Using Knowledge for Development
THE BRAZILIAN EXPERIENCE

This book looks at Brazil’s recent experience in using knowledge for development. It examines the major barriers confronting the country in its transition towards a knowledge-based economy, and presents elements of a viable strategy which would allow it to step confidently into the future. However, while Brazil has tremendous strengths and the ability to take immense strides forward in the medium term, there are formidable challenges which need to be faced. The country continues to be plagued by a number of weaknesses, hampering its potential for economic, technological and social development.

The report argues that Brazil needs to put in place a more comprehensive policy framework for the broad diffusion of knowledge. The Brazilian innovation system and the productivity of research need to be strengthened, while the policy frameworks which are key for disseminating the outcomes of research throughout society as a whole need reinforcing. These reforms should be carried out in such a way that they help build effective links to industrial activity and lead to the creation of marketable products.

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Using Knowledge for Development

THE BRAZILIAN EXPERIENCE
Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

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– to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and

– to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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FOREWORD

The role of knowledge in economic performance, and the associated issues it raises for individuals, organisations and policy makers, has become a topic of major significance for the OECD in recent years. Reports such as *The New Economy: Beyond the Hype*, and the *OECD Science, Technology and Industry Scoreboard*, as well as the special edition of the *OECD Science, Technology and Industry Outlook* on *Drivers of Growth: Information Technology, Innovation and Entrepreneurship*, testify to the high priority given to this new phenomenon. Countries are actively benchmarking their performances in various areas, as well as engaging in negotiations which should result in more consistent and coherent policy frameworks, e.g. in areas such as cryptography, and privacy and consumer protection in electronic commerce.

Although we have made enormous progress in our ability to access and make use of information, it was never argued that this new paradigm would lead to generally higher growth rates or would put an end to the business cycle as we know it. Rather, the growing role of knowledge brings new opportunities, but also challenges to exploit this new potential. The importance of knowledge is not limited to the OECD countries and it is now well understood that knowledge is a key to development in all regions of the world. This was the main message of the 1999/2000 World Bank report, *Knowledge for Development*. Since then, the World Bank and the OECD have made the knowledge economy one of their areas of co-operation, and this effort has given rise to a number of policy forums, to the development of new ideas and perspectives, and to reports such as the 2000 joint publication on *Korea and the Knowledge-Based Economy: Making the Transition*.

In an unprecedented Policy Forum hosted by the British Council, on “Using Knowledge for Development” (19-25 March 2001, Wilton Park), Brazil, China and India participated with delegations representing a broad spectrum of key players – ministries, authorities and organisations – whose actions will significantly affect how knowledge is developed and used in their respective countries. That Forum offered a prime opportunity for creative reflection on improving horizontal and international co-operation in the area. As part of the
preparations for the meeting, Mr. Claudio R. Frischtak was asked to provide a report on the Brazilian experience with using knowledge for development.

This report presents the results of that work, continued by Mr. Frischtak after the meeting in Wilton Park. It examines Brazil’s position in regard to the knowledge-based economy from a number of perspectives, points to strengths as well as weaknesses, and seeks to identify key avenues forward. The report argues that Brazil has a tremendous potential to successfully meet the challenge of the knowledge-based economy, but highlights the fact that the country faces formidable challenges: the innovation system and the productivity of research need to be strengthened, with improved education and human resource management remaining a critical issue.

The OECD wishes to thank the World Bank Institute and the British Council for co-operation in regard to the meeting in Wilton Park. The Organisation would also like to thank Mr. Carl Dahlman at the World Bank, as well as various colleagues at the OECD for their input and comments on this report.

Thomas Andersson  
Deputy Director, Science, Technology and Industry  
and OECD co-ordinator of the co-operation with the World Bank Institute on Building Knowledge-based Economies.
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I. INTRODUCTION

Brazil’s potential in the global knowledge economy remains largely unrealised. Its competitive position is weak and the country is definitely on the fragile side of the knowledge divide. This assessment may at first seem paradoxical, in view of the size, complexity and dynamism of the economy, as well as its long-standing and significant commitment to science and technology over the last 50 years. The latter has translated into graduate programmes in science and engineering, research institutions and a pool of specialised human capital – a large and differentiated system by the standards of the majority of industrialising countries. Moreover, what initially started as uncoordinated initiatives by individual states (as in the case of Sao Paulo and the large number of state-funded high-level research and teaching units), branches of government (exemplified by continued investments in the military engineering schools and related research programmes, for instance), or ad hoc sectoral priorities (such as the nuclear programme of the 1970s), have progressively been steered towards greater consistency of objectives and budgetary efficiency under a national S&T (science and technology) policy.

This does not mean that the Ministry of Science and Technology is sufficiently powerful to unify and single-command different programmes or that the states have given up their autonomy in S&T matters. In fact, under the 1988 Constitution, the position of the states was strengthened in the context of a generalised sentiment that power and resources were excessively centralised. However, increasingly tight budget constraints and a measure of continuity in key programmes, including federal financing of research, combined with a growing perception that the challenge posed by the concentration of S&T resources and results on a world scale cannot be addressed in a fragmented way, has impelled agents to attempt to co-ordinate their efforts and follow, or at least pay closer attention to, nationally set objectives and priorities.
The objective of this report is to examine the Brazilian experience in using knowledge for development, establish the major barriers facing the country in its transition to a knowledge-based economy and suggest elements of a viable country strategy. Despite over half a century of continuous commitment to S&T, the country has yet to accumulate sufficient knowledge capital to cross the divide and improve its position in the international division of labour. As is argued in Section II, the country remains preponderantly an exporter of natural resource-based products, with low to moderate technological intensity and demand growth. These products require the application of knowledge by firms, if only to maintain the country’s position in international markets; but rewards have been increasingly concentrated among those firms which apply and extend knowledge to the value-critical segments of the economic transformation chain. It is the pervasiveness and depth of knowledge which constitutes the basis for countries and firms to reposition themselves and capture those rewards.

Section III discusses the sense in which knowledge in Brazil is neither pervasive nor sufficiently deep. The spread of knowledge is limited by access to information, low levels of education and the fact that few firms function effectively as carriers of knowledge. Thus, aggregating leading-edge competences poses a double challenge:

- **First**, to strengthen the country’s innovation system and improve the productivity of research, having for reference frontier work being done within the country.
- **Second**, to disseminate research results to society at large by establishing effective links with industry and ensuring that results are turned into commercially viable products.

Section IV identifies elements of a national strategy focused on the accumulation and use of knowledge. This calls for: substantially broadening access to information; undertaking massive investments in education; fostering improved connections between local players and high-performance markets, while supporting entrepreneurship for the knowledge era in the context of an entry-promoting, stable, growth-oriented and competitive economy. Finally, adding to leading-edge country competences involves reorganising the institutional research system, (re)defining priority areas, attracting high-level human resources, and making more effective use of patents and other intellectual property right devices to reward researchers, while putting in place advanced infrastructure. Translating frontier research results into commercial applications supposes a multi-pronged strategy based on: promoting science-based first movers within pre-defined sectoral programmes and innovation
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systems or networks; stimulating expanded R&D efforts among a larger number of local firms; and attracting R&D and other advanced facilities from newly targeted or second-generation foreign firms on the basis of ongoing attempts to decentralise some of the high-end, expensive corporate functions as competition intensifies on a world scale. Section V concludes.

The main message of the report is that Brazil stands at the threshold of the knowledge divide. A confluence of forces may have finally brought the country to a position where just one more push – a massive effort in education and access to information, in the context of an entrepreneurial, flexible and change-oriented society supported by a new growth-enhancing macroeconomic regime – could allow it to reap the gains from investments and long-term commitment to S&T. Ultimately, the foundations for sustainable development will depend on projecting a mid- to long-term vision for the economy, based on the production and use of knowledge, establishing adequate strategies and policies, and mobilising society around the goal of knowledge for all.
II. BRAZIL IN THE GLOBAL KNOWLEDGE ECONOMY

This section discusses Brazil’s insertion in the international economy and shows that for the last 20 or so years only limited progress has been made in terms of strengthening the country’s position in global trade, despite the gains that have been made by industrial products in the composition of exports, and a growing – albeit slowly – knowledge-intensity of output. The country’s efforts have sufficed to avoid a more serious deterioration, but gaining market shares and improving the country’s competitive position in a significant way calls for knowledge to be localised and for firms to concentrate their efforts on value-enhancing activities for high-growth markets.

The country’s competitive position

An initial assessment of Brazil’s competitive standing in international markets as reflected in world export market shares reveals a slightly declining position over the 1980-96 period, following an initial recovery at the beginning of the 1980s, steep losses in the second half of that decade and quasi-stagnation in the 1990s, both overall and for industrialised products (Table 1). The contraction in export market share has affected both basic and industrialised products, with some significant exceptions (mining among the basic products, and most intermediate commodities among the industrialised ones). In this process, Brazil has radically shifted its export composition away from basic products (which in 1980 represented 41.3% of total exports, compared to 25.9% in 1996) towards industrialised goods, and consistent with world trends (although the latter were even more accentuated, with shares of basic commodities falling from 8.6% to 5.1% over the period, so that by 1996, industrialised goods made up close to 95% of world exports).
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Table 1. Brazil’s share of world markets, 1980-96

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>6.1</td>
<td>6.9</td>
<td>5.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Industrialised</td>
<td>0.81</td>
<td>1.21</td>
<td>0.80</td>
<td>0.79</td>
</tr>
<tr>
<td>Total</td>
<td>1.3</td>
<td>1.7</td>
<td>1.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Horta and Souza (2000).

These numbers encapsulate the paradox of the Brazilian economy: large, relatively dynamic and with an enormous latent entrepreneurial drive, but declining until recently in the global marketplace. Within a weakened competitive standing, a more detailed look at the country’s balance of trade statistics and revealed comparative advantage (RCA) data shows strengths in natural resource-based products, and deficiencies in the more knowledge-demanding sectors, with the single, more recent exception of transport equipment (Table 2).¹

Table 2. Competitive standing of major economic sectors

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agribusiness (9.9)</td>
<td>Chem. complex (-6.0)</td>
<td>Transport equipment (2.8); 0.895</td>
</tr>
<tr>
<td>Food 3.354</td>
<td>Chemicals 0.776</td>
<td></td>
</tr>
<tr>
<td>Meats 1.950</td>
<td>Petrochemicals 0.735</td>
<td></td>
</tr>
<tr>
<td>Ore and metals (6.4)</td>
<td>Pharmaceuticals 0.549</td>
<td></td>
</tr>
<tr>
<td>Steel 4.460</td>
<td>Electro-electronics (-7.5); 0.257</td>
<td></td>
</tr>
<tr>
<td>Non-ferrous metals 1.758</td>
<td>Mechanical equipment (-4.2); 0.728</td>
<td></td>
</tr>
<tr>
<td>Pulp and paper (1.5); 1.969</td>
<td>Instruments (-1.3); na</td>
<td></td>
</tr>
<tr>
<td>Leather and footwear (2.0); n.a.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


The country demonstrates strong competitive advantage in Group I goods of low to intermediate technological intensity, as evidenced by trade surpluses and a disproportionate share of such products in Brazilian exports relative to the share of these goods in world trade. Generally, these are products with an “inherited” comparative advantage. An abundance of natural resources and substantial investments (not only in capital-intensive intermediates such as...
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steel, pulp and paper, aluminium, but also along agribusiness production chains – soyabees, meat), provided the basis for the country’s standing. Nonetheless, it is worth noting that even in these sectors, the country lost market share over the 1980-96 period, as in the case of agricultural commodities and foodstuffs (Table 3).

