

# **The State of Science**

## **1. Investment in R&D**

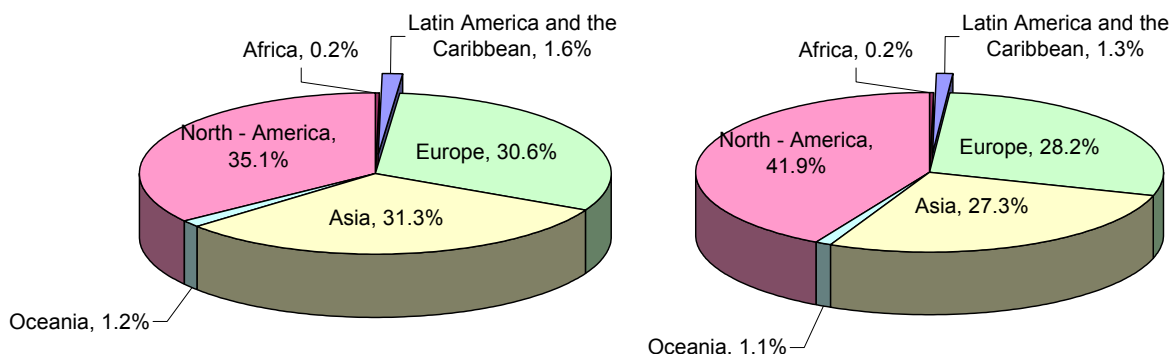
During the period covered by the present report (1994-2003), world investment in research and development (R&D) increased considerably, in line with world economic growth over the same period. With an upward trend with some fluctuations due to economic, political and social events during the years in question, an 82% increase in world R&D investment can be appreciated, rising from 470 billion current dollars to around 860 billion current dollars in 2003. Naturally this increase was concentrated in economically advanced countries, with the remainder experiencing a relative decline, as will be seen below.

Focusing on events in Latin America and the Caribbean, it is clear that optimal results were not achieved, since although R&D investment increased between 1994 and 2003, this rise was not sustained, and fluctuated largely as a result of economic and financial imbalances in the three largest countries in the region (Mexico, Brazil and Argentina) which not only faced external crises from Asia in 1997 and Russia in 1998, but also experienced internal crises with devastating consequences for their economies (Mexico in 1995, Brazil in 1999 and Argentina in 2001 and 2002).

### **1.1 Latin America and Caribbean share of world R&D investment.**

The dynamics of the Latin American and Caribbean share of world R&D investment was no different from most other regions, with this region and Oceania and Asia experiencing a slight decrease in their world share. Europe as a whole also experienced a relative decrease, although many individual European countries enjoyed the greatest increases in R&D investment. The exception was North America, which as a whole saw an increase. Africa maintained the same scant share as before. (Graph 1)

**Graph 1. World investment in R&D by geographic block, expressed in current dollars (1994-2003)**

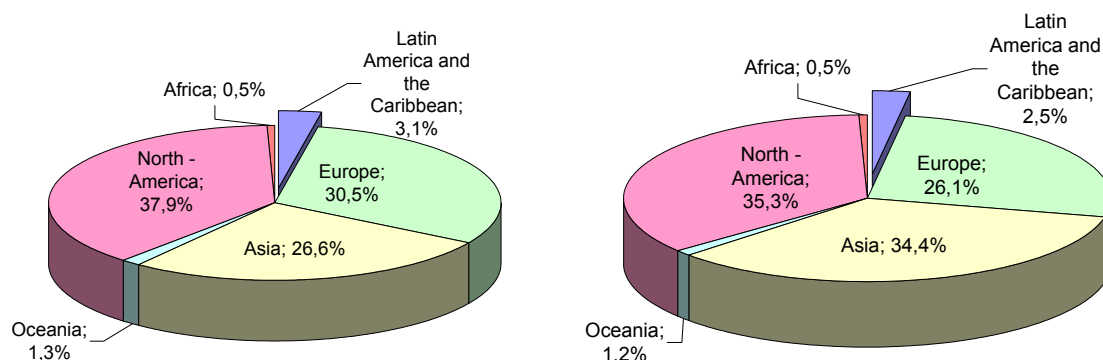


Note: Data estimated from OECD, UNESCO and RICYT sources  
 Calculation in dollars at current value for the years 1994 and 2003.  
 North America includes the USA and Canada, Mexico is included in Latin America and the Caribbean.

As can be seen here, the countries of Latin America and the Caribbean saw a decrease in their relative share, from 1.6% of the world total in 1994 to 1.3% in 2003. In contrast, North America as a whole increased its share from 35.1% to 41.9% of the world total.

If calculations are based on Purchasing Power Parity (PPP), development in the region does not change significantly, as the share decreases in both cases (Graph 1b). However, the PPP index does show a greater overall share for Latin America and the Caribbean than in current dollars, decreasing from 3.1% in 1994 to 2.5% in 2003. The dynamic of other world regions also changes when expressed in PPP, due principally to a decrease in the North American share and a marked increase in Asia's.

**Graph 1b. World R&D investment by geographic block, expressed in PPP (1994-2003)**

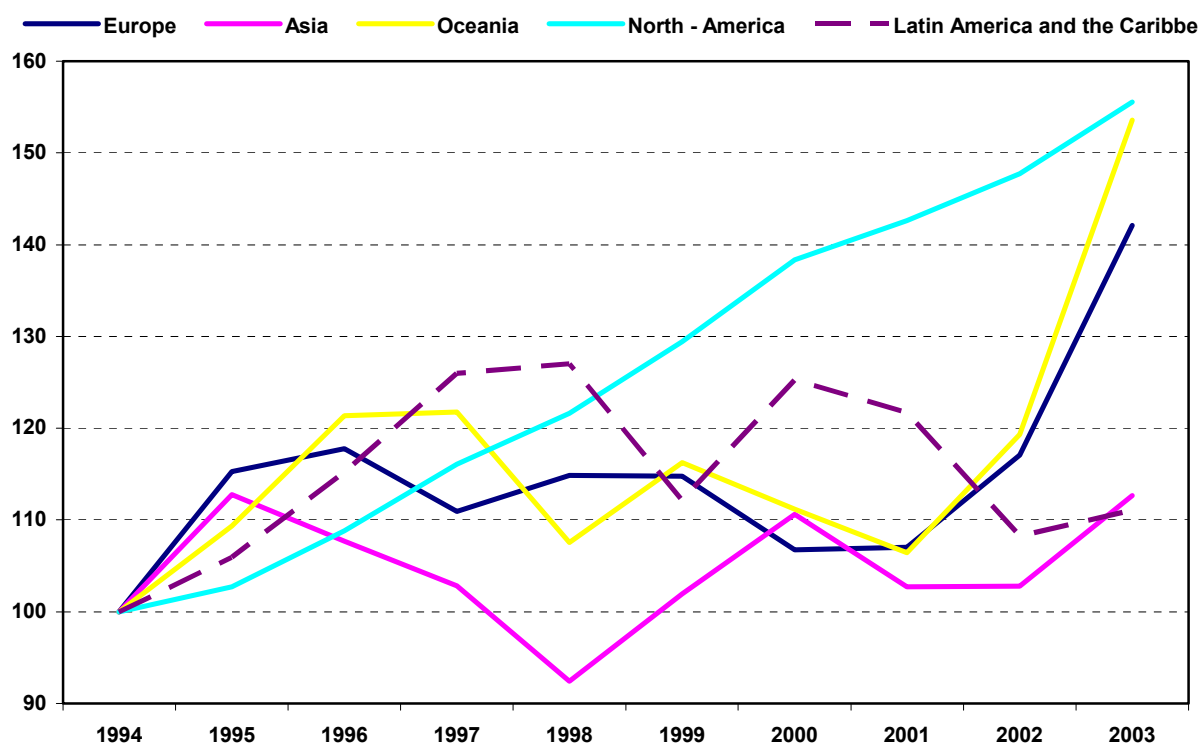


Note: Data estimated from OECD, UNESCO and RICYT sources  
 North America includes the USA and Canada, Mexico is included in Latin America and the Caribbean.

## 1.2 GDP growth and R&D investment in Latin America and the Caribbean

Graph 2 shows that the GDP in the various regions fluctuated as a result of economic events during the 1994-2003 period. The only region to maintain constant growth was North America.

