been conducted using indexes of scientific publications in Spanish. However, the number of LAC publications in Spanish does not exceed 7% of the world's total, while Spain accounts for nearly 90% (RICyT, 2001).

Graph 24 Publications in SCI-Search of Latin American Countries, 1990-1998



Source: RICyT, 2001.

The importance of agriculture in the productive structure of the LAC region has clearly influenced the scientific activities: LAC publications in CAB International (database specialized in agricultural science) far surpassed those in other scientific fields in number and dynamics (RICyT, 2001). This, in turn, reflects the region's comparative advantage in biotechnology, which has numerous applications in the agricultural sector. Thus, by 1998 57% of all scientists conducting basic science in the region were involved in biological research. However, chemistry and physics also attracted substantial numbers of researchers. Likewise, countries such as Mexico, Cuba and Argentina also have substantial competence in physics.

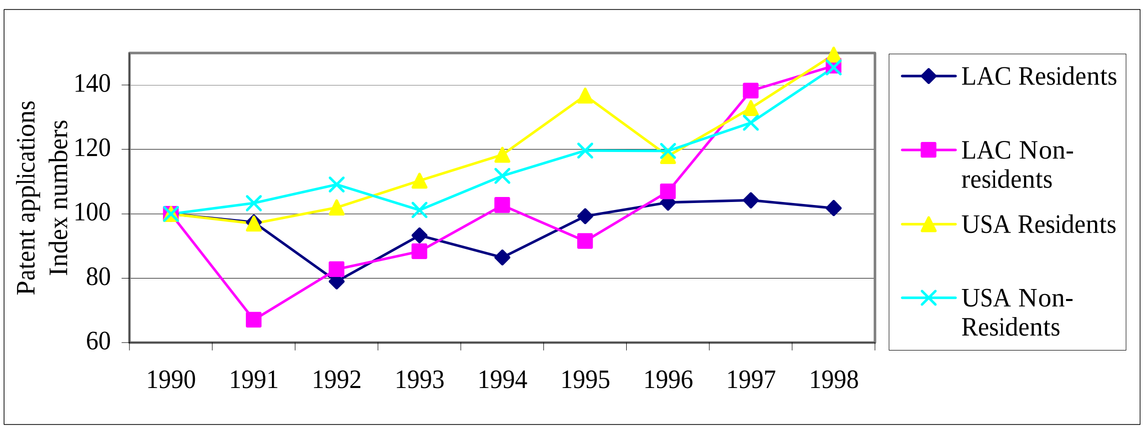
Moreover, the research results obtained within the primary sector have received strong government support. Hence a breakdown of public R&D expenditures reveals that the primary sector (agriculture, fisheries and forestry) received close 30% of total outlays. In the developed countries, on the other hand, such areas attract a smaller share of investment than more knowledge intensive sectors. In the LAC region, a significant part is also allocated to the promotion of knowledge in general, environmental protection, earth sciences and health and social development. Defense, on the other hand, is not a priority area for LAC. Most countries in the region spent less than 0.2% in this area. The exception is Brazil, which spends 4.2% of its total R&D expenditures on defense . [146]

Notwithstanding the comparative strengths of the LAC countries, the overall development in the region is disappointing in terms of publication of scientific journals. This, once again, is a clear statement of the significant knowledge gap, which continues to exist between the LAC economies and the G7 and NIC economies. The LAC scientific capacity is delimited to a comparatively narrow range of areas. India, by contrast, boasts strong scientific achievements within a broad range of sciences spanning from agriculture, atomic energy, electronics, environment, ocean, space, biotechnology, etc.[147] Hence, the proactive science policy of India has clearly paid off in terms of academic research.

Patents

LAC scientific output, as measured by the number of patent applications, grew by 30% during the 1990-1998 period. However, this does not reflect an increase in domestic innovation, since non-resident applications accounted for the increase. In comparison, both resident and non-resident patent applications increased with more than 40% in the United States (Graph 25).

Graph 25 The Evolution of Patent Applications, 1990-1998



Source: RICyT, 2001

Graph 26, which includes country level data, confirms the impression that LAC resident applications (per 100,000 people) have been stagnant over the 1990s. Thus, Chile is the only LAC country where the number of resident applications has increased significantly (from 1.2 in 1990 to 3.1 resident applications per 100,000 people in 1999). Furthermore, the graph illustrates