Table 3. World market shares of Brazilian exports: major product groups, 1980 and 1996

<table>
<thead>
<tr>
<th>Product Group</th>
<th>1980</th>
<th>1996</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic products</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture and livestock</td>
<td>6.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Mining</td>
<td>6.1</td>
<td>8.3</td>
</tr>
<tr>
<td>Soyabees and related products</td>
<td>5.9</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>Industrial products</strong></td>
<td>0.81</td>
<td>0.79</td>
</tr>
<tr>
<td>Non-metallic minerals</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Steel</td>
<td>1.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Non-ferrous metal</td>
<td>0.4</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Mechanical products</strong></td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Electro-electronics</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Transport material</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Wood and furniture</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Pulp and paper</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Petrochemicals</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Textiles</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Food products</td>
<td>2.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Cut and processed meats</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Other</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Horta and Souza (2000).

A second group of sectors is, to a large degree, the mirror image – the country suffers from substantial trade deficits, low RCAs and stagnant or receding market shares (with the possible exception of chemicals/petrochemicals, but including pharmaceuticals and fine chemicals). Within that group, the electro-electronics complex stands out through the combination of extremely low RCAs, significant market share losses and
sectoral trade deficit. Moreover, while the largest gain in the composition of world exports of industrial goods in 1980-96 was achieved by electro-electronics (90%), followed by pharmaceuticals (33.3%), textiles (20.8%) and transport equipment (10.5%), Brazil experienced a contraction in the relative composition of its exports in three of these segments, namely electro-electronics (-16.9%), textiles (-10.6%) and transport equipment (-4.7%). Thus, on a net basis, the losses in electronics were of a different order of magnitude, and were ultimately driven by weakness in design and manufacture of components (which in 2000 suffered a trade deficit of USD 5.1 billion), and other technology-intensive segments, including industrial automation and computer equipment (Table 4).

Table 4. Exports, imports and balance of trade of electro-electronics, 2000

<table>
<thead>
<tr>
<th>Product group</th>
<th>Exports USD million</th>
<th>Imports USD million</th>
<th>Trade balance USD million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components</td>
<td>1 546 (23)</td>
<td>6 678 (38)</td>
<td>-5 132 (44)</td>
</tr>
<tr>
<td>Telecommunications equipment</td>
<td>1 030 (170)</td>
<td>1 428 (10)</td>
<td>-468 (-49)</td>
</tr>
<tr>
<td>Computers, parts</td>
<td>359 (11)</td>
<td>1 056 (24)</td>
<td>-697 (12)</td>
</tr>
<tr>
<td>Electric material</td>
<td>136 (19)</td>
<td>617 (23)</td>
<td>-481 (24)</td>
</tr>
<tr>
<td>Industrial equipment</td>
<td>205 (6)</td>
<td>637 (-28)</td>
<td>-432 (-37)</td>
</tr>
<tr>
<td>Industrial autom.</td>
<td>64 (-9)</td>
<td>802 (0)</td>
<td>-738 (1)</td>
</tr>
<tr>
<td>Gen., trans, dist.</td>
<td>190 (19)</td>
<td>206 (-35)</td>
<td>-16 (-90)</td>
</tr>
<tr>
<td>Audio, video</td>
<td>786 (17)</td>
<td>354 (-6)</td>
<td>432 (-47)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Numbers in parentheses are 2000/1999 growth rates.

Among those high-growth product markets in which Brazil’s position deteriorated, recent investment and export dynamics suggest a reversal for transport equipment, which constitutes in this perspective a group on its own. Starting in the late 1990s, this group of industries adopted aggressive investment behaviour with substantial capacity growth, building on a relatively long track record in domestic markets or, in the case of aircraft, recovering partly through successful privatisation and a key position in the world commuter market. Be that as it may, activities clustered around transport equipment are arguably the only products in the moderate-to-high- or high-intensity technology categories in which the country has attained significant competitive gains in the last three or four years. This has important implications for the balance of trade.
More recently, there has been a surge in exports of telecommunications equipment (Table 4). Capacity has expanded in reaction to a large and fast-growing market as privatised telecommunication companies scramble to attain the coverage targets imposed by the regulatory agency, and investment incentive and business facilitation programmes (and a bit of jawboning from government, in view of an explosive sectoral trade deficit). To a lesser degree, exports of most other segments of electro-electronics also grew in 2000, partly as a result of the 1999 devaluation of the real. On balance, however, Brazil’s competitive position remains feeble for most high-technology and medium-technology products. The technology content of exports is low by world standards, although rising (Table 5).

Table 5. **Technology content of Brazilian and world exports**

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Middle-high</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil 1991</td>
<td>4</td>
<td>13</td>
<td>83</td>
</tr>
<tr>
<td>1998</td>
<td>5</td>
<td>19</td>
<td>76</td>
</tr>
<tr>
<td>World 1991</td>
<td>13</td>
<td>23</td>
<td>64</td>
</tr>
<tr>
<td>1998</td>
<td>18</td>
<td>25</td>
<td>57</td>
</tr>
</tbody>
</table>

**Source:** IEDI (2000).

**The knowledge divide and Brazil’s role in the international division of labour**

Despite substantial comparative advantage in certain sectors and product groups, Brazil’s fragile standing in international markets may be regarded as an outcome of a lack of competitive strength across the board. The so-called “Brazil cost”, imposed on producers by tax, financial, regulatory, infrastructural and other constraints, penalises domestic production and acts as a disincentive to exporters. The removal of this “wedge” would considerably improve the country’s competitive standing, particularly in products characterised by thin profit margins and intense competition.

However, such a measure would in all likelihood not be sufficient to reposition the country in international markets. The critical issue associated with the current pattern of Brazil’s role in the international division of labour is that Brazil preponderantly exports products which:
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- Operate in cyclical, unstable, mature and low-growth markets in which real prices are falling over time.
- Are situated at the “base” of the value-added chain, with the more complex and knowledge-demanding functions being performed outside the national borders.

Although the move towards markets characterised by higher growth and less instability implies shifting output and exports towards higher technology intensity, the most dynamic products are generally situated in the mid-high- to high-technology categories. This will not suffice to ensure that the process of creating value will follow on from the production of such goods. The reason for this is that, increasingly, value added involves the addition of knowledge. In Brazil, knowledge remains insufficiently diffused throughout the economy.

For a country to capture a greater share of value added, a higher proportion of the critical, highly knowledge-intensive stages of the production process (e.g. R&D, final processing, marketing and distribution) or essential corporate activities (such as those requiring command, control and communications capabilities related to the integration of market processes and agents) need to be performed domestically. The extent of knowledge localisation is at least as important as manufacturing localisation in boosting local value added. To the extent that companies decentralise production but retain key knowledge-intensive activities in their home countries, product-centred measures of technological content (such as the technology content of output or exports) become less relevant indicators of a country’s competitive position and role in the international division of labour.

While efficiently producing agricultural commodities, manufacturing capital-intensive intermediate goods and assembling technology-intensive products are valuable economic activities (if validated by markets), their economic importance tends to recede compared to more knowledge-intensive activities. Creating, developing, engineering, marketing and distributing (trading) goods and services – and integrating all those activities with production and into a coherent whole – tend to generate greater economic returns. In this sense, local economic welfare in a global knowledge economy is increasingly determined by companies’ ability to deploy knowledge-intensive activities in a particular region. This, in turn, is influenced by the availability of local knowledge resources.
Box 1. Agriculture: building comparative advantage

In agriculture, the country’s potential – as reflected in trade and comparative advantage statistics, as well as by large gains in output and productivity – has been realised at least in part through research efforts spearheaded by Embrapa (Empresa Brasileira de Pesquisa Agropecuária) in a wide range of crops and cultures. Embrapa’s expenditures grew substantially in 1994-96 before stabilising at around BRL 550 million, although the company suffered a sharp drop in dollar terms with the January 1999 devaluation. However, it is estimated that USD 304 million (2000 budget, at an average USD/BRL exchange rate of 1.85) would “buy” 2-3 times as much research in Brazil as in advanced economies on a purchasing power parity basis (assuming approximately equal productivity of researchers and similar costs of equipment and material). A relatively stable budget, a result-oriented management of a team of 2 100 researchers (955 PhDs and 1 018 MScs), and a well-developed research infrastructure underpin Embrapa’s goal to retain world leadership in the development of tropical agriculture. As in the past, the emphasis is on traditional genetic research (which currently absorbs 30%-35% of its investments in 128 projects), although Embrapa has allocated approximately 10% of its resources to work on genetically modified organisms, applied molecular markers, genetic prospection, biofactories, among others.

The country’s commitment to agricultural research has been significant and has produced striking results, with 396 new strains brought to the market over 1975-2000, accounting in 1999 for 53.5% of planted area in rice, 15.6% in corn, 53.2% in soya, 24.3% in wheat and 89.7% in beans. Embrapa’s success in the diffusion of its new varieties and hybrids goes a long way to explaining rising agricultural productivity. In grains, for example, over the last 30 years the source of output growth has shifted from the goal of bringing new areas into production to that of increasing productivity on existing land: in 1971-80, the average annual growth rate of output reached 5.62%, of which productivity growth explained 1.35% (or 24%); in 1981-90, for an average annual production growth of 2.18%, productivity growth was responsible for 1.70% (or 78%); and in 1991-98, while production increased by 4.04% annually, crop area shrunk at a rate of 0.21%, so that productivity gains accounted for 105% of output growth.

Despite the trade surpluses obtained in agribusiness and the revealed comparative advantage in foodstuffs in general, the country’s share of world markets in agriculture and livestock decreased across the board in the 1980-96 period, in terms of both in natura and processed goods (Tables 2 and 3). Of course, the relationship between research efforts and international competitiveness (as evidenced by export market shares) is not linear. This is particularly the case in agriculture due to its extreme diversity and long-term nature (which is not always directed at tradeable commodities or exportables), the absorption capacity of the domestic market, leveraged by significant price reductions resulting from productivity gains, and barriers to trade in agricultural goods imposed by the developed economies. Moreover, were it not for the localisation of agricultural research, the observed gains in terms of the expansion of cultivable land, higher productivity, the development of large agribusiness chains (particularly in grains and meat) and improved nutrition, would not have occurred on the same scale.
Box 1. Agriculture: building comparative advantage (cont’d)

At the same time, the difficulties involved in moving up the value chain, further increasing the extent of process and control of logistics and distribution channels, and reaching end-consumers in international markets, have led in the last few years to most gains being transferred away from the producing countries to those which house the companies which control these activities [as an example, Germany, the Netherlands and other countries have become major exporters of highly processed (semi-) tropical agricultural commodities]. Thus, it is not enough to localise knowledge (at the base of the chain), it is important to have in place agents capable of extending its application to the higher value segments, in order to avoid the risk that productivity gains in the context of intensifying competition may lead to a drop in commodity prices and thereby further impoverish the producer countries.


** Ibid, p. 9. For a detailed discussion of Embrapa’s contribution to agricultural productivity, see Bonelli and Pessôa (1998).

It is arguable that relatively few firms in Brazil are able to project themselves competitively in the more income-elastic, higher-growth international markets, while controlling or dominating the knowledge-intensive activities which will ultimately sustain their operations. This is not to say that knowledge is being applied to firms’ operations in only a very limited way. There have been substantial efforts to help producers match competition and retain – with differing degrees of success – their positions on world markets (Boxes 1 and 2).
The Brazilian Experience

Box 2. Forestry: moving up the value chain

The case of forestry is as instructive as that of agriculture. The localisation of knowledge has undoubtedly played a key role in developments in the forestry sector, with major Brazilian pulp and paper producers successfully raising the productivity of pulp-making eucalyptus through genetic and other research. Aracruz, for example, has 60 people dedicated to its R&D activities, for which it has budgeted USD 4.5 million for 2001 (approximately 0.6% of its sales).* CVRD spent in the order of USD 10 million on its Celmar project in search for adequate eucalyptus varieties and cloning.** Yet, while Brazil is a major exporter of pulp and (less expensive) paper, it is a marginal player in the publishing and printing industry (and a net importer of its products). Publishing and printing is a sector in which firms are less subject to steep price-output cycles, and are better able to defend their margins, introduce differentiated products and cater to more income-elastic segments of demand.