**Graph 2. GDP growth by geographic block, in current dollars (1994=100)**



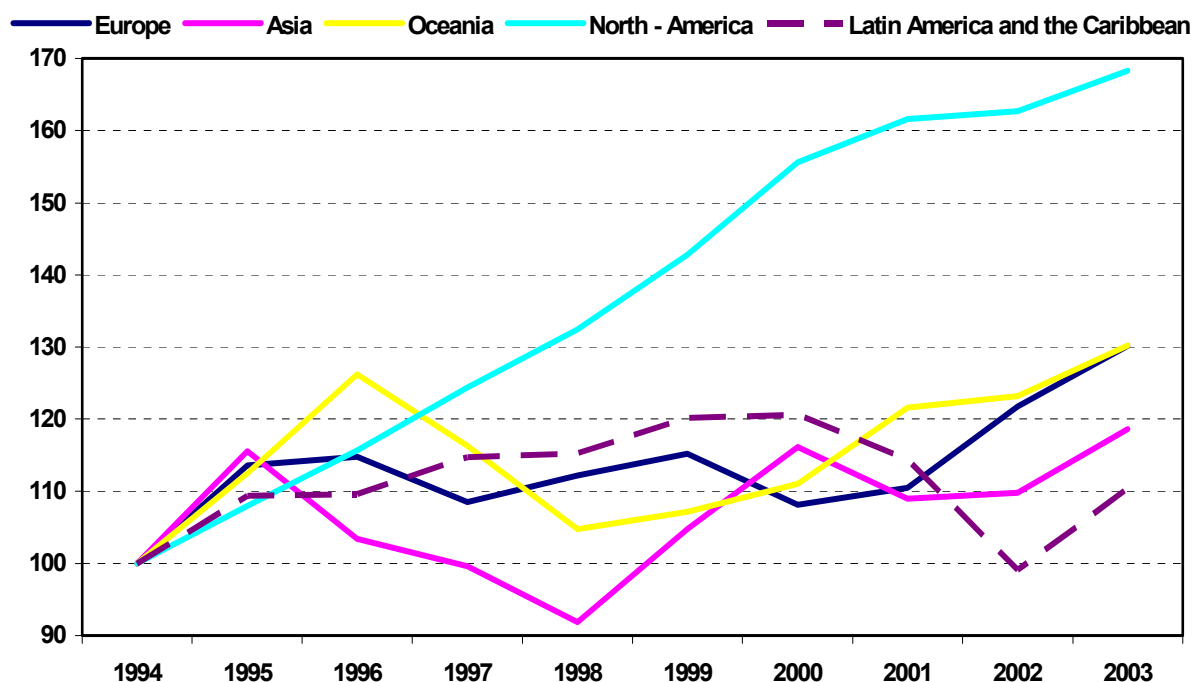
Note: Data estimated from OECD, UNESCO and RICYT sources

The line representing the GDP of Latin America and Caribbean countries shows two marked drops in 1999 and over 2001 and 2002, evidence of the effect of the Brazilian and Argentinian crises on regional GDP growth. In contrast, the Mexican crisis did not have a negative effect on overall GDP growth as this was countered by large GDP increases in Brazil in 1995, measured in current dollars.

R&D investment in the various regions coincided on the whole with GDP performance. In all geographic blocks there were marked fluctuations, with the single exception of North America which experienced constant growth between 1994 and 2003 (Graph 2b).

There was no dip in R&D investment in Latin America and Caribbean countries in 1999, in contrast to PBI performance in constant dollars, due to Brazil's relative weight in this variable and the country countering its GDP shortfall with considerable increases in science, technology and innovation investment and the creation of new sources of financing for this.

**Graph 2b. R&D investment growth by geographic block, in current dollars (1994=100)**



Note: Data estimated from OECD, UNESCO and RICYT sources

### **1.2.1 The cases of Argentina, Brazil and Mexico**

This section analyses GDP growth in Argentina, Brazil and Mexico over the period 1994-2003, and how this growth influenced R&D investment.

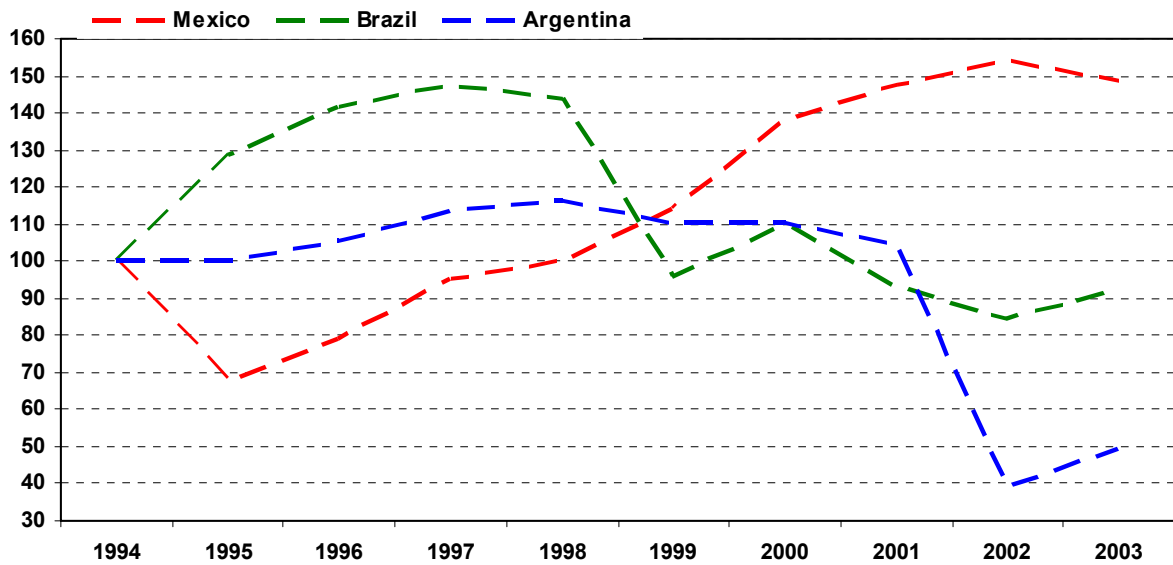
These three countries are the largest in Latin America and as a whole represent 90% of R&D investment in the region for the period 1994-2003. They are also the countries that suffered the greatest crises in the 1990s and the beginning of the present decade, triggering destabilising economic consequences of varying magnitudes on neighbouring economies and affecting large sectors of the world economy.

Graph 3 shows GDP trends for these countries over 1994-2003. In the case of Mexico there was a fall in GDP equivalent to 6.2% in 1995 as a result of the Mexican crisis dubbed the “Tequila Effect” and the subsequent devaluation of the Mexican peso between 1994 and 1995 with the dollar doubling in value. After this period, Mexican GDP returned to the upward trend seen before the crisis.

Brazil experienced an upward trend in GDP up to 1999, the year of the economic crisis and the subsequent abandonment of dollar-real exchange parity in place since 1995. Although this caused a drop in GDP in current dollars, the decrease is not clearly visible when considering growth in constant dollars.

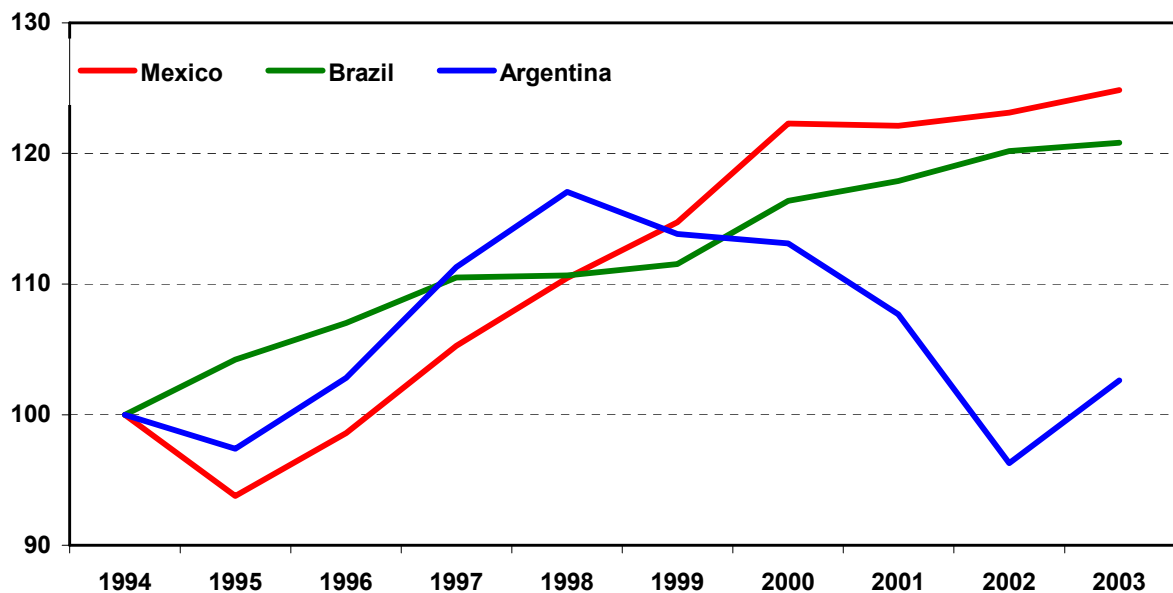
Argentina showed a similar trend to Brazil, with a drop in GDP observed in the year of the economic crisis and the abandonment of the currency board economic plan. Although this accounts for the abrupt decrease, it must also be taken into account that GDP in constant dollars also decreased around 20% between 1998 and 2002. Some growth was registered towards the end of this period, attributable to a rebound effect which often appears in economies that have suffered a deep, sustained recession, as was the case in Argentina over these four years.