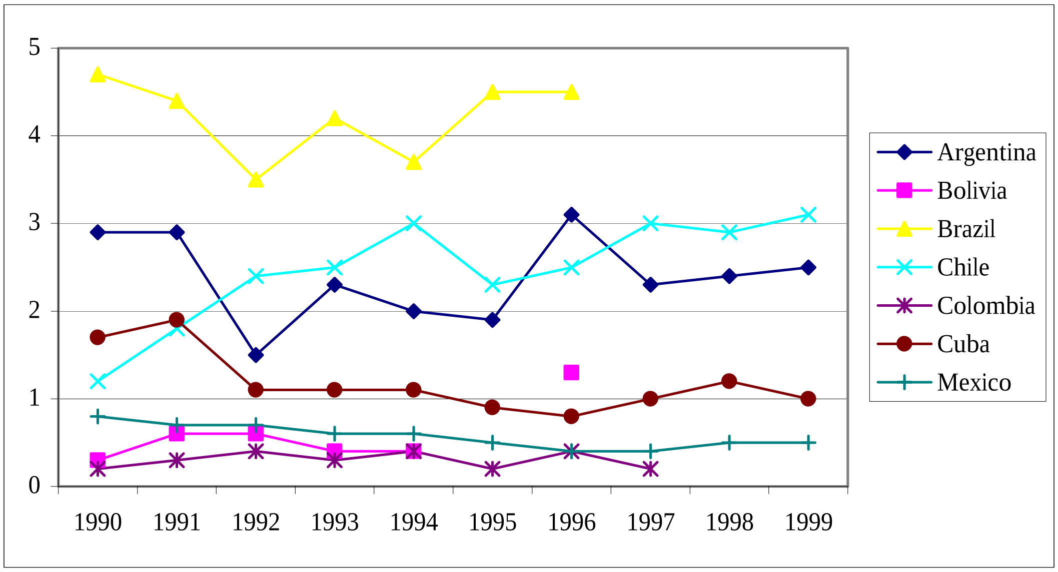
[146] RICyT, 2000

that Brazil is among the most innovative countries in the region followed by Argentina and Chile.[148] This is arguably testimony to the fact that these countries maintain the highest R&D investments in the region (per resident) (see Graph 20). Sector-wise, the distribution of patents largely reflects the academic strongholds in the region. Thus, a significant share of resident patents has been granted through the successful application of biotechnology. Argentina has developed various genetically modified products and a substantial number of pharmaceuticals. In Chile biotechnology has led to numerous innovations within agriculture, mining and cellulose, and Brazil has also made significant advances through the application of biotechnology. In addition, R&D efforts have also proven successful within the telecommunications sector, as a natural consequence of Brazil's strength in physics. This is especially the case in Brazil, which launched a highly successful project promoting the generation of optical fibers in telecommunications.[149] The relative success of Brazil in terms of patent applications could arguably also be seen as a reflection of the relatively high level of collaboration between the different parts of the S&T system.

Cuba, which features a sizable stock or researchers and significant R&D investments in relation to GDP, has seen the number of resident patent applications fall quite significantly during the decade. Hence, the marked drop in R&D expenditures has led to a significant fall in productivity, since cutbacks affect the critical parts of the S&T system, as pointed out above. Moreover, limited access to credit and risk capital could also be expected to impact the output of the Cuban R&D system. Notwithstanding the current drop, Cuban research has generally been quite successful in a LAC context, and a large number of patents have been granted within pharmaceuticals and medical electronic equipment, which reflects the country's large pool of researchers in these sectors.

[147] Other areas include non-conventional energy sources, defense and health (Mashelkar, 2001).
[148] Unfortunately no data available for Costa Rica
[149] This section builds on Dr. Juan M. Dellacha in RICyT, 2000 (p.20f) and Cetto and Vessuri, 1998.

Graph 26 Resident Applications per 100,000 people, 1990-1999



Source: RICyT, 2000

Most of the countries outside the LAC region included in this analysis have noted an increase in the number of resident applications during the 1990s. The United States, Ireland, Spain and India experienced an approximate 30% increase in resident applications during the latter half of the 1990s. As regards India, strong scientific achievements have been applied successfully to a number of sectors, including the pharmaceutical industry, agro-chemicals, weapons and computers.[150] However, India still maintains a relatively high degree of protectionism, and the potentials of S&T could arguably be exploited even more if demand was stimulated through further trade liberalization. The long-term development has also been positive for Korea, but the Asian financial crisis translated into a significant decrease in the number of resident patent applications in 1998. However, even bearing this in mind, Korea fares far better than countries in the LAC.[151]

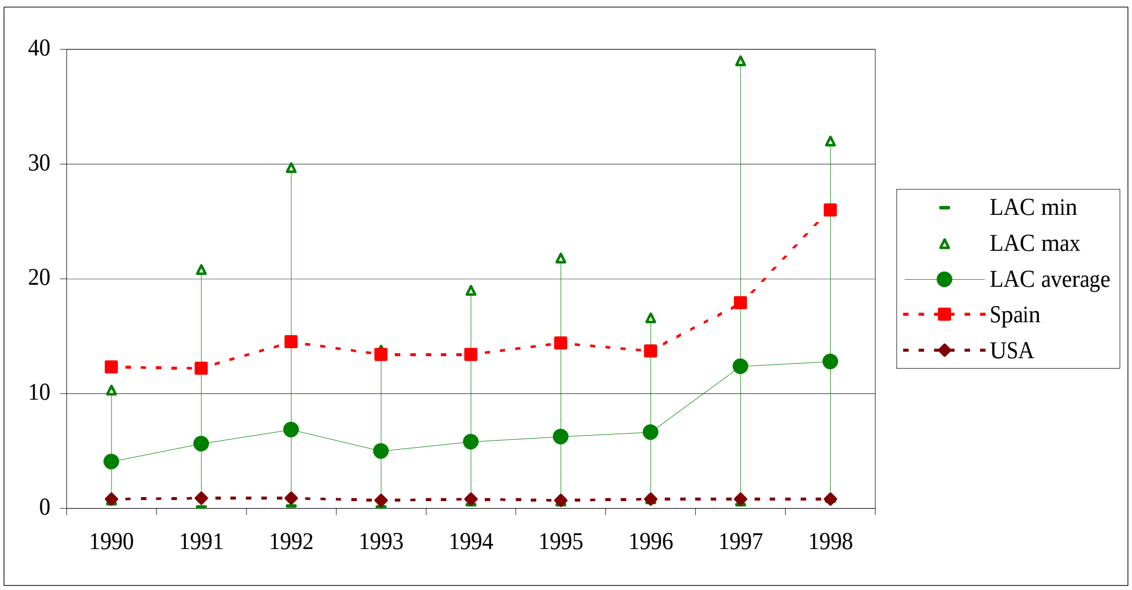
As a consequence of the slow growth in resident patent applications, the dependency rate of the LAC countries has increased significantly during the 1990s (Graph 27).[152] This, in turn is largely a consequence of the liberal reforms carried out since the 1980s, which have facilitated a massive transfer of technology to the region. Accordingly, the strong dependency rate applies to most of the countries in the region. Countries such as Bolivia and Cuba are exceptions displaying

[150] See Mashelkar, 2001.
[151] Calculations based on data from SIMA, 2001.
[152] The dependency rate captures the number of non-resident patent applications as a ratio to the number of resident applications. Thus the higher the number, the more dependent the country is on acquisition of foreign technology.

an almost equal relationship between resident and non-resident applications. Unfortunately, this is not an indication of a strong domestic innovative capacity, but rather a reflection of the fact that both resident and non-resident applications remain at a very low level.[153]

The general trend of high dependency rates is not unique to the LAC countries. A country like Spain also relies heavily on technology transfer and actually features a dependency rate far higher than the average LAC value (Dependency Rate, 1990-1998).[154] 1998 data for India likewise find that the number of non-resident applications in India was about four times larger than the number of resident applications.[155]

Graph 27 Dependency Rate, 1990-1998



Note: See endnote 152
Source: RICyT (2001).