* Source: Aracruz Celulose (2000).
** According to CVRD’s department of pulp and paper.

In fact, relatively few Brazilian companies have entered the international arena on the basis of the application and extension of knowledge to value-critical segments of the economic chain which call for an ability to innovate, introduce new products, processes and management practices, differentiate and “brand” goods, control logistics and distribution channels, while instilling loyalty among buyers. Even more importantly, many, if not most, companies – even those which perform R&D&E – are neither first movers nor quick to follow, in the sense of creating and occupying novel, dynamic markets. There are, however, some important and instructive exceptions (Box 3).
Box 3. Moving into niche markets

Embraer has undertaken substantial R,D&E efforts which have led to the creation of a new market for aircraft specifically designed for the commuter market. This has entailed the introduction of new production systems and a customer-oriented approach to product development, filling a large, untapped demand for jet-powered, more comfortable (and faster) commuter travel. Furthermore, the company has built up a reputation based on its close relations with and support for its clients worldwide. As of end-December 2000, Embraer had USD 24 billion in orders, of which 95% was destined for the export market (the company exported USD 2.7 billion in 2000, a 59% increase over the previous year).*

Although Embraer is exceptional by any standards (in terms of innovativeness, productivity, product excellency on price-performance criteria, customer support, etc.), a number of other companies have also been very successful in controlling their value-critical functions, diversifying markets, differentiating and creating new products on the basis of their knowledge assets. For instance, Usiminas and Siderurgica Gerdau, both major steel-makers, have been seeking ways to improve productivity and quality. Usiminas is a precursor in successful capital-stretching attempts, as well as conventional Ebitda margins, in line with the rest of the industry. In the last few years, these firms have attempted to differentiate what is essentially a commodity by providing value-added services to clients while shifting the composition of output to higher-priced goods (such as coated and laser-cut products). This has been achieved through two completely different strategies.

Based on a strong management team and mini-mill/EAF expertise, Gerdau has sought domestic expansion while becoming the country’s first steel-maker with global ambitions on the basis of significant acquisitions in Latin America, Canada and the United States.

Usiminas, on the other hand, has opted to use its outstanding engineering capabilities to supply steel-making technology, with approximately 50% of its contracts signed with foreign producers (in Chile, Venezuela and Argentina, among others), leading to USD 18 million in earnings in 2000, a 28.5% increase over 1999.**

* See Embraer (2000), for a detailed description of the company’s activities and financial situation.

** See Gazeta Mercantil, 12 December 2000. A similar move to enter the USD 600 million energy projects consulting market has recently been made by a number of local energy companies, among them the State of Minas Gerais’ integrated electricity utility Cemig, which sold USD 15 million in 2000 to clients in Latin America, and Braspower (a joint public-private venture with Copel, the State of Parana’s utility, which will be planning the construction of the Shuibuya dam in China, the highest in the world, at 233 meters, among other projects). Ibid.
A number of other examples could be used to illustrate companies’ attempts to dominate the value-critical functions in the economic transformation chain, whether in terms of exerting full control over production technologies (as is the case for Ultra Group’s Oxiteno, which over the years developed petrochemical technologies for the production of ethanolamines, a tensoactive input for the production of detergents, paints and foodstuff, including a proprietary process control hardware, allowing the company to market competitive turnkey production packages to the Iranian company Arak, an NIOC subsidiary, while tendering in Saudi Arabia and Iran), or reaching end-consumers in international markets by creating or enhancing distribution networks (as in the case of Santa Catarina state’s WEG, one of the largest manufacturers of small to middle-sized electric motors), acquiring production assets in other countries (like top bus manufacturers Marcopolo and Busscar), or attempting to build a brand name (as with Sadia, a major producer of meat/poultry and other processed foodstuffs).

In all cases where companies have attempted (often successfully) to overcome the traditional international division of labour, extending their reach into the value chain and entering markets which were formerly strongholds of advanced country firms, knowledge (and capital) has been the critical element. Overall, knowledge is scarce. In this perspective, the examples provided here, although far from unique, may still be regarded as exceptions, not so much because of a scarcity of entrepreneurs and markets, or even because of a lack of understanding of how important knowledge has become in the global economy, but because of the overall frailty of the system of production and dissemination of knowledge.

In this sense, Brazil needs to complete its transition to a knowledge-based economy. Knowledge is neither pervasive nor, with few exceptions, sufficiently deep and relatively few companies are able to break out of the mould and cross over the knowledge divide. As will be argued below, many of the preconditions exist. One major structural obstacle arises from the combination of unequal income distribution and large pockets of poverty from which the country suffers. Dramatic improvements in education and access to information, combined with effective measures to reduce poverty and improve income distribution in the medium term will be necessary to ensure that knowledge becomes a common (although not a public) good. No single piece of legislation can ensure that knowledge localisation takes place, unless it is broadly disseminated and becomes the basis for a high-productivity/high-income society, and is deep-rooted enough to lead to the continuous creation of new products/processes based on novel ideas.
III. THE PERVASIVENESS AND DEPTH OF KNOWLEDGE IN BRAZIL

There are no direct indicators to measure the spread of knowledge in Brazil. Access to information, levels of education and the extent to which firms function as effective carriers of knowledge illustrate how broadly it is disseminated in society and economy. Institutional strength in the economy as a whole, together with sectoral expertise, high-quality scientific results and the ability to turn such results into commercial applications are strongly suggestive of the depth of knowledge in a given country.

How pervasive is knowledge in Brazil?

Possibly the most synthetic (although rather roundabout) indicator of the pervasiveness of knowledge is an economy-wide productivity measure such as product or income per capita. Ultimately, it is arguable that low levels of per capita GDP denote limited and/or concentrated spread of knowledge. With a GDP per capita of USD 3,500 (after expanding by 4.2% in 2000, GDP is now estimated at BRL 1.065 trillion or USD 582 billion), Brazil may be regarded as a middle-income/productivity country, even taking into account cross-country differences in purchasing power parity.

Since it is an outlier in terms of income concentration levels (with a Gini index of 0.567 for 1999, according to IBGE), and to the extent that literacy and educational levels – as described below – are highly correlated with income, it is likely that knowledge in Brazil is poorly spread and highly concentrated – low among the majority of citizens and relatively high among an elite. Indeed, even if social status and position go some way to explaining income differences, in an increasingly competitive and socially mobile society knowledge plays a growing role in income determination.

At the same time, despite recent strides in education, easier access to information and lower entry barriers for knowledge-based firms, income concentration has yet to show significant improvements. Gini indices have
shown slight distributional gains (from 0.630 in 1989 to 0.567 a decade later), and the gap between the poorest 50 percentile of the population and the wealthiest 1% has decreased, with per capita income ratios between the two groups dropping sharply from 71.2 to 43.1 over the period. However, these trends have been largely attributed to the withdrawal of inflation tax, with the resulting rise in real incomes of the poor, and the post-stabilisation resumption of economic growth in 1994-98 (in 1999, the last year for which comparable data are available, the fall in income per capita for all groups differentially and adversely affected the upper brackets so that concentration ratios continued to fall). It can be argued that knowledge and its current pattern of dissemination contributes to increasing rather than alleviating the high levels of income concentration.

Clearly, poverty begets poverty. In Brazil, some 21 million children (35% of the child population, rising to 60% in the Northeast region) live in families with per capita monthly incomes of less than half the minimum wage – these are the people who face the greatest risk of being stranded on the wrong side of the knowledge gap. This group is responsible for the overwhelming proportion of the 8.6 million child labourers (of which 2.9 million are between 5 and 14 years of age). Low levels of education among parents (particularly mothers) – a factor which is highly correlated with low incomes – reinforce the likelihood of children having to work. Indeed, the probability of children starting to work at age 10 decreases monotonically with mother’s education: 14.3 % for mothers with no schooling; 11.9% for those with 1-3 years of education; 8.6% for those with 4-7 years; 4.16% for 8-11 years; 1.46% for 12-15 years; and 0.51% for mothers with more than 16 years schooling.

The reduction of poverty in Brazil, as is the case in many other countries, will be a product of rising incomes driven by economic growth and greater equality. Low levels and a very skewed distribution of education and information explain in large measure the difficulty of breaking the cycle of poverty and inequality among families and regions in Brazil. Cutting the Gordian knot of inequality and bringing the country closer to crossing the knowledge divide, means endowing people with the essentials of economic citizenship, above all, information and education, while linking knowledge to entrepreneurship.

Limited access to information. Informational constraints are a significant handicap for the majority of Brazilian citizens. The revolutionary nature of the Internet – and its capacity to subsume most other media – in terms of information access and exchange, as well as the far more limited informational content of the widely disseminated open TV (and radio), means that discussions
on the issue of access tend to centre on the use of Internet, since even with basic
dial-up connections, at reasonable prices, a wealth of information can be
accessed (insofar as the Internet’s ability to carry multimedia content only
comes into its own with broadband access and, for such services, it is far less
expensive to use traditional media such as TV and radios).

The Internet remains beyond the reach of most Brazilians. Although
estimates vary, partly due to definitional issues, approximately 9-10 million
people can be considered to be “connected” to the Internet, that is 54-60 people
per 1 000 population, which compares unfavourably with Mexico (95 per
1 000), Chile (156 per 1 000) or Argentina (174 per 1 000). Considering that
Brazil numbers some 129 million citizens aged 10 and above, this means that
between 7%-8% of the population has access to broad informational resources.
Ibope, a public opinion research institute which tracks Internet use, concluded
that 84% of users are in the A/B socio-economic class category (upper and
middle class), 14% in the lower middle class (class C), and only 4% in
classes D and E, which comprise the majority of the population. It is patently
clear that the potential of the Internet to address inequitable access to
information has barely begun to be exploited.

A combination of lack (or poor quality) of infrastructure, high prices for
critical services and equipment (sometimes in absolute terms, but generally
relative to families’ disposable incomes), and low education, all of which make
it cognitively difficult to use the Internet, are key restrictive factors and explain
why less than 10% of the “eligible” population is connected.

Until recently, access infrastructure in Brazil was limited and expensive.
Since 1998, with the privatisation of existing telecommunications services and
the call for tender for B-2-B mobile services, there have been major increases in
the supply of telephone lines, which reached a total of 67.5 million (fixed +
mobile) (at an average annual growth rate of 33.4% in 1995-2000), driven by an
investment-inducing regulatory system and an intensive investment programme
implemented by the telecommunication operators. Fixed line teledensity in
2000 was 23.1 lines per 100 inhabitants, approximately half the level in Spain
and one-third of that in the United States, and is expected to reach 32.6 by 2005.
Mobile service density, following a period of extremely rapid expansion, is
projected to grow from 14 to 32.6 subscribers per 100 population between 2000
and 2005 (Table 6).
Quality of service has been improving in significant ways for both fixed line and mobile telephone operators. By December 2000, most operators met the telecommunications regulatory agency (Anatel) benchmarks for being classified in the top category. This was in stark contrast to July 1998, when none of the 34 fixed line and only six of the 40 mobile operators were able to meet the targets (Table 7).