**Graph 3. GDP growth in current dollars (1994-2003)**



The following graph (Graph 3b) shows GDP growth for these three countries in constant values. For Argentina and Mexico 1993 is used as the base year, and for Brazil 2004.

**Graph 3b. GDP growth in constant dollars (1994-2003)**



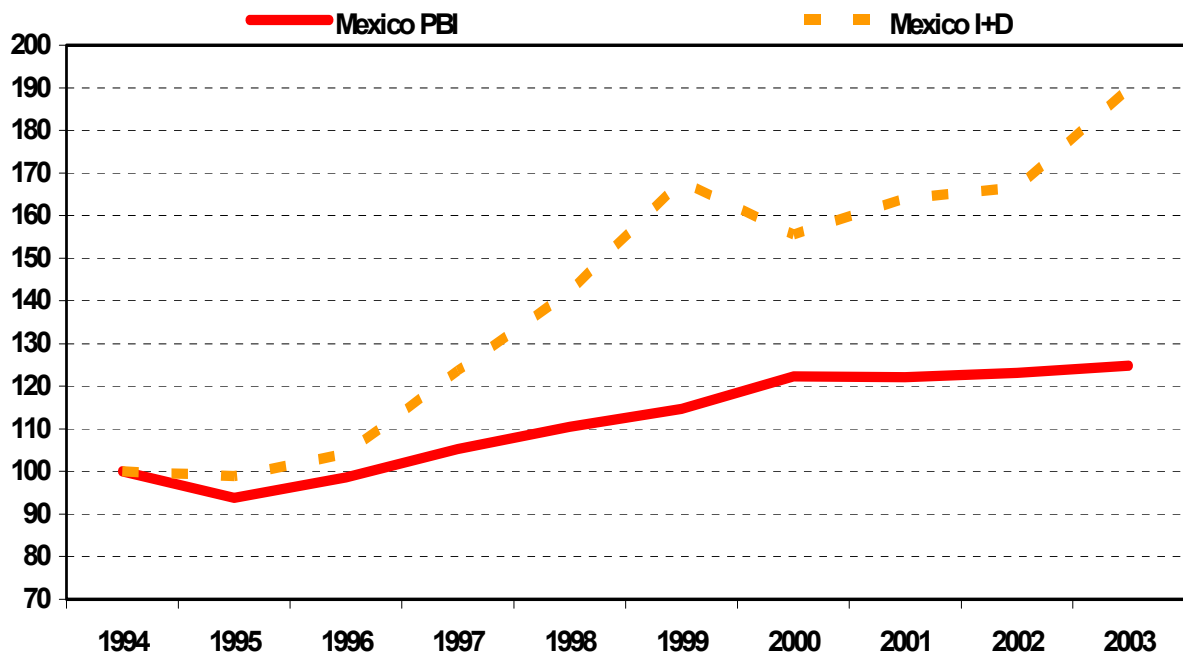
The figures shown here present a less fluctuating trend than in current dollars and gives a better idea of the GDP decreases in each country during the corresponding crises. Taking Mexico as the first case, it can be seen how the 1995 crisis affected GDP growth, interrupting an upward trend that the country had enjoyed since 1994. As mentioned

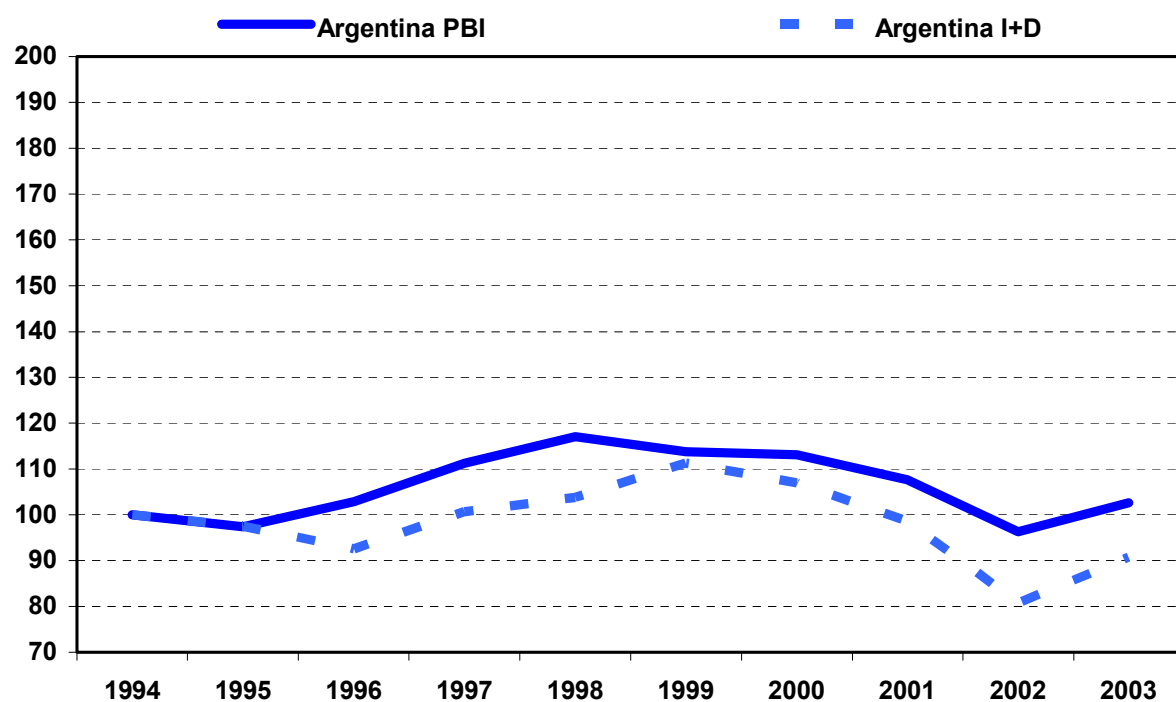
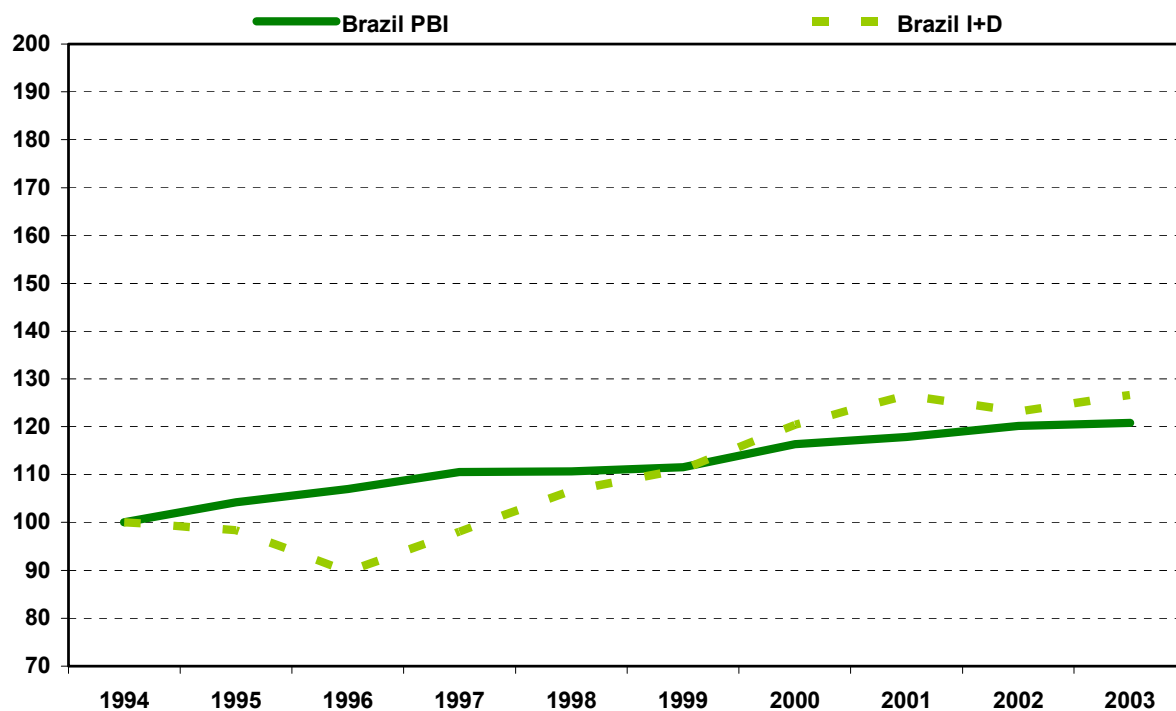
previously, there was a 6.2% decrease in GDP. Brazil showed a sustained upward trend throughout the greater part of the period, with a plateau between 1997 and 1999, as can be seen in the graph. This is due to the fact that Brazil experienced almost zero growth over these two years, with average growth below 0.5%. In the case of Argentina, in contrast, it is possible to observe continuous growth between 1994 and 1998, interrupted only in 1995 by the effect of the Mexican crisis on the Argentinian economy. Having resolved this crisis, Argentina returned to an upward trend until 1998-2002, when GDP decreased abruptly by almost 20%.