[153] Base on data from WDI, 2001 and RICyT, 2000.
[154] Spain benefited from the integration in the European Union in the same way that the LAC benefited from growing international trade and assistance. The growth of resident patent applications in Spain was also considerably lower than the number of non-resident applications: 124% of 1990 level for residents and 264% for non-residents in 1999.
[155] WDI, 2001

PART III – TECHNOLOGY TRANSFER

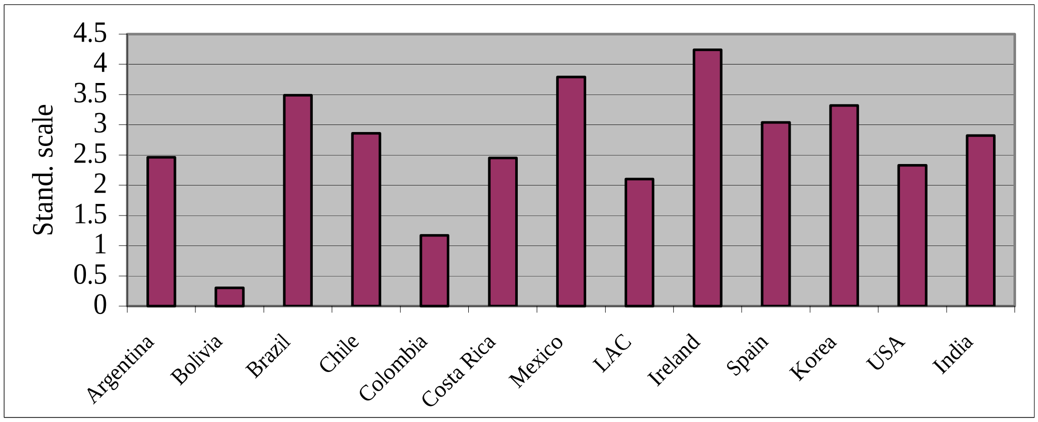
Tapping Into the Global Stock of Knowledge

The experiences of several countries including Japan and the East Asian NIC's have called attention to the fact that adaptations of foreign technologies can boost the economic creativity significantly. Thus, a considerable infusion of foreign technologies is part of the reason why countries such as Korea have been able to outpace most of the LAC countries over the last decades. Likewise, Spain and Ireland have also relied on foreign technologies to a very large extent. The LAC countries, by contrast, have like India been reluctant to tap into the global stock of knowledge, something that in great deal follows from the ISI-development strategy followed in these countries.[156] However, the recent liberalization of trade and investment policies in the LAC countries, have made it possible, and legitimate, to deliberately follow development strategies based on technology transfer.

The question of technology transfer is complex. Technology can be transferred in different ways and the mere transfer is far from sufficient. The technologies must be skillfully adapted to local conditions, which, *inter alia,* call for a minimum level of human capital. With regard to technology transfer, various channels are assumed to exist. First, technology can formally be acquired through licensing and royalty payments (disembodied technologies). In many cases this represents a cost-effective alternative to local efforts to invent similar technologies. Second, technologies can also be acquired as embodied in goods, services, investments and manpower. Hence, import of technology-intensive goods and services conveys important information about technologies to local companies. Third, FDI can bring new technology to the domestic economy, which in turn can spillover to suppliers and other parts of the domestic economy, conditional on the level of integration in the domestic economy. Finally, technologies can be acquired through the transfer of human capital. Thus, countries can gain access to a large reservoir of technological knowledge by attracting skilled people from abroad.

[156] See Pack, 2000.

Graph 28 Technology Transfer, 2000



Note: The technology transfer reflects two variables, which are given equal weight: The opinion of business executives on the importance of FDI as a source of new technologies and the technology-in-trade residual for 1999 or latest year available. Scale has been changed from –2,5 – 2,5 into 0 – 5.
Source: Warner, 2000

Graph 28 presents an overall view of the level of technological transfer in the selected LAC and non-LAC countries. Technological transfer appears to play an important role in a number of LAC countries, notably Argentina, Chile, Costa Rica and Mexico. This reflects that the recent liberalization of trade and investment regimes in the region has had a significant effect on the level of technology transfer, Bolivia being a significant exception. Interestingly, the countries which rank high in terms of technology transfer also fare comparatively well on the overall TAI-index (see Graph 2 on p.3). Colombia and especially Bolivia rank very low in terms of technology transfer. These countries, in turn, are also ranked in the lower end on the TAI-index. Hence, the evidence suggests that a certain level of technology transfer is a necessity for the LAC countries to perform well in terms of science and technology. With regard to the non-LAC countries, Ireland, Spain and Korea also depend on technology transfer to a substantial degree. The recent opening in India has likewise translated itself into a fairly high level of tech-transfer. In the United States, by contrast, tech-transfer plays a less dominate role. Still, the United States is ranked as one of the most innovative countries in the world, but the innovativeness of the United States is to a large extent based on a large domestic innovative capacity, which is facilitated by the power of the domestic economy, unmatched by any other economy.