Despite major progress in telecommunications (a rapidly increasing supply of telephone lines and entry of new competitors brought about a decrease in the cost of lines and connection charges, while long-distance tariffs shrunk by 49% between 1998 and end-2000), access remains severely constrained and over-priced. This is due to a combination of limited competition in the local loop, a lack of special tariffs for Internet use (access to the Internet is metered), and expensive connections between local and international backbones. Moreover, only 164 out of more than 5,000 municipalities are able to host Internet
providers, so that in these municipalities users are forced to pay long-distance charges to reach the Internet. Equally important, with few national backbones, the connection costs to the IP network charged by the dominant provider (the privatised Embratel, which controls an estimated 70%-80% of Internet traffic) costs a multiple of equivalent services in other countries (such as the United States) where competition is more intense (Table 8).

Table 8. Product/services price comparison: Brazil vs. the United States

<table>
<thead>
<tr>
<th>Services/products</th>
<th>Brazil</th>
<th>United States</th>
<th>Difference (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed line subscription</td>
<td>10.20</td>
<td>16.00</td>
<td>-36.3</td>
</tr>
<tr>
<td>Local call cost of 20 hours of Internet access</td>
<td>13</td>
<td>0.0</td>
<td>-</td>
</tr>
<tr>
<td>Pentium 3/800 Mhz/64 mega memory</td>
<td>1 008</td>
<td>924</td>
<td>17</td>
</tr>
<tr>
<td>Printer HP deskjet 640 C</td>
<td>152</td>
<td>99</td>
<td>54</td>
</tr>
<tr>
<td>Microsoft Office 2000 standard</td>
<td>438</td>
<td>468</td>
<td>-6.4</td>
</tr>
<tr>
<td>Connection of 1 Mbps to ip</td>
<td>7 200</td>
<td>700-1 200</td>
<td>500-900</td>
</tr>
</tbody>
</table>

1. For the United States, includes all local calls; in Brazil, each additional call over a set threshold is charged, implying a significantly higher total price than that charged in the United States.
2. Prices for UUNet in the United States, and for Embratel, according to Brazilian providers (for Embratel, the price ratio is 2.5 to 3.0).

Source: Valor, 12-14 January 2001. All prices inclusive of tax.

Traditionally, equipment costs have been one of the binding constraints to Web connection. More recently, the entry of new producers (Compaq, Dell, among others), with gains in scale and productivity (and continuing competition from grey market producers/imports, which supply an estimated 50%-60% of apparent demand) has led to a drop in prices. Nonetheless, the tax burden on ICT products (which, at 41%, is considerably higher than that in other countries), the cost and availability of credit, and the low income levels of the majority of the population push down the (potential) demand curve for ICT products. As a result, the rate of PC penetration remained low in 1999, at 26.3 per 1 000 habitants.

The impact of limited access and high prices affects not only households and firms, but also educational institutions, which could play a transforming role in bringing the Information Revolution to children and young adults. Conversely, the joint barriers of poverty and low educational levels constrain access to those most in need of the economic benefits of the Information Revolution. Breaking this vicious cycle will require a period of sustained
growth in per capita incomes backed by improvements in educational attainment.\textsuperscript{13}

\textit{Low levels of education.} Among the structural barriers to improved access to information, the one which is likely to prove the most resistant is education. In many ways, education may be considered the Achilles’ heel of development in Brazil, and the most critical obstacle to the dissemination of knowledge.\textsuperscript{14} Low levels of education, together with limited access to information, threaten the country’s efforts to cross the knowledge divide and its struggle against inequality. There is now strong consensus for a greater emphasis on education, and this has translated into increased resources and the adoption of progressive educational reforms since the early 1990s.

Despite significant improvements in the last few years,\textsuperscript{15} social indicators remain relatively low, and Brazil is classified in the middle ranks of the Human Development Index – HDI (0.747 or 74\textsuperscript{th} out of 174 countries in the 2000 Report – base year 1998), compared to 79\textsuperscript{th} a year earlier.\textsuperscript{16} Some important long-term gains have been made in education – the average number of years of schooling for adults aged 29 and over doubled for those born in 1970 compared to the 1930 cohort. Yet the picture remains very uneven.

It is undeniable that formal education has attracted increasing attention both due to its obvious significance for the Brazilian economy and to the growing income differentials among individuals with different levels of schooling. As a result, total public and private expenditures in the sector have grown over the years to 5.6\% of GDP in 1997 (against an average of 5.1\% in 1995-97), compared to an OECD average of 6.5\% (for reference, comparable figures are 5.9\% in Chile and 7.4\% in Korea). However, on a per capita purchasing power parity (PPP) adjusted basis, the figures are significantly different: USD 350 for Brazil, USD 722 for Chile, USD 1 071 for Korea and USD 1 368 for the OECD countries.\textsuperscript{17} Moreover, on a PPP basis, the country spends considerably less than these comparators on public primary and secondary education, while the ratio of resources allocated between university and lower levels seems to be distorted on both efficiency and distributional grounds (Table 9).\textsuperscript{18} It appears therefore that government spending on education is insufficient, particularly if the aim is to attain the objective of providing good-quality primary and secondary schooling for all children throughout the country and bringing down illiteracy rates, including in its functional dimension.
The Brazilian Experience

Table 9. Expenditures per student: Brazil and comparator countries

<table>
<thead>
<tr>
<th></th>
<th>Brazil</th>
<th>Chile</th>
<th>Korea</th>
<th>OECD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>859 (12.6)</td>
<td>2 115 (4.1)</td>
<td>3 308 (2.1)</td>
<td>3 769 (2.9)</td>
</tr>
<tr>
<td>Secondary</td>
<td>1 002 (10.8)</td>
<td>2 292 (3.8)</td>
<td>3 518 (1.9)</td>
<td>5 507 (2.0)</td>
</tr>
<tr>
<td>University</td>
<td>10 791</td>
<td>8 775</td>
<td>6 844</td>
<td>10 893</td>
</tr>
</tbody>
</table>


Despite limited resources, quantitative gains have been significant, with primary school attendance now almost universal (at least for the early years, with 95.7% of children aged 7-14 in 1999 attending school – attendance rates are 94.1% in the Northeast, compared to just 82.2% a decade earlier). Literacy levels remain low: in 1998, 13.8% of the population (or 15.26 million people) could neither read or write – although this was the lowest level ever and the nadir in absolute numbers since 1950. Moreover, illiteracy in the 10-14 age bracket fell from 14% to 5.5% between 1995 and 1999. However, most schools do not seem to be capable of proving quality education to large numbers of students from poor and low-educated families. This is reflected most starkly in repetition rates: elementary school students repeat 2.23 years on average, the highest rate in a UNESCO/OECD comparison of 16 developing countries (comparable figures are, for example, 0.61 in Argentina, 0.34 in Chile, and 0.11 in the Philippines).

Secondary schooling has also experienced important quantitative gains, as reflected in the growing (albeit low) share of the population with secondary education: 19% in 1999, compared to 15.5% in 1995. Among those at work, 21.2% of men and 30.2% of women have completed secondary-level education. Yet, with less than six years of schooling on average, Brazilian workers are at a disadvantage compared to their Chilean or Korean counterparts, with respectively over seven and nine years. This confirms the widely shared notion that despite the existence of a flexible, creative and adaptable labour force, development is hampered by low levels of education and limited workforce skills.

The growing number of students at the primary and secondary level has led to a pent-up demand for university education: parents and young adults have a clear (and correct) perception that tertiary and graduate education propitiates a jump in earnings compared with individuals having only secondary training (over three and six times, respectively, according to PNAD base year 1997). In response to the growing pool of high school graduates, private universities have
increased the number of entries and introduced generally low-quality capacity expansion, while the public system has stagnated. The university system is characterised by a relatively high-productivity, low-quality private subsystem (with some important exceptions, notably the Catholic University of Rio and the Getúlio Vargas Foundation), and a public network with lower productivity but higher educational standards, centred on the federal universities (particularly those in the South-Southeast) and the outstanding state system of S. Paulo.22

The private sector response has been differentiated in terms of both disciplines and careers. Private education generally focuses on areas that are less demanding in terms of recruitment of high-level professionals as teachers and purchases of expensive equipment and labs for support, and tends to turn out professionals that are insufficiently prepared for the job market. At the same time, the public system, which benefits from far higher resources (Brazil’s spending is more or less similar to expenditures in other OECD countries, and exceeds that of Chile or Korea in PPP-adjusted USD for public university education – see Table 7), and is therefore better able to provide high-quality education in “hard” subjects, has faltered and stagnated. This has resulted in significant problems in science and engineering education outside the elite state, federal and military engineering schools clustered in S. Paulo, and to a lesser extent in Rio, Minas Gerais, Santa Catarina and RGS (the Federal University of Pernambuco is probably the major exception outside the South-Southeast regions).

Limited access to information, generally low levels of education and the weak performance of the university system have given rise to a situation in which human capital cannot act as an effective vector for the dissemination and absorption of knowledge, and the acquisition of skills. There have been clear gains in recent years, following on from the engagement of public and private forces. The Brazilian Government has recognised the importance of primary and secondary education and is carrying out fairly effective reforms to ensure that it becomes more inclusive. Firms are increasingly committed to improving the levels of education and training of their workers, while social organisations have been mobilised and individuals have volunteered to invest time and resources in the task of redressing years of educational inequality. However, the goal of universal high-quality primary and secondary schooling – which is in all likelihood the linchpin to mass participation in the knowledge economy – calls for a massive effort by both government and society. As such, it should be a priority goal of public policy.

At the same time, well-trained, university-educated individuals can play a vital role in the dissemination of knowledge by providing the human capital
base and making it possible for technologically sophisticated and knowledge-based firms to enter the market. The scarcity of such individuals – mostly in engineering and other technical disciplines, and to a lesser extent in management (the number of management courses offered is now on the rise, as are the incentives for university graduates in business administration) – deter firms from realising their potential as carriers of new and useful information.

Limited role of firms as carriers of knowledge. Knowledge is not evenly spread throughout Brazilian society not only because of the dearth of well-educated individuals but also because of the low share of firms which can function as effective carriers of knowledge and are able to bring to the market and disseminate new ideas, methods, and ways of producing and distributing goods and services.

Historically, foreign direct investment (FDI) has been a key source of innovation and the application of science, engineering and advanced management to production, which otherwise remained incipient, fragmented, and concentrated among the larger domestic firms. Brazil has been able to attract large volumes of FDI in the last few years, with flows growing in the last decade at an average annual rate of 40.7%, rising from USD 1-2 billion to USD 33.5 billion in 2000. This improvement has been driven by a combination of economic stability, domestic (and sub-regional) market size and dynamism, and a positive investment climate. In an annual survey of 1 000 companies responsible for approximately 70% of total transnational flows, Brazil ranked third (behind the United States and China, compared with fourth place a year earlier) among countries in which companies placed the most confidence (as attractive investment sites – see Table 10).