If R&D investment growth is analysed taking into account the GDP of these three countries, it can be observed that this has not been unaffected by such macroeconomic turbulence. Graph 4 shows how the trend in R&D investment was very similar to that of GDP, whether calculated in constant or current values. In the former case investment appreciably rose and fell in line with GDP, influenced by the crises in the region during the period.

The analysis of the data concerning R&D investment growth in relation to GDP shows that the country that grew the most under this indicator was Mexico, which in spite of maintaining low figures in relation to desirable investment (1% of GDP) increased investment from 0.29% in 1994 to 0.45% in 2003. In the case of Brazil, the most noticeable aspect is that this was the only country in Latin America and the Caribbean to reach the goal of 1% of GDP allocated to R&D in 2001, although this later decreased to 0.95% in 2003. With regards to Argentina, this relation saw few fluctuations over the period, with R&D investment remaining at an average of 0.44% of GDP, with a drop in 2001 worsening in 2002 as a result of the economic crisis.

**Graph 4. GDP growth and R&D investment in constant dollars (1994-2003)**

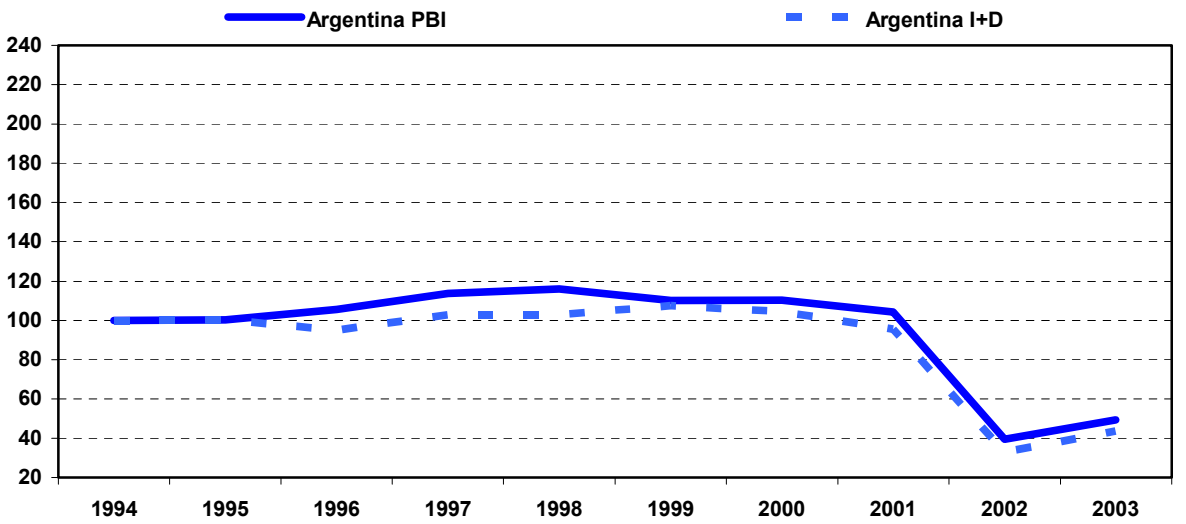
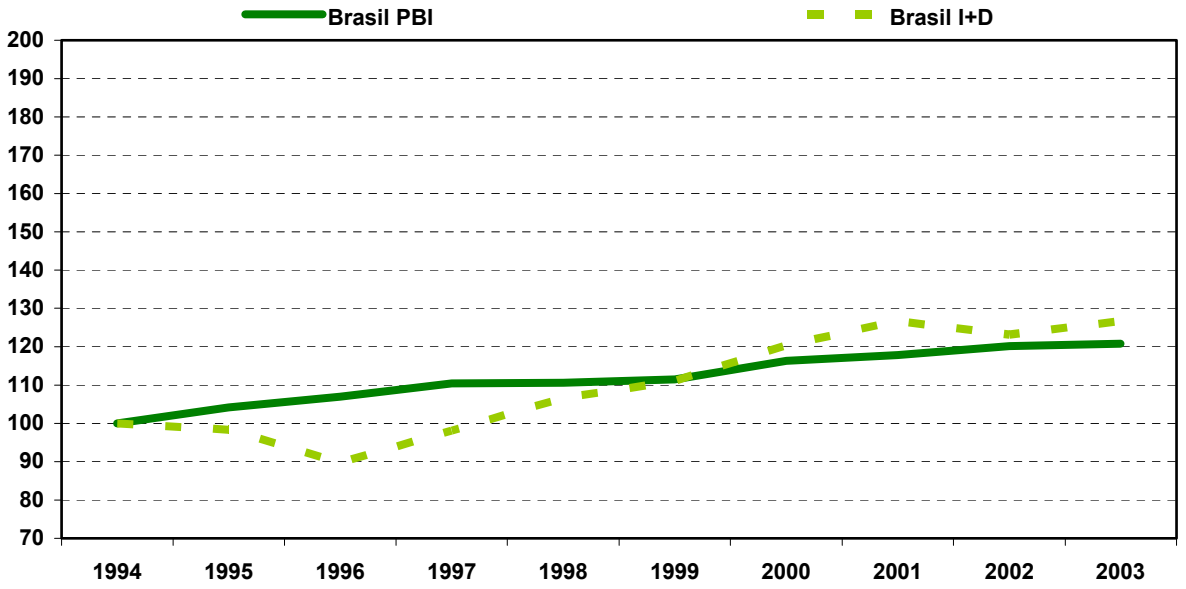
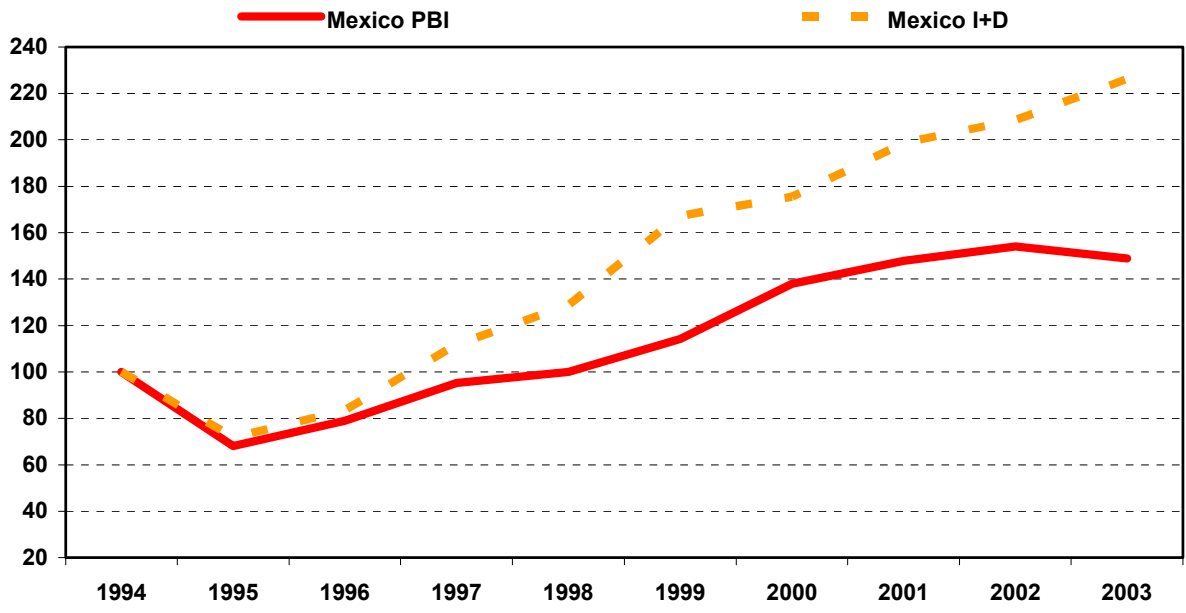