Embodied Technologies

The recent openings of the trade and investment regimes have caused a significant rise in the amount of goods, services and investments flowing into the LAC region. Hence, the value of manufactures flowing to LAC grew from a level of US$90.9 billions in 1990 to US$266.07 billions in 2000. This rise is largely due to substantial increases in various semi-manufactures, automotive products and office and telecom equipment.[157] The numbers for Brazil are particularly impressive. Thus, overall merchandise imports more than doubled over the 1990s, and at the same time the share of manufactures in total imports grew from approximately 50% to 75%. Mexico and various countries in Central America and the Caribbean likewise noted a large increase in imports of semi-manufactures. This is largely testimony to the prevalence of maquila-industry in the region, based on import of semi-manufactures from the United States, which are assembled and re-exported by low-cost facilities in the LAC region.[158] Still, it has been pointed out that the Mexican maquila-facilities are poorly integrated with the rest of the domestic economy, which implies that the level of technological spillover remains negligible. With regard to services, the region has also seen a notable increase. Thus, overall imports of commercial services increased from US$34 billions in 1990 to US$71.6 billions in 2000.

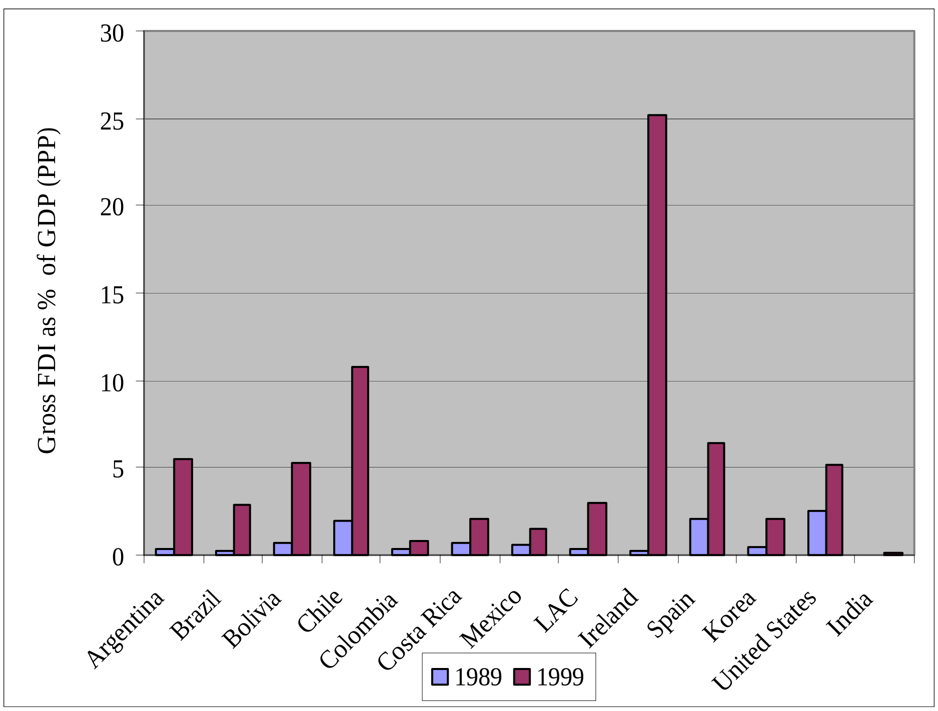
On the investment side, FDI in LAC increased from 0,4% of PPP GDP in 1989 to 3% of PPP GDP in 1999 on average (Graph 29). As such FDI is not only a means of acquiring technologies; it also represents a strongly needed capital infusion, seeing that domestic finance markets are underdeveloped in large parts of the region (see the section on Finance, p.20ff).

Brazil is the most significant host of FDI in the region in absolute terms (US$34 billions in 1999) followed by Mexico (US$13 billions) and Argentina (US$11 billions). In relative terms, Chile receives the largest fraction of FDI in the region (10,3% of PPP GDP in 1999), followed by Argentina and Bolivia (5.5% and 5.3% respectively). The overall increase in FDI largely reflects the liberalization of investment regimes throughout the region and fiscal incentives designed explicitly to attract foreign investors. Thus, Mexico's position as the second largest reservoir of FDI in the region is largely a result of NAFTA, which boosted US investments into Mexico. Costa Rica is a case in point with regard to the effects of fiscal incentives on the flow of FDI. The general improvement of IPR-regimes is another factor, which arguably has increased the incentive to invest in the region. For some of the lesser-developed countries, the increase is also due to substantial transfers of development aid. Still, the flows are still volatile exemplified with an approximate 50% drop in 2000 in FDI flowing into Chile and Argentina. However, this partly reflects that 1999 was a particularly good year, where major Mergers and Acquisitions (M&A) by Spanish companies in Argentina and Chile accounted for large inflows.

[157] See WTO, 2001
[158] See CEPAL, 2001, p.91.

Ireland is an extreme case with regard to FDI. Thus, based on the evidence presented in Graph 29, FDI represented approximately 25% of GDP (PPP) in 1999 (with a large share originating in the United States), compared to a level of 0.2% only ten years earlier. This remarkable increase is partly a result of fiscal incentives, the presence of a skilled workforce proficient in English and a location within the Common European Market. Spain has also seen a notable increase over the past ten years, but to a much smaller extent than the case of Ireland. Thus, Spain has like Ireland benefited from EU-membership, but Spain cannot compare to Ireland in terms of work force skills and tax regime. By contrast, Spain has been troubled by a rigid labor code, which possibly has compelled potential investors to place their money elsewhere. In the case of Korea, FDI takes up a fairly low share of GDP (PPP). This is partly testimony to government policies, which consistently have preferred import of capital goods to FDI.[159] Lastly, FDI has negligible importance in India [160]

Graph 29 Foreign Direct Investments, 1989 & 1999



Source: WDI, 2001

Notwithstanding the sources and causes of FDI, it remains without doubt that FDI is a significant conveyor of new technologies to the LAC region. Hence, as shown in Graph 25, the number of non-resident patent applications in the LAC region clearly picked up in the LAC

[159] See Viotti, 2001.