<table>
<thead>
<tr>
<th>Table 10. Investor Confidence Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>On a scale of 1-3</td>
</tr>
<tr>
<td>United States</td>
</tr>
<tr>
<td>2.03</td>
</tr>
</tbody>
</table>


Despite the growth in FDI flows and continuing investor confidence, the potential for FDI to operate as a source of new knowledge is tending to recede.
Using Knowledge for Development

First, it is likely that DFI flows reached a post-privatisation peak in 1999-2000, and current projections for 2001 suggest an inflow of USD 24 billion, dropping to the USD 20-30 billion range in the following years. Second, DFI is increasingly directed towards services and other non-tradeables, where competitive pressures are less intense, the knowledge gap is not as pronounced (if it exists at all), and where advantage often centres on inexpensive capital. However, the importance of critical services – such as information and communication – to a modern, knowledge-based economy should be kept in mind. While the stock of investment in industry at the end of 1995 reached 55% of the total, and investment in services (including finance and infrastructure) accounted for 43.4%, the cumulated flows in 1996-99 were 19.2% for industry and 79.2% for services. Third, although investment in new or modernised facilities, integration with local suppliers, and the progressive human resource policies which often characterise industry-oriented FDI have unquestionably had a continuing positive impact on the spread of knowledge, the value of FDI required to effect the transition to a knowledge economy will depend increasingly on the quality of the investment. Despite recent decisions by IT manufacturers to set up R&D and related facilities in Brazil, and despite the continuing commitment to local design, product development and testing activities by automotive producers, among others, one should not expect the latter to have a determining role in the country’s ability to cross the knowledge divide. Rather, this role will fall to local firms which are either knowledge-based or connected to high-performance markets.

The basic characteristics of high-performance markets are the moderate to high intensity of competition, the strict requirements on output (and the quality of inputs) they impose and their information-rich nature. In less than a decade Brazil has become a more open and competitive economy, where cartelised or non-competitive arrangements to supply domestic markets (including the government) have become less pronounced, and firms face growing exposure to international markets, either directly or through buyer-supplier relationships with globally competitive companies. These new circumstances appear to have led to a growth in the number of local firms supplying such markets.

Although there are no reliable estimates of the number and relative importance of indirect exporters or of companies which supply and therefore adhere to the strict standards of firms connected to high-performance markets, information on exporting firms points to a significant enlargement of their universe in the last decade. The number of such firms has grown at an average annual rate of 8.59% since 1990, and represented approximately 14 000 companies in 1999 (Table 11). Although in that year 450 firms were responsible for nearly three-quarters of total manufactured exports, new entries
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have been observed in practically all export size categories since the beginning
of the decade. Moreover, while firm size remains the most important variable
explaining export performance (with the probability of entering export markets
increasing exponentially with size), the trend towards the creation of SME-
based export consortia points to a more stable, long-term and substantial
commitment of small and medium-sized firms to export markets.

Table 11. Size distribution of manufactured exports
1990 and 1999

<table>
<thead>
<tr>
<th>Size category (USD million)</th>
<th>Number of firms</th>
<th>% total firms</th>
<th>% total exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1</td>
<td>5 294</td>
<td>11 829</td>
<td>79.19</td>
</tr>
<tr>
<td>1 to 10</td>
<td>1 087</td>
<td>1 755</td>
<td>16.26</td>
</tr>
<tr>
<td>10 to 50</td>
<td>252</td>
<td>357</td>
<td>3.77</td>
</tr>
<tr>
<td>50 to 100</td>
<td>31</td>
<td>56</td>
<td>0.46</td>
</tr>
<tr>
<td>100 to 250</td>
<td>13</td>
<td>28</td>
<td>0.19</td>
</tr>
<tr>
<td>250 to 500</td>
<td>7</td>
<td>7</td>
<td>0.10</td>
</tr>
<tr>
<td>500 to 1 000</td>
<td>2</td>
<td>0</td>
<td>0.03</td>
</tr>
<tr>
<td>Over 1 000</td>
<td>1</td>
<td>1</td>
<td>0.00</td>
</tr>
</tbody>
</table>


It is expected that knowledge-carrying capacity will grow among firms as
export propensity and the numbers of direct and indirect exporters increase and
firms become integrated in more demanding markets where rivalry tends to be
intense and overall requirements more strict. Still, it will be a few years before
the country is able to substantially increase its low export/GDP ratios (in the
order of 10% in 2000), improve its fragile competitive position in the value-
critical segments where application of knowledge is most significant (see
Section II), and overcome the low overall propensity of both local firms and
multinationals to export (4.8% and 12.2% in 1999, respectively). Combined
with continuing FDI flows to manufacturing (albeit on a smaller scale) and a
greater exposure of firms to the forces of competition and the imperatives of
modernisation, a growing number of firms will begin to function as effective
vectors of knowledge in the economy.

It is unlikely, however, that an expansion in the number of firms connected
with and deriving information from high-performance markets – however
important this source may be – will be sufficient to ensure the consolidation of a
knowledge economy. It will take the emergence of large numbers of knowledge-
based entrepreneurs – bringing to market new ideas and research results,
mostly conceived in universities and research institutions – to help complete the transition.

New evidence seems to confirm that entrepreneurialism is thriving as the notion of creating gainful employment supersedes pure job seeking in the context of relatively low entry barriers and a multiplicity of schemes to support micro enterprises and SMEs. In a recently compiled index, Brazil ranked top among 21 countries in the level of entrepreneurialism, a combination of the proportion of adults starting new companies – where Brazil came first (with 1 in 8 adults, defined as individuals in the 18-64 years age bracket), followed by the United States (1 in 10), Australia (1 in 12), Argentina (1 in 16), Germany (1 in 25), the United Kingdom (1 in 33), and Ireland and Japan (in 100) – and the percentage of adult employees working in firms which have been in existence for less than 42 months, where Brazil ranked third, behind Korea and the United States (Table 12). Large numbers of micro, small and medium-sized firms have emerged: current estimations point to 4.5 million, with a significant number operating in the informal sector.

Table 12. Index of Entrepreneurial Activity

<table>
<thead>
<tr>
<th>Country</th>
<th>Index Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>16</td>
</tr>
<tr>
<td>Korea</td>
<td>13.6</td>
</tr>
<tr>
<td>United States</td>
<td>12.6</td>
</tr>
<tr>
<td>Australia</td>
<td>10.9</td>
</tr>
<tr>
<td>Canada</td>
<td>7.9</td>
</tr>
<tr>
<td>Norway</td>
<td>7.9</td>
</tr>
<tr>
<td>Argentina</td>
<td>7.7</td>
</tr>
<tr>
<td>India</td>
<td>6.3</td>
</tr>
<tr>
<td>Italy</td>
<td>5.6</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5.1</td>
</tr>
<tr>
<td>Germany</td>
<td>4.7</td>
</tr>
<tr>
<td>Spain</td>
<td>4.5</td>
</tr>
</tbody>
</table>


Yet, knowledge-based entrepreneurship is scarce insofar as it requires skills grounded in science, technology and engineering, in a context where the hurdles to formal education are formidable. Such highly skilled individuals are generally found in universities – on a prima facie basis they come from the pool of the (approximately) 52,000 full-time faculty with graduate degrees and a proportion of their more entrepreneurially-minded students with technology backgrounds – and depend on supportive structures to make the transition to commercially viable projects.

In this regard, a relatively successful experience has been that of firm incubators, generally established on university grounds, with the first dating back to 1988. By end-2000, there were 135 such units hosting 1,100 businesses
in 17 states, with a turnover of approximately USD 300 million. Many of these incubators are undergoing significant expansion and it is expected that there will be 200 in operation by the end of 2001. It is noteworthy that at end-2000 these incubated businesses employed a total of only 462 PhDs, less than 1.7% of the pool of 27 662 PhDs located in university departments and research institutions – this clearly points to the growth potential for knowledge-based incubator-supported SMEs. Most incubated companies are in the electronics, software, telecommunications, biotechnology and agro-food industries. Partly due to the high levels of support provided – physical infrastructure, but more importantly, management consultancy and finance from public and private sources – firm mortality for these incubated firms is in the range of 20% (compared to 56% after three years for all entrants).

In a few instances, incubators are (becoming) part of more complex structures – science or technology parks – established with the aim of attracting to university (or research institution) campuses, firms which demand knowledge as a basic input and emerging companies which use the knowledge generated at such institutions. Examples of such structures – some of which are still at an incipient stage – can be found in Santa Catarina, Rio de Janeiro, Pernambuco, Rio Grande do Sul, Ceará and Brasília. Possibly the region where the first cluster of science/technology parks is beginning to consolidate, is that centred around the city of Campinas in S. Paulo and the University of Campinas (Unicamp). The area boasts 13 universities and research institutions, the latter with an emphasis in IT (CPqD, CTI), physics and related subjects. Unicamp itself is responsible for approximately 16% of the country’s scientific output, while the region of Campinas as a whole generates 9% of Brazil’s GDP. In the last few years, 110 IT companies (30 in the last four years) have been attracted to Campinas, including such giants as Lucent, Motorola, Nortel, Compaq, Ericsson, IBM, among others, some of which have established both industrial and research facilities. In a move that could be read as signalling the maturity of the region, IBM is creating a “Tech Town” – an industrial condominium – that is expected to host a total 20-25 IT firms (six are already in situ), not all of which are IBM suppliers or “partners”. Outside Campinas, there are at least three important axes long which new clusters are being formed: those linking Campinas to S. Paulo (where the major campus of the state university is located which, together with Unicamp, and the Federal University of Rio, form the most prestigious universities in Brazil), S. Carlos (seat of two universities, one federal, another state, both with a solid tradition in science and engineering) and S.J. dos Campos (the seat of ITA/CTA, the premier Air Force engineering school and research facilities, and Embraer).
Despite the relatively recent emphasis on support for knowledge-based firms and on enhancing conditions for companies to link to export and other high-performance markets, the stock of high-productivity SMEs in the economy appears to be considerable. In 1998, there were 10,565 firms with between 20-500 employees, earning gross revenues per employee of between BRL 500,000 and BRL 600,000. The fact that over 10,000 SMEs have emerged as part of a high-productivity pool of companies suggests that a substantially larger number could be tapped if support were provided in the form of adequate structures and institutions focused on enhancing the connectivity of firms to demanding markets and broadening their knowledge base. There are, in fact, a significant number of export- and SME-supporting policies and programmes, the latter spearheaded by Sebrae – the well-funded Brazilian Service for Support of Small and Medium Enterprises – in conjunction with government and private actors and social organisations, while certain institutional arrangements are focused on knowledge dissemination, particularly among SMEs, including the 45 national centres of technology (Cenatec) and “dial-technology” services provided by a number of universities.

The depth of knowledge

So far, this section has highlighted the critical loci of knowledge in an economy: well-educated and informed individuals; firms that use knowledge as (one of) their differentiating asset, (originating in or connected to) information-rich and competitive markets; and institutions (universities and research facilities) capable of spawning knowledge-based entrepreneurs. These individuals, firms and other organisations are not only sources of knowledge, they are also (under certain conditions) its carriers and play an instrumental role in spreading knowledge throughout the economy and society.

The volume of expenditures in S&T activities generally, and in R&D in particular, are relevant indicators for assessing the depth of knowledge, insofar as they are (or are expected to be) strongly correlated with the creation (and application) of knowledge in specific fields. In 1997, Brazil spent an estimated USD 10.7 billion on science and technology, or 1.34% of GDP (compared to USD 6.2 billion or 0.96% of GDP in 1993): 64% by government, 32% by firms and the remaining 6% by private universities. This pattern of allocation is the reverse of that of many other OECD and advanced industrialising countries, although it compares favourably with the early 1990s, when only some 25% of S&T expenditures could be attributed to the productive sector.
The Brazilian Experience

In attempting to translate these S&T/GDP ratios to the more usual indicators of R&D/GDP, the following considerations may be useful. In 1997, R&D expenditures proper (as defined by MCT) by the federal government were an estimated USD 1.5 billion, while a sample of 364 innovative companies from the Anpei database generated approximately USD 1 billion in such expenditures. Considering the incomplete nature of the database and additional commitments by other levels of government, it may be safely assumed that total R&D expenditures in Brazil in 1997 were in the order of USD 3.5 billion or 0.436% of GDP (at a pre-devaluation figure of USD 803 billion). Compared to OECD countries, which spent an average of 2.2% of GDP on R&D in 1997, these expenditures are relatively small, on a par with the least R&D-intensive OECD Members (e.g. Mexico, Greece and Turkey). Nonetheless, in absolute terms, the USD 10 billion committed to S&T, of which some USD 7 billion by government and approximately USD 2 billion in R&D expenditures by the public sector, with another USD 1-1.5 billion by companies, are far from negligible and, provided they are productively spent, could produce noticeable results.