Note: Graphs by Centro REDES from data sources from the Instituto Nacional de Estadística y Censo de Argentina, Banco Central do Brasil and the Instituto Nacional de Estadística Geografía e Informática de México.

The current dollar calculation shows better the devaluation measures implemented by each country to tackle the economic crisis: Mexico in 1995, Brazil in 1999 and Argentina in 2001-2002. As Graph 4b shows, there was a clear decrease both in GDP and in R&D investment in the years when these measures were implemented. The only radical difference was seen in Brazil, where although the currency was devalued in 1999 the impact on R&D investment is not noticeable in added values due to the country simultaneously increasing resources for science, technology and innovation, as mentioned above.

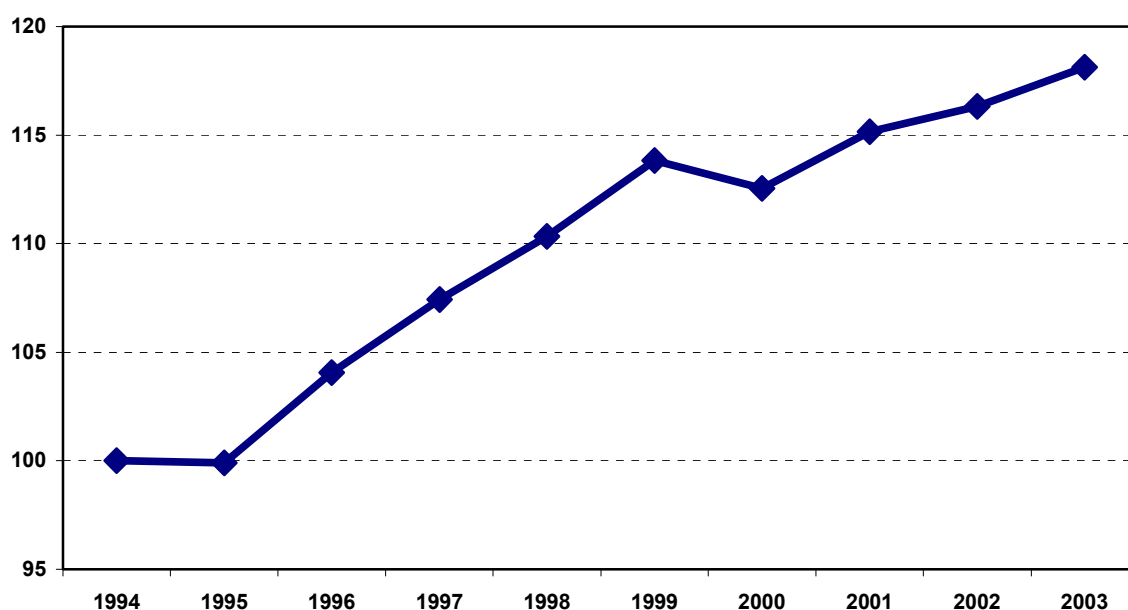
**Graph 4b. GDP growth and R&D investment in current dollars (1994-2003)**



## 2. Human Resources

The number of people working in R&D saw sustained growth throughout the world over the period in question (Graph 5). This phenomenon is a clear sign of the importance in the political agendas of developed countries of high-level training as part of the process of shaping the knowledge society. More than ever before, the number of researchers available to a country in relation to its population can be interpreted as an indicator of modernity and consequently the growth of this has become the object of deliberate policy.

**Graph 5. Researchers (FTE) in the world (1994=100)**

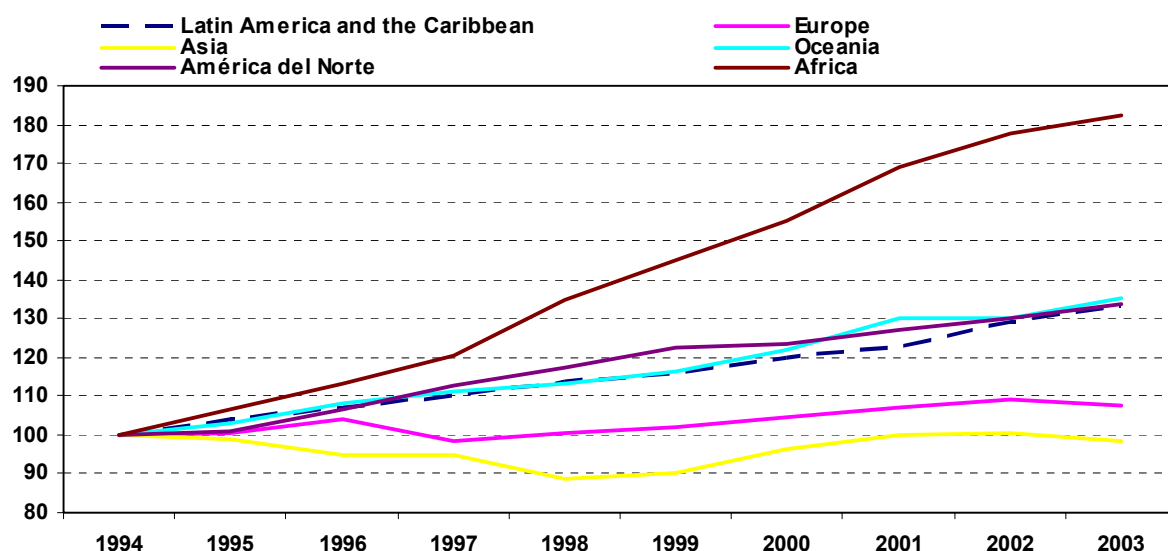


Note: Data estimated from OECD, UNESCO and RICYT sources

Over the ten years in question an increase in the number of researchers in different areas of the world was registered. In some regions this trend saw moderate growth, such as in Asia and Europe, while in others the number of researchers increased rapidly, as was the case in Africa, although it should be remembered that the starting number was very low.

With regards Latin America and the Caribbean, the growth in the number of researchers in the region was similar to that of North America (Graph 6). Between 1994 and 2003 the region as a whole experienced constant growth of 33%.