region, following the full implementation of various liberalization schemes, such as NAFTA and Mercosur. Moreover, a large share of FDI has gone into the services sector, notably M&A's in the telecommunications sector and banking. Thus, the services sector in Brazil received the largest fraction of FDI in 2000. FDI has also made a significant contribution to manufacturing exemplified by General Motors and Volkswagen's decision to set-up production plants in Brazil. Mexico has along a similar line seen large sums of FDI (approx. 50%) go into the manufacturing sector.[161] Moreover, as noted by Perry, the increase in FDI into Mexico following the accession to NAFTA, has led to a marked increase in the rate of innovation.[162] This, in turn, points to the potential spillover effects of FDI in terms of technological innovation. Costa Rica provides another example of how even small countries can have their S&T capacity boosted through FDI. Following the decision of Intel to set up set up a plant in Costa Rica, additional plants followed, which has had significant spillover effects. Consequently, Costa Rica today boasts a highly competitive microchip sector.[163] However, critics have pointed out that the liberalization and the ensuing surge in FDOI and M&A's have caused many domestic firms to discontinue local engineering activities in order to adapt to products and processes technologies coming from their respective parent companies.[164]

Lastly, the question of mobility of labor and skills embodied herein should be addressed. However, this discussion has already been touched on under the heading of Brain Drain (p.39). This section stated that LAC as a region suffers a net loss in skilled human capital. This applies to most of the countries in the region, especially Mexico and Colombia, where the net immigration of skilled people translates into export of high-tech knowledge rather than import. Elsewhere in the region, notably Chile, Brazil and Costa Rica, brain drain is less of a problem,[165] but overall LAC does not seem to benefit from the current mobility of highly skilled labor.

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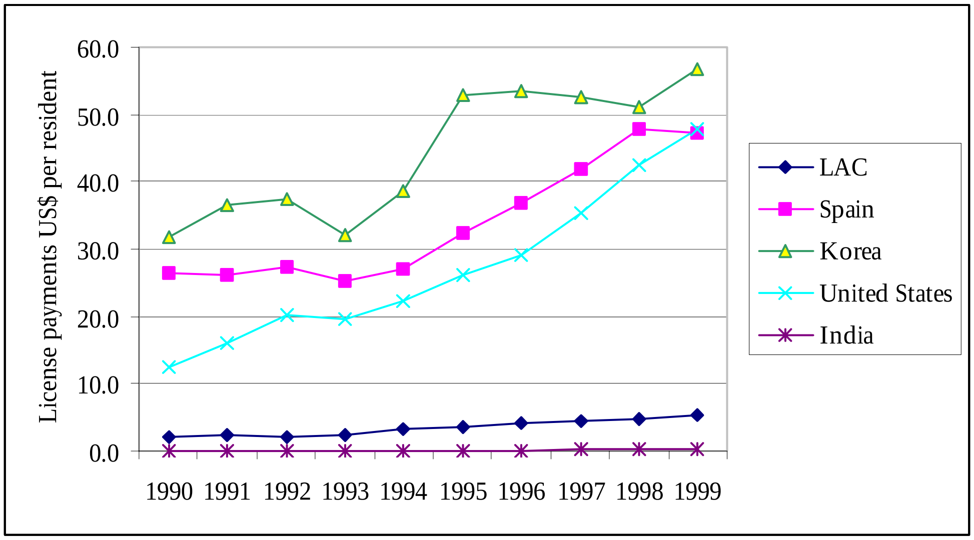
[160] See Pack, 2000, p.74.
[161] See UNCTAD, 2001; Purcell, 2001 and CEPAL, 2001, p.66.
[162] Perry, 2001
[163] The Economist, 2001.
[164] A further consequence of trade liberalization was the increase of mortality among SME's incapable of technological upgrading. The causes of this problem arguably have to be detected in the failure of financial and technological markets. Although the opening up of the economy had a particularly negative effect on SME's as a group, the SME's that did survive operated in the economy's faster growing industries showing a tendency to improve their performance with respect to large-scale companies. Conversely, the performance of SME operating in slow-growth sectors deteriorated. This evidence suggests that the sectoral environment and externalities, rather than forces emerging from the firms themselves, are the main determinants of small, family-run firms' success in improving their performance over time (Katz, 2000).
[165] The Economist, 2002.

Disembodied Technologies

As noted, technology transfer through license payments is in many cases a cost-effective alternative to transfer of disembodied technologies, seeing that the knowledge is provided in a more accessible manner. Korea ranks in the top end in Graph 30 with license payments taking up approximately US$55 per resident in 1999, which represents a doubling from the 1990-level. Similar developments have taken place in Spain and the United States. However, nowhere is the flow of disembodied technologies greater than in the case of Ireland. Which paid close to US$2000 per resident in the end of the 1990s, approximately 40 times as much as Korea (not shown in the graph).

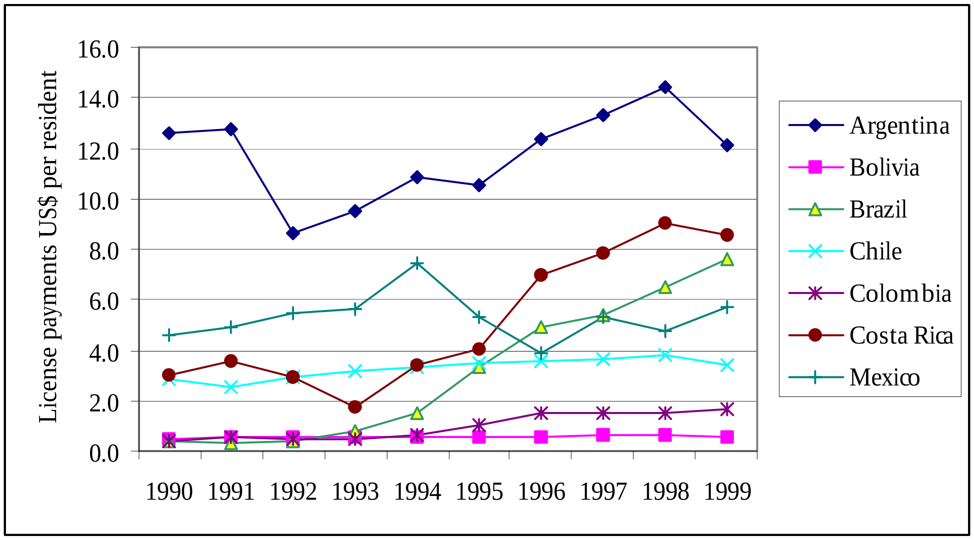
Graph 30 License payments, LAC av. and selected non-LAC countries, 1990-1999



Source: Authors' calculations based on WDI, various years

Thus, all of these countries rely to a significant degree on transfer of disembodied technology, and clearly outstrip the LAC region, where the average license payments only took up US$5 per resident by the end of the 1990s (Graph 30). Still, the current level of license payments in LAC represents more than a doubling compared to the level of 1990 and lies well above India, where royalty and license payments remain negligible.