Most research in the country has an institutional base and in 2000 was being carried out by more than 48,771 researchers (56.7% with doctoral degrees), clustered around 11,760 groups in 224 universities and research institutes. Brazil has a relatively strong and consolidated tradition of open competition for public finance among research groups and graduate programmes, and the systematic evaluation by government agencies of the quality of their output is readily accepted. In this context, the apparent low productivity (and quality) of research produced is somewhat surprising in view of the existence of a number of areas of true excellency and high scientific productivity (in terms of internationally accepted and recognised results).

Although limited data are available for measuring scientific productivity, one strong (although not indisputable) indicator is the number of articles published in international scientific journals. In 1997, a total of 6,831 articles were published, at a time when over 8,632 research groups were in activity, totalling 30,040 researchers (of which 18,724 held doctoral degrees). This translates into a mere 0.79 articles per group and 0.54 articles per PhD researcher. Of course, these can be viewed as transitory figures, relating to a period when research groups were in the process of maturing, but in any event these ratios appear to be rather low. It is in this context that CNPq ranked only 10% of standing research groups as being up to international standards, while another 20% are regarded as “consolidated”, with stable and good-quality output. Thus, it is arguable that, despite major quantitative and qualitative gains in the last few years, and despite substantial investments, only 1,000 or so
research groups can be said to be “internationally competitive”. It is probably this core that produces most good science in Brazil.

Possibly the area that demonstrates the country’s capability to conduct frontier research, if well organised and funded, is that of life sciences, within which genomic research stands out, both in terms of the quality and significance of the achievements, and the productivity which has characterised the three-year effort. In sum, the state of S. Paulo-led programme (spearheaded by Fapesp, the state science foundation and financing arm) has:

- Sequenced, for the first time, the genetic code of a plant (citrus) pathogen – the *Xylella fastidiosa* – in a two-year USD 13 million joint effort by 35 labs and some 200 researchers, and published in *Nature* as a cover article on 13 July 2000. The goal was to achieve the complete (2 700 genes, with 2 679 000 “letters”) sequencing of an economically relevant microorganism (the *Xilella* bacteria causes an estimated USD 100 million of losses in an industry which has a leading global position, exporting USD 1 billion worth of orange juice annually), while training a large number of researchers and acquiring full capabilities in a frontier and highly significant area.

- Sequenced the *Xanthomonas Citri*, another loss-causing pathogen attacking orange groves (citric cancre causes an estimated USD 55 million of annual losses). Fourteen labs were involved in this project which demonstrated large productivity gains: 5.2 million sequences (close to twice as many as the *Xilella*) were deciphered in 14 months, at a cost of USD 4 million (half the original budget estimation).

- Sequenced 81 000 “express genes” of sugar cane (out of an estimated total of 300 000), in a USD 4.5 million, 60-lab seven-state effort which looks into only part of the genome of the plant. The first phase of the project is scheduled to be wound up in approximately half the projected time (at 70% of the estimated cost). This effort will be followed in the next two years by an applied genome project which aims to bring genetic improvements in view of the creation of a plant variety which is more resistant to disease and climatic variations, in response to the specific needs of producers (who, in conjunction with researchers, drew up a list of the most economically relevant issues).

- Achieved a significant milestone in the 1999 Cancer Genome project, a 39-lab consortia led by the S. Paulo branch of the Ludwig Cancer Research Institute, after sequencing some 1 million genetic fragments
of the most common tumours in Brazil, twice the original target, in a timeframe which was well in advance of the June 2001 target date. The Clinical Genome project focused on the genes responsible for changes in tumourous cells. A follow-up project will attempt to establish a correlation between the genetic characteristics of tumours and the development of cancers (with the ultimate aim of arriving at a biochip capable of genetically identifying tumours and contributing to their treatment).

Recently, and in the wake of the successful network-based genome project results, the (federal) government launched a 30-lab (involving 150 researchers), 15-state effort named BRGene, to genetically map the *Chromobacterium vilaceum* bacteria, commonly found in the Amazon region, and thought likely to be able to contribute to the treatment of Chagas disease and leishmaniosis, as well as in the development of less expensive biodegradable plastics.

The project was launched on 18 December and appears to be progressing ahead of schedule, having achieved the first successful results in terms of genetic sequencing of the bacteria (and the corresponding deposits in the databank) before February 2001, partly as a result of adequate financing, the network structure of Internet-linked assembled labs, and the experience gained in the previous projects. The State of Rio, with the support of Faperj (which plays the same role as Fapesp, albeit on a smaller scale), has also launched a USD 4 million programme (RioGene), involving in this instance a consortia of seven institutions and approximately 40 researchers, in a first step, to map the genome of the *Gluconacetobacter Diazotrophicus* bacteria which is responsible for nitrogen fixation in sugar cane, sweet potatoes and coffee.

At the same time, having allowed the State of S. Paulo and other institutions to acquire (global) leadership in the sequencing of vegetable pathogens, Fapesp is promoting the mapping of another disease-causing bacteria, *Xanthomonas campestris*, 85% of which is already sequenced and is due to be completed by the first semester of 2001, as well as planning two further projects, one focused on the sequencing of the pulp-making short-fibre eucalyptus, the other on a disease-causing fungus which has caused a major drop in the cocoa crop over the last ten years. In addition, Fapesp is putting together a 15-lab consortia for a USD 3.5 million, four-year Structural Genoma project aimed at gaining a better understanding of 200 proteins of the human proteoma (of which 30 will be studied in depth), and which will ultimately allow industry to design drugs able to inhibit or facilitate the action of specific proteins. The Structural Genoma project will be led by the Campinas-based Laboratório Nacional de Luz Sincrotron (LNLS) and its Centre on Structural Molecular Biology, which will purchase nuclear magnetic resonance equipment.
for the structural analysis of smaller proteins (to complement the labour- and time-intensive method currently employed at LNLS using a synchrotron light ring), on the basis of its merits attested by an open competition and judged by a Fapesp-assembled international panel.

In large measure, these results were made possible by the depth of Brazil’s institutional and human capital resources in life sciences. Equally important was the decision to bring the country to a position of leadership in a key area by emulating the positive experience of having well-defined objectives, linking and motivating researchers, establishing networks or consortia of labs, and irrigating these with sufficient resources to allow them to attain – and even surpass – the programmes’ aims.

As is argued above, genomic research, a stellar case in scientific work in Brazil, is an exceptionally high-productivity, high-quality work programme. However, even in those areas in which the country exhibits outstanding scientific achievements, there are very few instances where these are turned into commercial products, or even prepared for commercial applications. The very limited patent activity by local researchers is possibly the most glaring evidence that results most often remain on the “shelves” of universities and research institutions. Thus, in 1997-99, only 946 patent requests were originated by the (average) 39,000 researchers (21,700 of whom have doctoral degrees) active in the period, i.e. just 1.8% of the total 52,658 patent requests.

From a broader perspective, Brazilian researchers, institutions and firms were responsible in 2000 for only 161 patent applications routed through the World Intellectual Property Organization (WIPO) to third countries, or 0.18% of total requests from all countries (Table 13). Although this represents a 30% increase over the 126 applications of the previous year, it is still a minuscule participation for the country (which ranked 27th), and inconsistent with both scientific output and growing (although still limited) commitment to innovation by Brazilian firms. It is worth stressing that since 1990 the number of patent applications submitted through the WIPO has grown from 19,159 in 1990 to 90,948 in 2000, or an annual average rate of 16.9%, jumping to 22.9% in 1999-2000. This clearly denotes the growing importance that researchers and innovating institutions and companies attach to protecting intellectual property, due to its increasing economic value – a notion not yet sufficiently internalised in the country.
Table 13. **Patent applications submitted through WIPO, 2000**

<table>
<thead>
<tr>
<th>Number and %</th>
<th>United States</th>
<th>Germany</th>
<th>Japan</th>
<th>United Kingdom</th>
<th>France</th>
<th>Sweden</th>
<th>Netherlands</th>
<th>Switzerland</th>
<th>Austria</th>
<th>Canada</th>
<th>Korea</th>
<th>China</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>38,171</td>
<td>12,039</td>
<td>9,402</td>
<td>5,538</td>
<td>3,601</td>
<td>3,071</td>
<td>2,587</td>
<td>1,701</td>
<td>1,627</td>
<td>1,600</td>
<td>1,514</td>
<td>579</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>42.0</td>
<td>13.2</td>
<td>10.3</td>
<td>6.1</td>
<td>4.0</td>
<td>3.4</td>
<td>2.8</td>
<td>1.9</td>
<td>1.8</td>
<td>1.8</td>
<td>1.7</td>
<td>0.64</td>
<td>0.18</td>
</tr>
</tbody>
</table>

*Source: WIPO.*

The critical issues facing scientific research in the country could be posed as two questions:

- **First**, how to improve the productivity (and quality) of research in Brazil in view of the substantial resources committed?
- **Second**, how to translate first-rate research achievements into commercial applications which will bring widespread gains to the economy and society?

The contribution of universities and research institutions to deepening the country’s knowledge base varies widely, being quite substantial in some areas and far less significant or inconsistent with the resources allocated in others. The same highly variable picture emerges in an analysis of firms’ R&D&E activities and results.

As noted above, firms’ share of overall R&D expenditures in the country is estimated at 30%-35%, compared to 50%-80% in OECD and advanced industrialising countries. However, even this figure compares favourably with the early 1990s, when firms were responsible for only 20%-25% of total allocations. Two firm-level surveys – one of 427 companies (undertaken by Anpei), the other of 85 multinationals (led by Sobeet), both taking 1998 as the base year – provide an approximate picture of the technological behaviour and performance of the Brazilian corporate sector. The surveys show that as a percentage of sales, firms’ purchases of technological capabilities, although lower than in other OECD countries, are significant at 1.3% (Table 4).
At the same time, in both samples, a significant proportion of expenditures were spent on activities other than R&D, and within the latter the greater part of such funds were devoted to experimental development. In the Anpei sample, firms spent on average 14.6% of total R,D&E for technical services, 12.3% for the purchase of technology, and 13.8% on non-routine engineering. Thus R&D proper made up 59.3% of expenditures, with 33.2% on experimental development, 20.0% on applied research and 6.1% (or 10.3% of R&D itself) on basic research, the latter comparable to the 8% spent on that category by US firms. The Sobeet sample presents similar results: R&D makes up 57% of total technological expenditures, with 38.8% allocated to experimental development, 13.4% to applied research and 4.8% to basic research. Thus, in both samples, research activities were limited to 20%-25% of expenditures, with the Anpei sample confirming the marginal use of senior researchers (on average only 0.65 PhDs per sampled company were engaged in R,D&E work), and limited patent activity – over the ten-year period 1989-98, the average number of patents registered annually as a result of firms’ technological activities was a mere 0.46. In this context, the role of firms in pursuing innovative, frontier work which helps to deepen knowledge in specific fields, seems to be rather modest.

Again, however, there are some important exceptions: a number of companies are actively creating and applying technology in complex and multidisciplinary projects, advancing knowledge in areas such as petroleum engineering, optics, biotechnology, aerospace, among others.