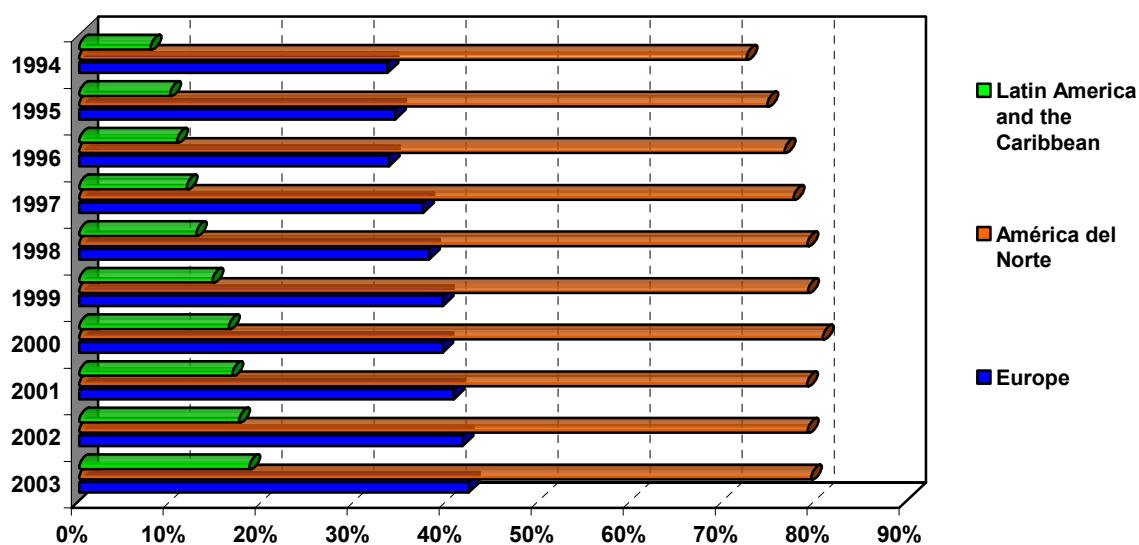
**Graph 6. Researchers (FTE) by geographic block (1994=100)**



Note: Data estimated from OECD, UNESCO and RICYT sources

However, it is important to mention some relative differences between Latin American and Caribbean countries and other geographic blocks with regards to the distribution of human resources by work sector. While in Europe and North America a high percentage of researchers and technologists are employed in the private sector (approximately 45% in the former and 80% in the latter), in Latin American and Caribbean countries it is the public sector that employs the majority of this kind of personnel –whether through institutions dependent on public administration, or higher education institutions– while the private sector employs a lower percentage, generally around 20% (Graph 7). However, in Latin America and the Caribbean the number of scientists and technologists grew continuously while in Europe and North America the number fluctuated over the years in question.

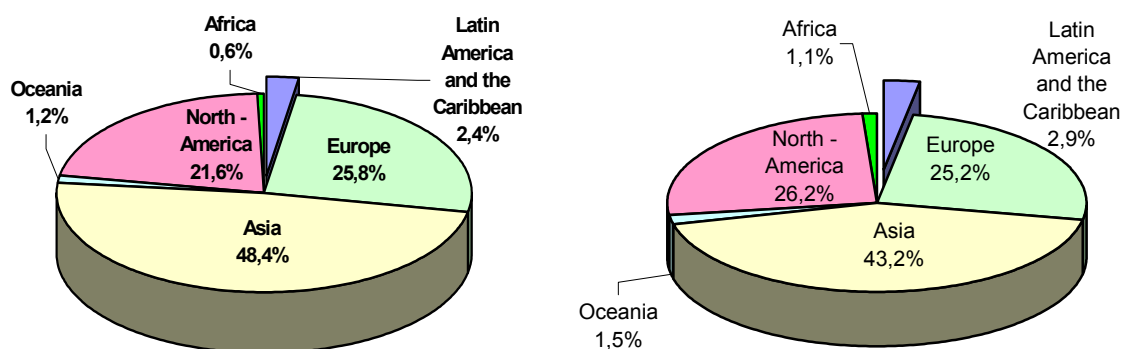
**Graph 7. Percentage of Researchers (FTE) in private employment (1994-2003)**



Note: Data estimated from OECD, UNESCO and RICYT data

With regards to the growth in the percentage of Latin American and Caribbean countries in the world total of researchers and technologists over the period in question, it can be appreciated that the countries in this region improved slightly, although they did not exceed the 3% mark (Graph 8)

**Graph 8. Researchers (FTE) by geographic block (1994 and 2003)**



Note: Data estimated from OECD, UNESCO and RICYT sources

### 3. Results of regional scientific and technological activity

Evaluating the results of R&D activities is an issue of central importance in science, technology and innovation policies. It is an indispensable tool for reorienting these policies and to guarantee an increase in their effectiveness in social and economic terms. In Latin America and the Caribbean this is also an issue and one that increasingly merits greater attention, particularly in countries making sustained efforts to use science and technology to drive development.

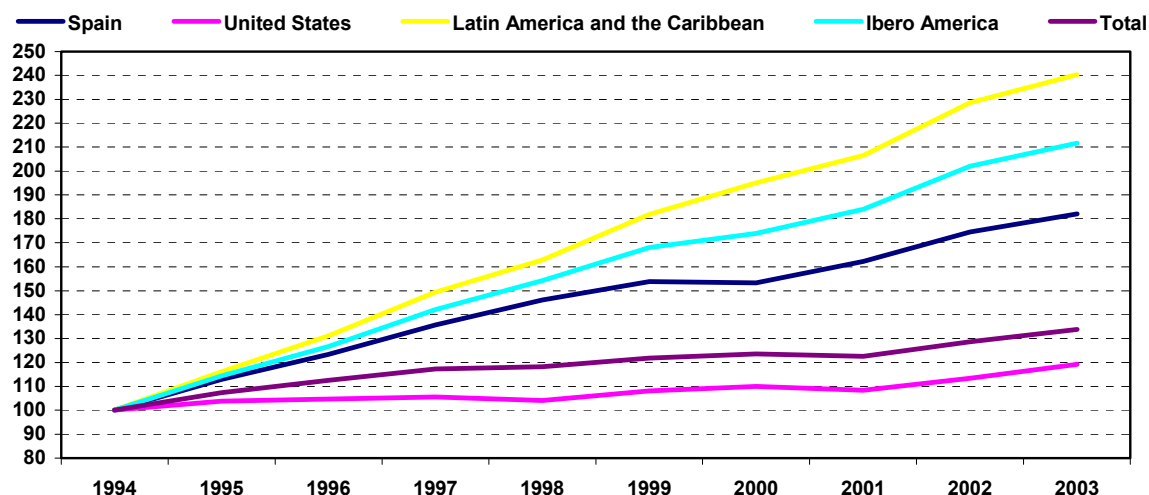
In terms of comparative indicators at an international level, the measuring of results is limited to the awarding of patents and bibliometric registers. Both types of indicators are relatively controversial, although they do provide a standardised method for measuring results attained in basic or applied research and technological development. The measuring of the presence of authors belonging to each region on international databases makes it possible to evaluate Latin American researchers' contribution to the science mainstream. The analysis of patent registers is more problematic, due to their vulnerability to regulatory and organizational aspects, but they are revealing about technological activity in the countries of the region and the contribution of local technological centres.

#### 3.1 Publications

The quality of Latin America science has increased constantly in recent years according to bibliometric indicators. The number of publications registered in the *Science Citation Index* (SCI) for Latin America and the Caribbean saw a marked increase over the 1994-2003 period of 140%. This growth rate is surprisingly high, doubling that of the total of registers on the database (33%). It is also greater than the increase in Spanish production, which rose considerably over the period.

It is notable that the growth rate in publications from Latin America and the Caribbean in this database shows a constant trend, and does not reflect the strong fluctuations registered on the region's financial resource indicators.

**Graph 9. Publications in the Science Citation Index (Base 1994=100)**

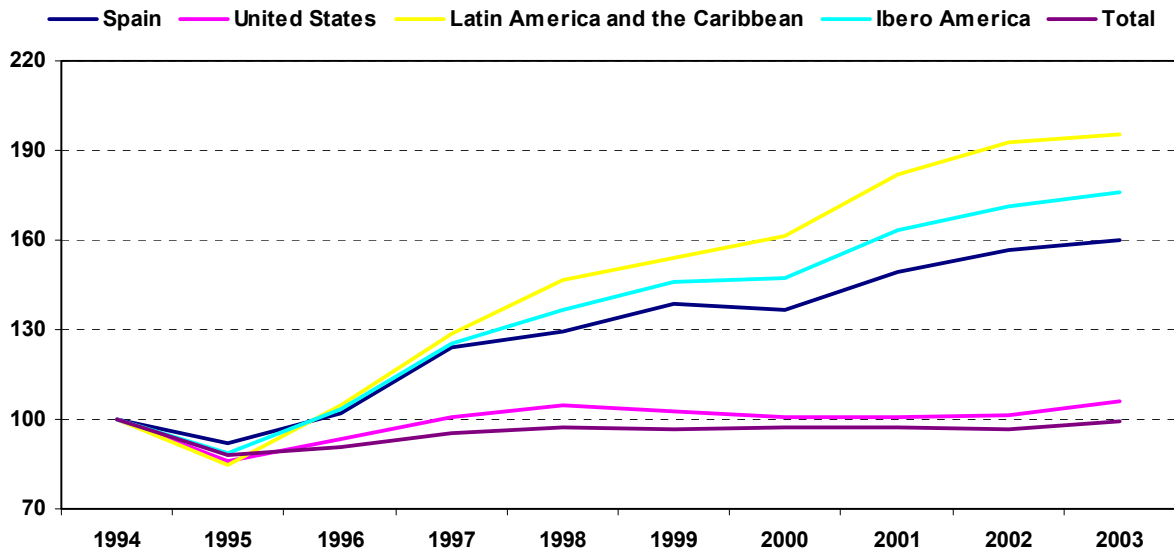


Graph by Centro REDES

A similar trend can be observed in publications registered by the PASCAL base, produced by the French *Institut de l'Information Scientifique et Technique* (INIST), like the SCI a multidisciplinary body. Leaving aside the decrease registered up to 1995, when the output of authors in Latin American and Caribbean countries coincided with an equally marked fall in the number of indexed registers in this source, the region witnessed a 95% increase between 1994 and 2003, while the total remained stable.