Graph 31 License payments, selected LAC countries, 1990-1999



Source: Authors' calculations based on WDI, various years.

A closer look at the LAC data reveals significant variation between the countries in the region. Argentina is clearly the largest recipient of disembodied technologies with a level of US$12 per resident. However, Costa Rica and Brazil also pay relatively large sums in royalty and licenses (approx. US$8). Moreover, the current levels of Brazil and Costa Rica represent significant increases from the level of 1990. Bolivia and Colombia, on the other hand, have featured low levels of license payments throughout the 1990s (Graph 31).

PART IV –CONCLUSIONS & RECOMMENDATIONS

This study opened with a brief assessment of the S&T capacity of the LAC countries, which showed that the LAC countries are comparatively weak in terms of science and technology. These results have been corroborated by the subsequent analysis, which have documented that resident patent applications have been stagnant in the region throughout the 1990s. Furthermore, the contribution of LAC researchers has been modest in terms of scientific articles. Still, some of the LAC countries have shown elements of progress and significant achievements within certain areas, notably Brazil, Argentina, Chile, Costa Rica and Mexico. Still, other countries in the region, Bolivia is a case in point, lags behind on every dimension included in the analysis. Moreover, the performance of Bolivia is likely to be representative of a larger sample of LAC countries, mainly located in the Andean, Central American and Caribbean parts of the region. Hence, the picture of S&T capacity in the LAC region is one of diversity, yet none of the countries are truly competitive on a global scale.

Still, it is hardly surprising that the LAC countries as a whole trail a country like United States. The country remains the world leader in science and technology par excellence, which in turn has been facilitated by a propitious institutional framework and strong economy incentives. The bottom-up process leading to the emergence of Silicon Valley is only one example of the importance of a strong IPR regime, a highly developed financial system and a entrepreneurial business culture.

The LAC countries cannot expect to craft these characteristics overnight and catch up with the highly successful economies in the short and medium term. Still, there are plenty of policy options, and the LAC countries can make significant progress if they commit themselves to adopting a comprehensive policy program for science and technology improvement.

Institutional framework and economic incentives. Some of the LAC countries including Brazil and Colombia have improved their IPR-regimes, and Chile and Costa Rica today boast consolidated legal frameworks. Likewise, the finance sector appears to develop quickly in terms of volume and diversification, but most of the countries still face a long uphill struggle in broadening access to investment. Moreover, the recent wave of liberalization and deregulation has clearly improved the competitive environment in the region, but it remains yet to be seen how the LAC region as a whole will be affected by these changes.

However, change has not affected all LAC countries alike and financial markets in Bolivia and Cuba are still underdeveloped. Moreover, regulatory environments, and legal frameworks continue to be seriously flawed in most of the countries with Chile and Costa Rica being the main exceptions. This has wide implications for venture capital markets, which are unlikely to expand as long as the institutional framework remains flawed.

LAC countries should devote considerable resources to strengthening the institutional framework. As pointed out, this cannot be done overnight, but this does not make it a less pertinent area for action. IPR-regimes should be strengthened further, but any effort to upgrade IPR-regimes should be coupled with efforts to consolidate the rule of law. As pointed out in the analysis, the rule of law is still flawed in the LAC region, which implies that the existence of formally strong IPR-regimes will remain de facto weak. The importance of establishing a competitive framework should also be stressed, seeing that this is one of the main ways to stimulate private sector participation in R&D.

Development of finance markets, especially venture capital markets, is another priority area. However, The question is what the public sector should do to meet these objectives. Little speaks in favor of letting the public sector run venture funds. Venture capital markets are more likely to be sustained through the intervention of private investors, foreign and domestic. Hence, the challenge for the public sector is to create an environment, which is favorable to formation of private venture capital. This, in turn can be assured, through the strengthening of IPR-regimes and, more generally, the consolidation of the rule of law.

Information and communications technologies. Awareness and penetration of ICT-technologies seems high in the LAC region, but again the picture is one of diversity: Countries such as Argentina, Brazil, Chile and Costa Rica are well equipped in terms of ICT-penetration, and high levels of investment in Colombia augur well for the future of that particular country. Bolivia and Cuba, on the other hand, lag far behind, and these countries accordingly run the risk of missing out on the possibilities ICT has to offer in terms of promoting S&T activities.

If LAC countries can success in nurturing private investments, the ICT sector is likely to receive considerable funding. Governments should at the same time work to promote the ICT-technologies in the education system.

Human Capital. Although the LAC countries have extended education significantly in the last decades, they still have a long way to go, especially when compared to countries like Ireland, Korea and the United States. However, countries like Argentina, Chile, Colombia and Costa Rica have managed to increase tertiary enrollment significantly and Argentina and Chile feature significant proportions of students enrolled in S&T related studies. However, this does not change the overall impression of LAC as a region, which needs to put a lot of efforts into extending tertiary coverage in the coming years.

The need for change and improvement also concerns the quality of education. Thus, based on the existing evidence, most of the education systems in the region do not meet the needs of a competitive economy. Hence, a carefully planned reform of current education systems and curricula is needed.

Moreover, it is important to keep in mind that investments in human capital will help stimulate private investments and venture capital specifically. Costa Rica, for example, has succeeded in attracting substantial foreign investments because the workforce is highly skilled relative to other countries in the region.