In some cases, where there is a clear leader providing demand, finance or other support, results have been obtained with collective, network-based efforts. This has been the case for Petrobras’ Procap, whose long-term efforts to explore for oil in deep waters have been highly successful by any standards. The coincidence of economic and technological objectives – the country’s self-
sufficiency in oil and its experience of searches at ever greater depths – meant that by end-2000 Petrobras had discovered oil at the record-breaking depth of 2,243 meters in (“ultradeep”) water, in a well reaching down 5,510 meters beneath the sea’s surface. On the basis of its achievements in deep sea oil exploration (over 90% of the country’s production of 1.3 million barrels per day come from the Campos Basin, off the coat of Rio), the company has been awarded, for the second time, the most prestigious award in the oil industry, offered by the Offshore Technology Conference, for its Roncador field project, a previous world record holder for exploration at depths of 1,877 meters below the sea. Procasp developed under the leadership, integration capabilities and finance of the company, and defined in terms of target depths to be achieved (from 1,000 meters, to 2,000 meters, and reaching 3,000 meters by 2004), involved a multiplicity of agents – universities, research institutions (particularly Cenpes, Petrobras’ leading-edge R&D lab, located at the Federal University of Rio), and private firms, many of them knowledge-based SMEs – as well a range of technologies and disciplines (geology, hydrodynamics, seismic studies, robotics, complex modelling and simulations, etc.).

Aerospace technology is another field in which the country has attained significant competence, with an emphasis on the design and construction of aircraft and satellites, among other aerospace products, led respectively by Embraer, and the National Institute of Space Research (Inpe) and the Brazilian Space Agency, the major focus of the latter being to ensure that the Alcantara satellite launching facilities are operational and competitive.

Progress in space technology spearheaded by Inpe, in particular, has permitted the country to acquire imaging and remote sensing technology, with the launching of the Chinese-Brazilian Earth Resources Satellite (Cbers-1) in October 1999 and the forthcoming Cbers-2 (currently being tested at Inpe’s Integration and Testing Lab for its mechanical and mass characteristics, followed by a further series of tests in Taiyuan, China, and scheduled to be launched in April 2002). Inpe’s R&D emphasis is on the development, integration and testing of critical satellite components in both service and cargo modules (including rocket propulsors, propellants, high-definition cameras), while launch vehicle technology – which the country has yet to fully dominate – is still being concomitantly acquired.1

The country’s space technology efforts have led to important achievements in satellite imaging and remote sensory, a sensitive and strategic area in view of its impact on knowledge in areas as diverse as natural resource availability and use (including pollution, burning and occupation of tropical and semi-tropical forests), geomorphology and cartography, crop forecasts, population shifts, etc.
While it is arguable that significant depth has been acquired in this field, the country is still a few years away from paying back its investments through the sale of services (and eventually) equipment. Most likely, the satellite launch services of the Alcantara (State of Maranhao) base are the closest to achieving a measure of economic success once the project becomes fully operational.

The one area in space technology where the country has achieved technological and commercial pre-eminence is in the design, production and sale of aircraft to the civilian market, and to a somewhat lesser extent, for military purposes. The frontrunner of this effort is Embraer (see Box 3), which develops and manufactures what is possibly the most advanced family of commuter jet aircraft for 35, 42, 50, 70, 98 and 108 passengers, competing head-on with Canada’s Bombardier, and in the future with Boeing’s new 717, 106-passenger jet. By end-2000, the new 70, 98 and 108 “subfamily” had already registered 325 orders (120 firm orders and 205 options) out of a total of 944 orders. According to industry standards, on average, 20% of orders are cancelled (the estimated breakeven point is 300 planes, and the sales target is 650 aircraft over a ten-year period). What is more, the company is making use of its commuter jet platform to enter the corporate jet market (with its Legacy planes) and, in partnership with Ericsson (which provides the electronics), to supply lower-cost early warning and surveillance and sea-patrol aircraft (with sales to Greece and, more recently, to Mexico). Other military projects include a highly proficient jet-emulating propeller trainer (which equips, in its different versions, the air forces of 20 countries), and a bomber and troop support jet – a joint Italy-Brazil project, among other products.

In addition to its design and integration capabilities (bringing together a multiplicity of parts, components, systems), as well as marketing, sales and post-sales assistance, Embraer has excelled in reducing turnaround times in both the development and production stages: while the development of the 50 passenger ERJ-145 took a total of 60 months, the new 70-passenger ERJ-170 is expected to take only 38 months, with its first flight in November 2001 and commercial delivery starting second half of 2002 (the 108-passenger ERJ-190-200 is expected to be delivered in July 2004, and the 98-passenger version a year later), the aircraft production cycle has been reduced from 14 to five months, with the pace of delivery increasing from 97 jets in 1999, to 160 in 2000 and a projected 200 deliveries for 2001, when the monthly production rate should reach 20 jets by June. As a result, productivity per employee has reached USD 308 000 (a more than seven-fold increase since 1995, and significantly above Bombardier’s, which stands at USD 155 000). Embraer’s efforts are expected to consume USD 875 million in development outlays in the
2000-05 period, plus USD 386 million in plant and equipment, of which USD 151 million in IT tools and systems.\(^{45}\)

While Petrobras, Inpe and Embraer stand out as success stories of corporate and institutional leadership in highly complex and knowledge-intensive projects involving a multiplicity of suppliers, “risk partners” and research institutions, there are other instances in which smaller, science-based companies, have taken a groundbreaking role. Optoeletronica, for example, is a S. Carlos-based “university” company (60% of its 97 employees are from S. Carlos’ S&E university departments), founded by six researchers and staff of the Physics Institute of the S. Carlos campus of the University of S. Paulo. The firm has become a leader in precision optics, laser measurement tools, among others, with 20 patents (five of which are international) and an average annual growth rate of 35%.\(^{44}\) Biobrás, the country’s only producer of insulin with a 65% market share, has patented in the United States a new bacteria-based DNA recombinant method for insulin production, to compete on an equal footing with US Lilly and Denmark’s Novo Nordisk. The new method, co-developed over a ten-year period with the University of Brasilia, and which is already responsible for 15% of Biobras’ output, lowers production time (from approximately 90 to 30 days) and costs compared to the traditional method of extracting insulin from pigs’ pancreas.\(^{45}\)

Although there are other examples of successful companies working at the knowledge frontier, they are not enough in number or critical mass to deepen the country’s knowledge base across a sufficiently large spectrum of disciplines or fields to cross the knowledge divide. What is Brazil missing? One could summarise by stating that the country lacks:

- **First**, science-based companies, engaged in frontier work.
- **Second**, a greater number of local firms linked to information-rich markets and committed to the acquisition and deployment of knowledge.
- **Third**, international firms with major local R&D investments.

Despite the apparent distance, Brazil is in fact on the threshold of crossing the knowledge divide. Most of the restrictions and barriers identified in this section can be addressed – and many are being effectively so – in the medium term, that is, in a 3-5 year horizon, and some even in a shorter period. Much of what has to be done is known, or at least there is a fair understanding of its importance, while successful programmes or companies’ experiences point to the path to be followed. What might be missing is a clearly articulated strategy,
some elements of which are suggested below. The level of education – as already indicated above – represents a serious structural barrier, however, the removal of which will require an enormous effort by government and society as a whole. Brazilian society has become acutely aware of the importance for its future of having an educated population, and of the critical need to break out of the vicious circle of inequality – both social and economic – from which its citizens suffer. If this can be achieved, the country can be transformed in a definitive and positive way.
IV. ELEMENTS OF A VIABLE COUNTRY STRATEGY

Economic growth and the transition to a knowledge economy. Macro stability in an open economy constitutes the basic frame for economic growth, with important effects for:

- Employment creation, and the derived incentives for improvements in education and acquisition of skills.
- Growth of personal income, with the concomitant expansion of individuals’ and families’ ability to acquire goods and services, including access to information and education.
- Entry of local and foreign firms, attracted to a growing, and increasingly competitive and globally linked market, in an environment of policy stability, predictability and responsible government.
- Government finances, allowing for an expansion in public investments in information infrastructure, education, science and technology.

After two decades of slow growth, a successful economic stabilisation plan implemented in mid-1994 and a major devaluation in early 1999, the Brazilian economy underwent significant recovery in 2000, with 4.1% growth in GDP, and projected expansion in the order of 4%-5% for 2001 and thereafter (Table 15). Although seen from a long-term historical perspective, these rates are below the country’s potential – growth rates averaged over 6% in 1950-80, and are estimated to have been (on a per capita basis) among the highest of the late industrialisers in the previous hundred years – nonetheless, if they can be sustained, they would bring a further and significant improvement in the environment for the acquisition and utilisation of knowledge. It is only within a scenario of sustained growth that crossing the knowledge divide becomes a feasible proposition. What are the remaining obstacles to lasting economic expansion?
Table 15. **Brazil: average ten-year GDP growth rates**

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<tbody>
<tr>
<td>1951-60</td>
<td>6.1</td>
<td>5.1</td>
<td>7.2</td>
<td>1.3</td>
<td>2.3</td>
</tr>
</tbody>
</table>


At the macroeconomic level:

- **The domestic fiscal deficit**, with implications for the medium- to long-term ability of the government to pay and finance the domestic and external debt. With the drastic lowering of the inflation rate after the real stabilisation plan, the government was unable to finance itself out of the inflation tax. This led to growing debt levels (which reached a post-devaluation peak of 51.9% of GDP in February 1999, and remained at 49.5% in early 2001), in the context of the high interest rate policy required to maintain the country’s competitiveness in capital markets (due to an overvalued exchange rate), and the issuing of new debt to pay for unaccounted government liabilities in 1997-98. The goal of maintaining the country’s solvency and growth at an annual rate of 4.5% in 2001 and 2002, and 4% thereafter, will require the government to achieve a (primary) surplus on its accounts in the order of 2.2% over the next ten years in order to lower the net debt/GDP ratio by 0.7% per year to 43.3% by 2010.\(^7\)

- **The current account deficit**, related ultimately to the weakness in the country’s competitive position, and to the size and service structure of the external debt. By end-January 2001, the Brazilian deficit in current transactions stood at 4.39% of GDP or USD 25.9 billion on an annual basis.\(^8\) Although most of the deficit in 2001 is expected to be covered by foreign direct investment, it is unlikely that over the next few years the country will be able to finance this gap without substantially increasing its vulnerability to external shocks, thus threatening its goal of sustained growth. It is estimated that an economic expansion of 4.5%-5% requires average annual rates of growth in exports in the range of 7.5% to 10% in order to avoid the current account deficit spilling over and leading to an imbalance in the debt/GDP ratio.\(^9\) Increasingly, export growth will have to be supply-driven – less dependent on the growth of the world economy and prices of commodities – if such expansion rates are to be sustained. As argued above, a shift in the composition of exports towards a greater knowledge content, and the ability of domestic firms to control the
value-critical segments of the production-distribution chain will have a determinant role in this transition.

The fiscal and current account deficits have adverse implications for Brazilian firms’ capability to respond to the challenges posed by a more open and competitive market, including:

- **The cost of capital in the Brazilian economy**, as reflected in real interest rates, related to relatively thin capital markets and an elevated country risk.\(^5\) This dampens private investment and has an adverse impact on the competitive standing of firms, as well as constraining finance of knowledge-based (risky) ventures. Lowering the cost of capital is a slow and systematic process which requires convincing financial markets and investors of the country’s long-term commitment to stability and solvency.

- **The tax structure and the size of the burden on businesses and individuals**, a product of government fiscal requirements, which has taken away some of local companies’ competitive edge and has not worked as an effective catalyst for R&D, venture capital and other innovation-critical activities.\(^5\) Tax reform is on the agenda of government and Congress, although tax relief and/or incentive measures targeting companies engaged in R&D and other technological activities are relatively modest by international standards.