In the PASCAL database, however, it is possible to see a deceleration in the increase in regional publications in the last year. This phenomenon may reflect the decrease registered in regional R&D investment between 2000 and 2002. In this case the difficulties faced by the regional scientific system in these years would also be noticeable in scientific production registers. This phenomenon is clearest in Argentina, the main country affected by the crisis, with a drop in 200 registers compared to the previous year. Brazil also showed decelerated growth, while Mexico stayed practically the same as the previous year.

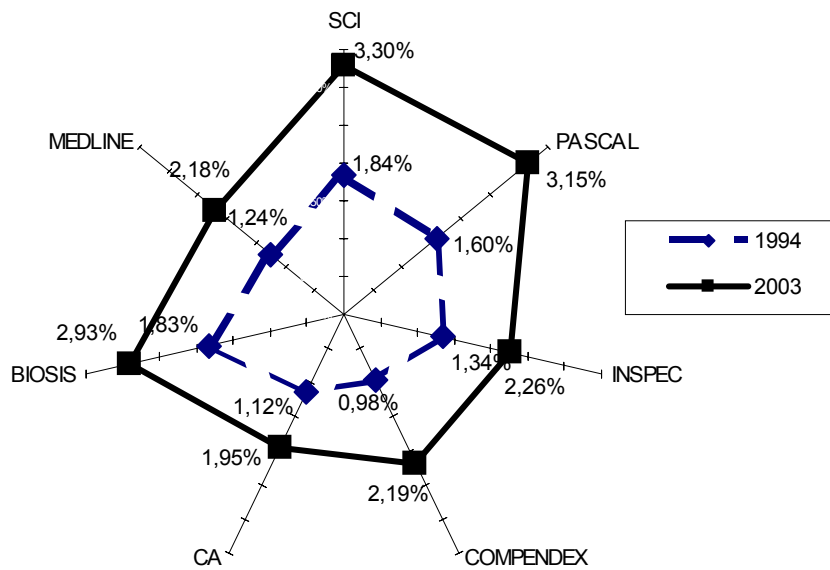
**Graph 10. Publications in PASCAL (base 1994 = 100)**



Graph by Centro REDES

The participation of Latin American and Caribbean countries increased significantly over the period in question, more than doubling their percentage in SCI and PASCAL. Although this represents a low fraction overall, it is necessary to consider that the number of researchers in relation to the world total is lower and the percentage is greater than Latin American countries' relative participation in world R&D investment. The figures show that in the SCI, the 14,692 articles in 1994 made up 1.84% of the total for that year, but a decade later the 35,299 registers in the same source were equivalent to 3.3%.

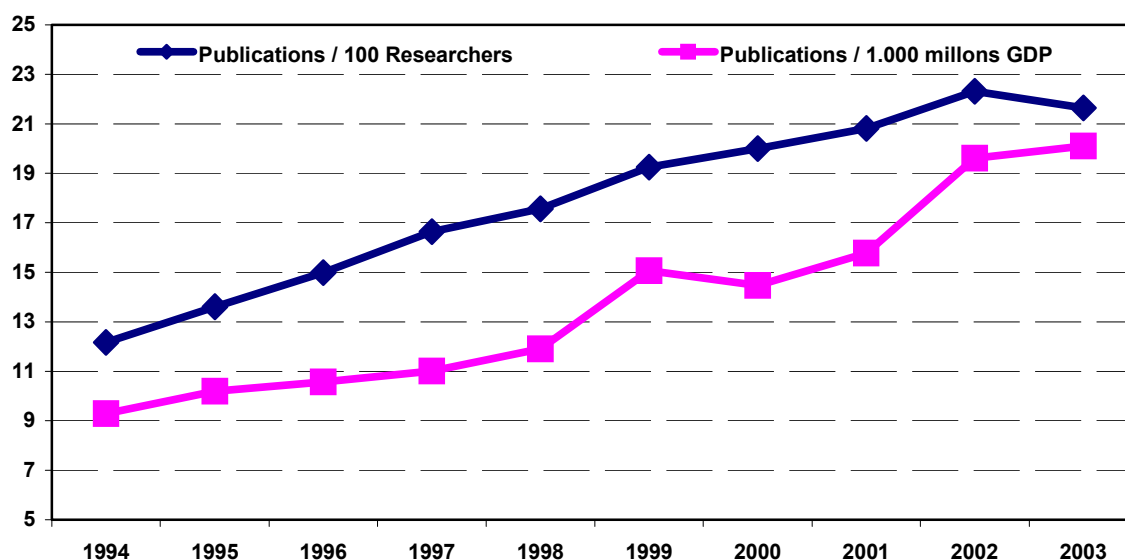
**Graph 11. Latin American and Caribbean percentage participation in international databases, 1994 and 2003.**



Graph by Centro REDES

This growth in regional participation in international bibliographic databases is corroborated by specialised databases in specific disciplines. The databases presented in Graph 11 show an average growth of 120%, with the greatest increase of 181% over the period in the engineering database COMPENDEX. The lowest growth over the period is registered in the health sciences database MEDLINE with an increase of 89%, increasing from 1.24% to 2.18%.

**Graph 12. Publications in SCI by every 100 researchers and every \$1 billion GDP in Latin America and the Caribbean**



Graph by Centro REDES

In short, over the period in question a notable increase was registered in the productivity of Latin American science, measured according to its presence in international bibliographic databases, although regional participation in the world total of researchers and R&D investment did not vary greatly over the same period. Graph 12 shows how the number of publications both in relation to researchers and in relation to investment increased by over 100%.

This phenomenon appears to be related to the growing internationalisation of research, particularly the increase in joint publications by researchers from different countries, which has brought about a greater presence of Latin American authors in international journals. It is also possible to relate this phenomenon with the Latin American science issue agenda, which has been oriented mostly towards study issues and problems relating to the science mainstream.

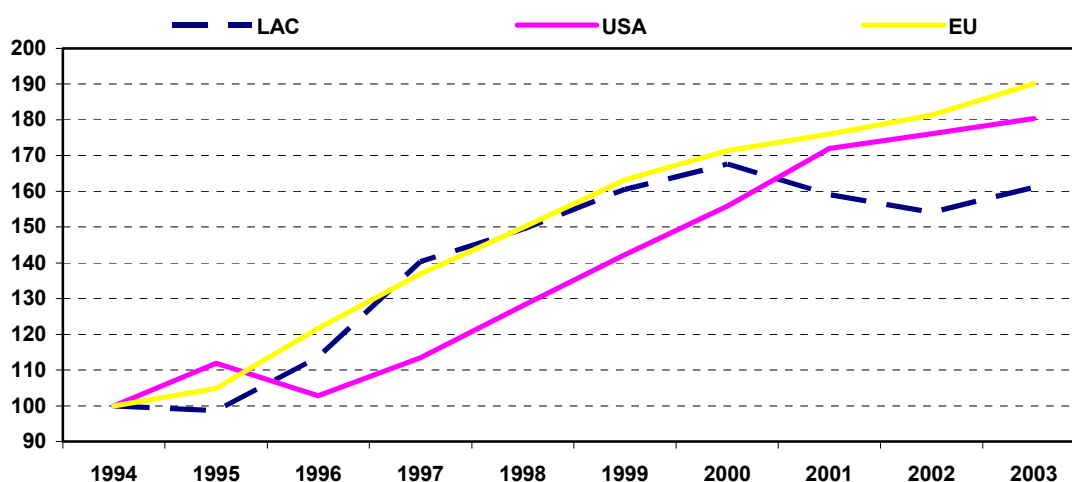
## 3.2 Patents

Latin America and the Caribbean have on the whole seen an upward trend in the number of patent applications, although in 1995 slightly fewer were registered than in the previous year, as can be seen in Graph 13. This was due to Mexico's decrease on the indicator, which could not be compensated by other countries' results. At the start of the new millennium there was a marked decrease, due to the effect of the above-mentioned crises on this indicator's performance.