Input factors. Notwithstanding recent spending increases, the general level of R&D funding still needs to be increased in the LAC region. This, in turn, warrants increased participation by the private sector, which in most of the OECD countries contributes significant shares to R&D funding. Hence, governments should aim to strengthen the institutional framework and the economic incentives, which in turn will allow the private sector to take on a more active role in the S&T system. LAC countries also need to expand the number of researchers, which lags far behind the levels of more developed countries.

Public Policies. The public sector has been in the driver's seat in the LAC region. Hence, most policies have been executed by government ministries, research institutions, through public procurement or via higher education research. Yet, the effects of these policies are far from clear. Government projects have often developed into large-scale projects, whose benefit to society remained unclear. Moreover, the effects of government policies have in some cases been reduced due to red tape and government inefficiency.

Future government policies could take a bottom-up approach, be responsive to the needs of the economy and society at large and strive to eliminate government inefficiency. This can be promoted through the establishment of private-public partnerships where appropriate, notably in relation to technology institutions and fund management.

The evidence is inconclusive as regards whether direct subsidies should be substituted for fiscal incentives, especially with regard to the LAC region, where little research has been done. Based on the assumption that the LAC region needs to support the development of SME's, direct subsidies may be the best policy option. Still, direct subsidies should be made conditional on co-funding in order to avoid crowding out private R&D.

The overall contribution of higher education research also remains unclear. Evidence suggests that academic research agendas have been uncoupled from the needs of the economy. This is not to suggest that the private sector should have complete control of research carried out in universities. But a change of reward structures could make the academia more responsive to applied research. Changes to the legal framework, the Bayh-Dole Act is a case in point, is another policy option.

Several LAC countries have experience with policies promoting R&D collaboration. Brazil even has a relatively long tradition of nurturing science parks. Still, no evidence exists to document that these parks have a positive effect on the S&T capacity. Arguably, the odds may even be against such initiatives. Policy experiences from outside the region suggest that the success of science parks is largely dependent on a strong legal framework, availability of venture capital and bottom-up planning. None of these factors have been particularly salient in the LAC region.

Considering the significant size of the knowledge gap between the LAC region and other regions, the rationale for promoting technology diffusion is clear. This makes a case for improving ICT-technologies further, seeing that a high ICT penetration facilitates a wide and rapid diffusion of technologies.

The need for boosting technology diffusion also points to the importance of sustaining current liberalization efforts. Both Korea and Ireland have benefited significantly from technology transfer, either through import of technology-intensive merchandise (Korea) or through FDI (Ireland). The growth in FDI already seems to play an important role in Brazil, Costa Rica, Mexico and Chile and the available evidence suggests that major spillover effects can be realized. Still, the Mexican maquila industry calls attention to the fact that technology transfer may not necessarily have an impact if the sectors in the domestic economy are poorly integrated.

Interaction. The final remark concerns the importance of interaction. Ireland and Korea are cases in point. Both countries increased the level of funding to R&D combined with efforts to extend tertiary education and improve science skills. Likewise, the increase in skills have allowed these countries to take more effectively advantage of ICT technologies, which has boosted their S&T capacities further. Accordingly, governments in the LAC region, and elsewhere for that matter, should work to design internally coherent policies, which capitalize on interaction effects.

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ANNEX: EXPLANATION OF VARIABLES

Note that all the variables have been standardized into a scale running from 0-10.The scales referred to in this section are the original scales. Variables are listed in alphabetical order.

Adult literacy rate (% age 15 and above) 1999

The Adult Literacy rate presented in the HDR are estimates and projections from UNESCO's February 2000 literacy assessment.

Availability of Venture capital 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether "entrepreneurs with innovative but risky projects can generally find venture capital" in their country. (1= strongly disagree, 7 = strongly agree).

Companies invest heavily, to attract, motivate, and retain staff 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether "companies invest heavily, to attract, motivate, and retain staff" in their country. (1= strongly disagree, 7 = strongly agree).

Computers per 1,000 persons 2000

Computers are self-contained computers designed to be used by a single individual.

Control of Corruption 1999

This indicator corresponds to "graft" measures of corruption. Notably, corruption measured by the frequency of "additional payments to get things done" and the effects of corruption on the business environment.

Daily newspapers per 1,000 people, 1996

Daily newspapers refer to those published at least four times a week.

Easy to start a new business 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether " starting a new business is easy " in their country. (1= strongly disagree, 7 = strongly agree).

E-Commerce 2000

This reports the percentage of companies in a country that use the internet for electronic commerce.

Entrepreneurship among Managers 2001

This is a statistical score awarded on a 1-10 scale to a country based on a survey that asks if managers generally have a sense of entrepreneurship

FDI as % of GDP 1990-1999

This is an average of the FDI as % of GDP for 1990-1999. It was calculated from data available on the SIMA database , World Bank, Washington D.C.

Government Effectiveness 1999

This indicator combines into one grouping perceptions of the quality of public service provision, the quality of the bureaucracy, the competence of civil servants, the independence of the civil service from political pressures, and the credibility of the government's commitment to policies.

Gross Capital Formation as % of GDP (Average) 1990-1999

Gross Capital Formation consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. The above variable is an average of the Gross Capital Formation as % of GDP for 1990-1999. It was calculated from data available on the SIMA database , World Bank, Washington D.C.

High-Technology Exports as % of Manufactured Exports, 1999

High-technology exports are products with high R&D intensity. They include high-technology products such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

Human Development Index (HDI) 1999

The HDI is based on three indicators: longevity, as measured by life expectancy at birth; educational attainment, as measured by a combination of adult literacy rate (two-thirds weight) and the combined gross primary, secondary and tertiary enrollment ratio (one-third weight); and standard of living, as measured by GDP per capita (Purchasing Power Parity US$).

ICT Expenditure as % of GDP 1999

Information and communications technology expenditures include external spending on information technology (“tangible” spending on information technology products purchased by businesses, households, governments, and education institutions from vendors or organizations outside the purchasing entity), internal spending on information technology(“intangible” spending on internally customized software, capital depreciation, and the like), and spending on telecommunications and other office equipment.