A comparison of the development of Latin America and the Caribbean with the EU and the USA shows a higher growth rate for the former, which can be accounted for by a relatively

low starting point and specifically the opening up of the Brazilian and Argentinian economies over the last decade of the 20<sup>th</sup> century.

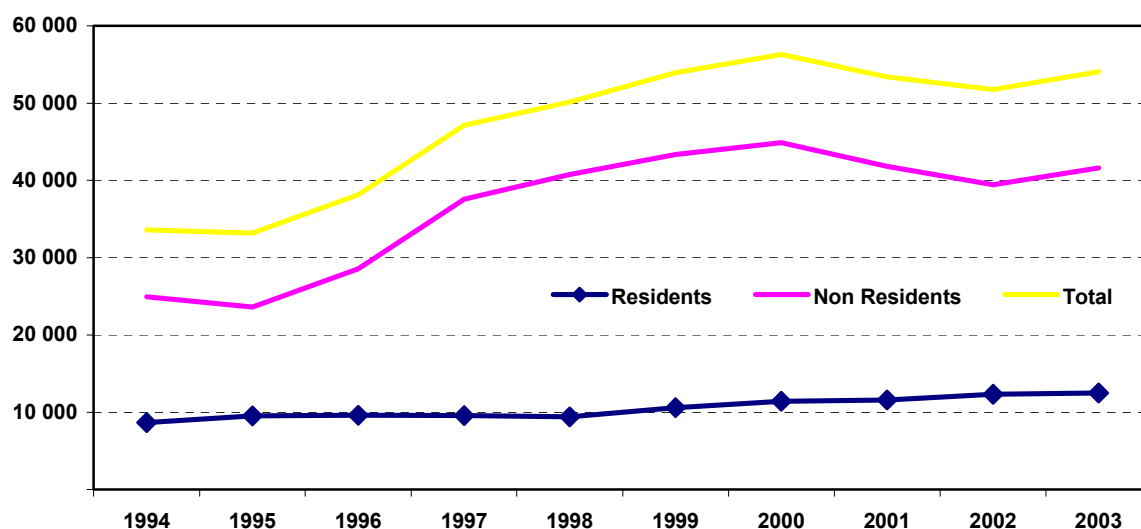
**Graph 13. Growth of patent applications, by geographic block (1994=100)**



Graph by Centro REDES. EU data for 2001, 2002 and 2003 are estimated.

It is noticeable in analysing the total number of patent applications in Latin America and the Caribbean during this period that the average percentage of patent applications made by residents remained almost constant at 25% of the total, which constitutes a very high rate of dependence on patent applications from non-residents. As a result, the total curve of patents is markedly influenced by the previous curve (Graph 14).

**Graph 14. Patent applications in Latin America and the Caribbean**

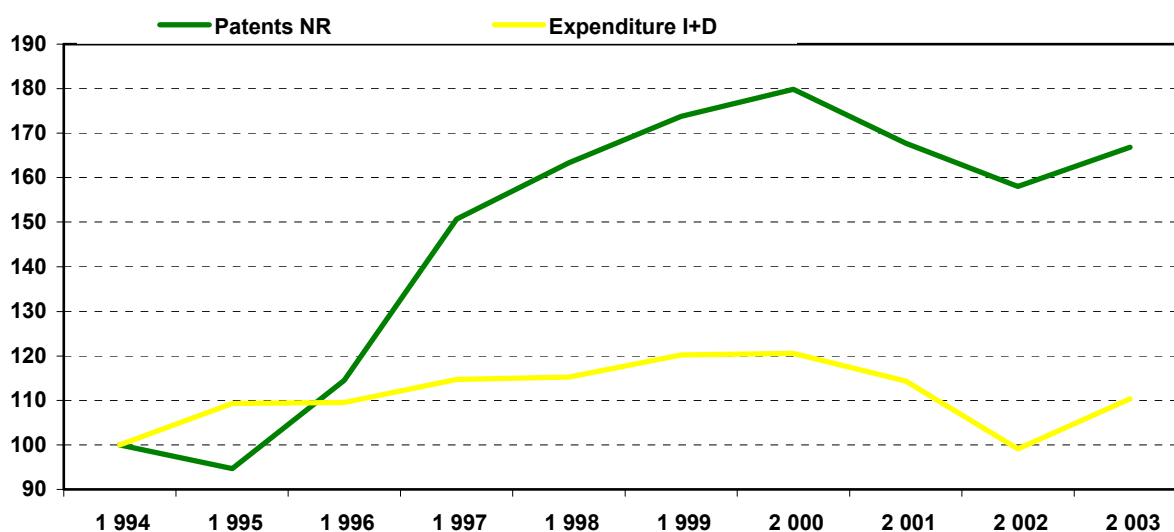


Graph by Centro REDES

It is possible to appreciate similar growth between patent applications by non-residents and investment in R&D in the countries of the region (Graph 15). The growth in patent applications from non-residents was influenced by the crises in Latin American economies, most likely because the climate of uncertainty to some extent discouraged foreign companies from applying for patents. This is not the case in applications made by residents, whose stability in the registers appears to show that they were able to remain

unaffected by the economic crises and even showed a slight upward trend during the period, as can be seen in the previous graph.

**Graph 15. Relation between patent applications by non-residents and R&D investment (1994=100)**



Graph by Centro REDES

## 4. Final considerations

The data presented here offer an overview of the growth in scientific and technological activity in Latin America and the Caribbean over the last decade. One of the main conclusions that can be drawn is that it should be a strategic priority for the region to strengthen scientific and technological capacity as a tool for development. To do so a baseline of both financial and human resources is necessary. The values of 1% of GDP invested in R&D and of three researchers for every thousand of the labour force are internationally considered requisites for sustainable scientific and technological development in emerging countries.

Over the last decade the countries of Latin America and the Caribbean have made progress towards these goals. However, the vast majority of these are still very far from achieving the requisite values. The economic fluctuations affecting the region over this period had in all cases a negative effect on R&D investment levels. Beyond economic limitations, there does not appear to be a sustained policy to guarantee the continuity of scientific and technological activities and soften the blow of economic fluctuations. It is necessary for these countries to put into practice medium and long-term policies in the knowledge that growth in science and technology will become a development tool and contribute to overcoming the cyclical crises faced in the region.

Although the increase in R&D investment is a necessary condition, in itself is not enough to consolidate scientific capacity in Latin American countries. The availability of a sufficient number of highly-trained researchers, technologists and professionals is also a critical challenge. A level of R&D investment of 1% of GDP requires a like correlation in the field of human resources. It is therefore fundamental that science and technology policies improve higher, further and postgraduate education to a suitable level of excellence. In this respect it is important to consider the processes of migration affecting the R&D human resources stock in Latin American and Caribbean countries. A desirable option would be the creation

of more opportunities for insertion in national scientific and technological systems for new graduates and the strengthening of ties with those who have migrated.

In the scientific production area a strong increase was observed in regional levels, with Latin America and the Caribbean the block with the greatest growth in various bibliographical databases in the last ten years. These indicators show the quality of regional research, which has managed to find a place in international knowledge production networks in spite of limited resources. However, these indicators do not necessarily show the connection between scientific production and the social and economic demands of each country. There appears to be a bottleneck in the application of knowledge, which is also connected to a lack of innovation in most Latin American companies.

Overcoming the multiple problems recurrently facing science and technology in Latin America and the Caribbean requires medium and long-term policies to integrate systems for producing and applying knowledge that guarantee the continuity of a country's efforts and stimulate greater involvement from the production sector in these activities. This would contribute to not just the State but society as a whole working to drive this process, with a wide range of actors and relationships collaborating together. This would naturally include a public opinion informed of the potential of scientific and technological knowledge and the risks that this can entail.

Lastly, the strengthening of regional cooperation and the integration of efforts in science and technology is an unavoidable challenge since no country in the region –not even Brazil– has sufficient critical mass in various strategic areas.