Information Society Index 2000

The Information Society Index is the world’s first measure of 55 nations’ abilities to participate in the information revolution. It provides government planners, global IT and telecommunications corporations, and asset management firms with the data and analysis required for measuring progress toward a digital society, assessing market opportunities, and developing policies.

Intellectual Property is well protected 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether “ intellectual property is well protected” in their country. (1= strongly disagree, 7 = strongly agree).

Internet hosts per 10,000 people, 2000

Internet hosts are computers with active Internet Protocol (IP) addresses connected to the Internet. All hosts without a country identification are assumed to be located in the U.S.

International telecommunications, cost of call to US ($/3 min), 1999 (2001 WDI)

Cost of calls to U.S. is the cost of a three-minute peak rate call from the country to the United States.

Legal Regulation of Financial Institutions 2001

This is a statistical score awarded on a 1-10 scale to a country based on a survey that asks if legal regulation of financial institutions is adequate for financial stability

Management education is locally available in first-class business schools 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether "management education is locally available in first-class business schools" in their country. (1= strongly disagree, 7 = strongly agree).

Management/Worker Relations 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether "labor/employee relations are generally cooperative" in their country. (1= strongly disagree, 7 = strongly agree).

Number of technical papers per million people 1997

The number of technical papers refers to scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

Overall Central Government Budget Deficit as % of GDP, 1998

Overall budget deficit is current and capital revenue and official grants received, less total expenditure and lending minus repayments.

Patent Applications granted by the USPTO (per million pop.)

This is the number of patent applications granted by the USPTO to a country in 1999 divided by the population of that country in 1999.

Political stability / Lack of violence 1999

This index combines several indicators, which measure perceptions of the likelihood that the government in power will be destabilized or overthrown by possibly unconstitutional means and/or violent means. This index captures the idea that the quality of governance in a country is compromised by the likelihood of wrenching changes in government, which not only has a direct effect on the continuity of policies, but also at a deeper level undermines the ability of the citizens to peacefully select and replace those in power.

Private Sector Spending on R&D 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether “companies invest heavily in research and development relative to their international peers”. (1= strongly disagree, 7 = strongly agree).

Professional and technical workers as % of the labor force 2000

This involves calculation of total number of technical and professional workers as a percentage of the labor force.

Protection of Property Rights 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether “property rights are clearly delineated and protected by law” in their country. (1= strongly disagree, 7 = strongly agree).

Regulatory framework 1999

This indicator measures the incidence of market-unfriendly policies such as price controls or inadequate bank supervision, as well as perceptions of the burdens imposed by excessive regulation in areas such as foreign trade and business development.

Research collaboration between Companies and Universities 2000

This is based on the statistical score of a large sample group in a particular country responding to the question of whether “companies collaborate closely with local universities in research and development activities” in their country. (1= strongly disagree, 7 = strongly agree)

Royalty and license fees payments $ millions 1999

Royalty and license fees are payments and receipts between residents and nonresidents for the authorized use of intangible, non-produced, non-financial assets and proprietary rights (such as patents, copyrights, trademarks, industrial processes, and franchises) and for the use, through licensing agreements, of produced originals of prototypes(such as manuscripts and films)

Rule of Law 1999

This indicator includes several indicators, which measure the extent to which agents have confidence in and abide by the rules of society. These include perceptions of the incidence of both violent and non-violent crime, the effectiveness and predictability of the judiciary, and the enforceability of contracts.

Scientists and Engineers in R&D per million 1987-97

Scientists and engineers in R&D are people trained at the tertiary level to work in any field of science who are engaged in professional R&D activity.

Secondary Enrollment 1997

Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject or skill-oriented instruction using more specialized teachers.

Tariff & Nontariff barriers 2001

This involves a cumulative score assigned to each country based on the analysis of its tariff and non-tariff barriers to trade, such as import bans and quotas as well as strict labeling and licensing requirements. This score is part of the larger group of indices comprising *The Index of Economic Freedom* provided by the Heritage Foundation. *The Index of Economic Freedom* is a practical reference guide to the economies of 161 countries, with detailed information about economic policy. It offers an annual in-depth examination of the factors that contribute most directly to economic freedom and prosperity.

Technology Assessment Index 2001

The Technology Assessment Index (TAI) from UNDP aims to capture how well a country is creating and diffusing technology and building a human skill base. It is a composite index focusing on four dimensions of technological capacity that are important for reaping the benefits of the network age- *creation of technology, diffusion of recent innovations, diffusion of old innovations, and human skills.* For more information, please refer to the page 46 of the 2001 UNDP Human Development Report.

Telephone per 1000 people 2000 (telephone mainlines + mobile phones)/1000 people

This is a number obtained by first obtaining a composite sum of “telephone mainlines per 1000 people “(from 2000 ITU) and “mobile phones per 1000 people” (from 2000 ITU) and then taking the natural log of that composite sum.

Tertiary enrollment 1997

Tertiary education, whether or not leading to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level.

Total expenditure for R&D as % of GNI, 1987-1997

Expenditures for R&D are current and capital expenditures on creative, systematic activity that increases the stock of knowledge. Included are fundamental and applied research and experimental development work leading to new devices, products, and processes.

Trade as % of GDP, 1999

Trade is the sum of exports and imports of goods and services, measured as a share of GDP

University education meets the needs of a competitive economy 2001

This is a statistical score awarded on a 1-10 scale to a country based on a survey that asks if university education meets the needs of a competitive economy

Well educated people do not emigrate abroad 2001

This is a statistical score awarded on a 1-10 scale to a country based on a survey that asks if well-educated people in that country emigrate abroad

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Latin America and the Caribbean Region
Department of Human Development (LCSHD)
The World Bank
1818 H Street, N.W.
Washington, D.C. 20433

Fax: 202-522-0050
E-mail: LACED@worldbank.org