To the extent that such interrelated barriers to sustainable growth and disincentives for the acquisition and dissemination of knowledge are removed, the transition to a knowledge-based economy will require expanding the reach of knowledge by meeting the challenge of providing universal high-quality education, and adding leading-edge competences to the country’s portfolio of frontier capabilities.

**Expanding the reach of knowledge**

From the perspective of human capital as a vehicle of knowledge, it is necessary to:
Undertake massive investments in education, with a renewed commitment to tertiary educational reform

Education must be a critical element of any strategy aimed at reducing inequality, increasing efficiency and productivity, and bringing the country closer to crossing the knowledge divide. In fact, the only element of a multi-pronged knowledge-creating and using strategy which cannot be fully addressed in the short-to-medium term (that is over a 3-5 year horizon) is probably the education dimension. In all other aspects – physical, institutional and human – the country is now in a position to mobilise resources and overcome the barriers to the broad dissemination of knowledge, provided that there is the political will and a clear view of the direction in which the country should move.

Fundamentally, three critical objectives need to be achieved in order to bring a quantum or discrete leap in the educational standards of the country:

- Target the eradication of functional illiteracy in language, mathematics, science and information technologies nation-wide among teachers and students.
- Establish as a national goal universal quality primary and secondary education by 2005 to effectively democratise access to tertiary education.
- Improve the quality and productivity of tertiary education in private and public institutions.

The present government has made education a priority, with an emphasis over the last six years or so on improving primary (and more recently, secondary) education, with the (correct) presumption that unless one can build a solid base, the human capital “pyramid” will be unable to stand up. In addition, many states and municipalities have committed themselves to ensuring that no student is left out of the primary public system, to making effective use of federal and other resources allocated to improving teachers’ compensation and training, and to guaranteeing that the essentials of minimally effective teaching (books and other didactic materials, as well as meals – an essential element in poorer communities) reach students.

The universality of primary and secondary education is, however, a few years away. More will need to be done before the goal of quality education can be achieved. Currently, an estimated 97% of children aged 7-14 attend school, although a large number have family-related obligations which force them to work part- or full-time. Eleven million children aged 6-15 live in families with
incomes of less than half the per capita minimum wage. These are the most vulnerable and are the target of an expanded income support programme which makes cash transfers conditional on children attending school for at least 85% of the term. This approach has been tested in 1999-2000 in over 1,000 poor municipalities with approximately 2.8 million children and young adults, and the exercise will be broadened using resources from the “War on Poverty Fund”, initiated and voted by Congress.32

Despite the clear (and immediate) gains in poverty alleviation, and the greater opportunities for economic citizenship resulting from this (and related) initiatives, rendering the system universal while providing quality education will rely on several preconditions: that students take up full-time schooling; a far greater emphasis on teachers’ training, motivation and education; the use of new technologies in distance education to complement classroom activities; and reliance on volunteer and community efforts to assist poor families in breaking out of the cycle of ignorance and low levels of education. Although in the foreseeable future, government will continue to take the lead role in the provision of education, the country has a large, generous and relatively well-educated middle class which is well aware of the criticality of breaking the aforementioned cycle and whose capacity and availability for volunteer work has barely been tapped. Firms, too, are motivated and provide another source of committed and socially responsible individuals, as shown by the campaign against hunger spearheaded a few years ago by the late social activist, Betinho.

No matter how enlightened government programmes are, attaining the target of universal quality primary and secondary education by the middle of this decade is highly dependent on mass mobilisation and a permanent partnership of government and society.

Finally, advances in tertiary education are contingent on two distinct forces: first, the expected massive increase in the numbers of (better educated) young adults eligible (and, as incomes rise, capable) to enter university; and second, a growing adherence of income to productivity and schooling, with educational quality (and not the privileges associated with university diplomas) determining the distribution of rewards. Competition for resources, already a common practice in graduate teaching and research, and for students, the norm among private universities, will be progressively extended to public university education, as public institutions attain a greater degree of administrative and financial autonomy and as government transfers are made in direct proportion to productivity and quality of output (in the model of “social organisations” which already contract with government targets against funding).
Using Knowledge for Development

Greater competition, however, is not expected to translate automatically into better or expanded S&E education. While engineering-intensive firms are often willing to spend resources to train (or even bring into the country) engineers in short supply, the problem is particularly critical in science education. The demand for science-trained individuals, however, is not as explicit and their scarcity has a pervasive rather than an immediate or obvious impact on the widespread diffusion of knowledge. Improving the teaching of science at all levels, and in both public and private universities, should thus be a primary object of government attention.

Broaden access to information, by

- Lowering the prices of equipment.
- Lowering the prices of services.
- Increasing access to services at home and in schools.

The prices of equipment and services are essentially driven by the same factors: intensity of competition among suppliers; availability of less expensive substitutes; and the tax regime. Competition in the supply of equipment ranges from intense in the low end of the market to moderate at the other end of the spectrum. As the market expands, new suppliers are being attracted to produce servers and other more sophisticated and complex equipment. The government is attempting to promote the production of a “popular” PC, priced below the industry consensus that BRL 1 100-1 200 would be the bare minimum for a no-frills machine. At the same time, competition in services – as argued above – has not sufficed to lower interconnection costs, with the IP provider Embratel, for example, maintaining a dominant position in this market and charging what appear to be monopoly prices. That situation may change, however, with the entry and consolidation of other carriers (providing both dark and light fibre/capacity on a national scale) and related service suppliers, and the opening of the telecommunications market beginning 1 January 2002.

The role of policy in facilitating access goes beyond stimulating competition in the context of a growing (and increasingly open) market. Establishing a low, universal Internet-specific connection rate and user charges, irrespective of the distance from user to provider, would be an important step towards facilitating access. Operators should also be encouraged to provide unmetered access to the Internet, at least for schools, libraries and other educational institutions. In addition, lowering taxes on ICT products and services, currently at an estimated 41% and, possibly even more importantly,
The Brazilian Experience

reducing interest rates (partly a reflection of high intermediation costs) on the purchase of equipment (which stand at 2.5% monthly or 34.5% yearly), would allow for lower monthly instalments and could have a determinant impact on equipment sales and access levels in households, workplaces and schools.53

Public schools, in particular, are generally the least well-equipped and are currently the object of an ambitious effort by government to equip and link the country’s secondary and technical schools (13 200 units with approximately 7 million students) to the Internet by end-2002 (60% of these establishments had more than 600 students at end-2001).54 This USD 460 million two-year programme is financed by a 1% tax on the gross turnover of communications and related service providers (such as cable TVs).55 The new programme will utilise the institutional basis of Proinfo, an ongoing programme sponsored by the Ministry of Education, which has distributed 32 200 computers among 2 477 schools in 1025 municipalities, and which requires schools to prepare their own IT use projects and States to set up their nuclei for education technology (NTEs), so as to provide technical support and teacher training programmes. However, critics question the effectiveness of such crash programmes in a situation where the physical and human resource base remains fragile.56

Foster improved connections between local players and high-performance markets

This would enable firms to tap the “knowledge banks” available in the export and internal markets of larger firms. Arrangements that help internalise economies of scale and scope, lower transaction costs and supply market information to buyers and sellers, should be expanded through:

- Co-operative horizontal networks.
- Supplier-buyer relationships.

The growing opportunities available in international markets in the context of a fluctuating exchange rate regime and a more supportive environment for exports, have attracted a growing number of firms to enter more demanding and knowledge-intensive markets. Export-oriented, industry-specific firm consortia have been formed with the stimulus of both government and private associations. The SME-focused and Sebrae-supported Export Promotion Agency (APEX) has been a major catalyst of consortia in furniture, garments, jewellery, beverages and other light industrial segments. At the same time,
sectoral and geographical SME clusters (sometimes suppliers to the same set of companies), are being set up, often with the support of local industry associations. The trend towards greater SME participation in export markets within firm consortia points to an expanded number of local companies functioning as carriers of knowledge. This promising situation would be reinforced by improving the vertical links between SMEs and larger, knowledge-intensive firms in demanding and high-performance internal markets.

Although subcontracting relationships are common, local firms face a number of obstacles to establishing more permanent, alliance-like relationships with larger producers. In addition to the tax-related disincentives with which subcontracting is burdened (such as PIS, Cofins, CPMF), larger companies increasingly require their suppliers to “follow them around the globe”, which imposes obvious limitations on SMEs (and even on larger domestic firms).

At the same time, many local companies, despite having acquired important capabilities, are not known outside their local markets. While the distortionary tax wedge should be addressed in a forthcoming tax reform, size- and information-related barriers are not directly dealt with and depend to a large extent on the nature and organisation of industry. In high-growth, entry-intensive, regulated industries – such as oil and gas, and telecommunications – the concessions and finance that have been awarded are not independent of local content in investment commitments, thus facilitating vertical links. At least in the case of oil and gas, the creation of institutionally-driven quasi-markets have been instrumental in calling attention to, supplying information on, and enhancing local suppliers. In other sectors, specific, joint government-industry programmes may be required to bring SMEs, in particular, closer to high-performance corporate internal markets.

**Stimulating entrepreneurial drive for the knowledge economy**

Promoting knowledge-based entrepreneurship in the country will require not only a renewed emphasis on science and engineering education, but also:

- Massive training of new entrepreneurs and differentiated technological support.
- Provision of incubators and other supportive structures for new S&E and business-trained entrepreneurs.
The Brazilian Experience

- Enhancing markets linking demand for innovative products and ideas, and their local supply.

A number of programmes and institutions support entrepreneurship, and continued emphasis should be placed on training and technical assistance in order to promote knowledge dissemination. Increasing the number of incubators and science parks is high on the agenda of the government and the private sector, both of which are sensitive to the need to create the physical and institutional conditions for the emergence of new firms capable of creating value on the basis of novel ideas. It is arguable that existing initiatives fill, at least for the moment, basic entrepreneurial requirements for support, although more could be done in supplying information and linking agents in incipient markets.\textsuperscript{32}

Adding frontier country competences

To deepen its knowledge base, Brazil needs to expand and add leading-edge competences by:

- Translating public resources into scientific output that help the country move further towards the frontier of knowledge.
- Ensuring that research results which have commercial applications are taken to market.

Building an advanced knowledge base

Two important areas must be addressed:

- \textit{The institutional S&T delivery system}. Reorganising the system is possibly the most complex task facing administrators in the country. Greater autonomy in decision making and finance for universities and research institutions should be combined with increased accountability and relevance in teaching and research. Recently, after two years of internal discussions, IMPA (the Pure and Applied Math Institute) became the second research institution in the country to acquire managerial independence for the next five years, in the context of a management contract and a new mode of operation as a “social organisation” with goals and specific targets agreed between government and staff. The dissemination of this model (and its
variants) across institutions holds promise for effective institutional reform. It may be pursued as part of government efforts to improve the allocation of new sources of S&T finance, including the newly instituted sectoral funds for R&D in energy, ICT, transportation, among others.

- **High-level human resources.** The focus should be on attracting “top-notch”, highly-specific human capital, including individuals experienced in the management of complex research projects and capable of leading research teams/labs. Such recruitment efforts must be closely matched with challenging opportunities in new areas of advanced priority research and well-funded projects. In this context, the intellectual property rights regime should be used as an additional incentive for top-level research, improving the speed, lowering the costs and simplifying the patenting process, while preparing institutions and researchers to make effective use of the system, in order to ensure that material and symbolic gains from research are not dissipated or unduly transferred away.

**Translating research results into commercial products**

The country has a significant potential for exploiting research-related commercial applications in, among other areas:

- **Life sciences,** in view of the country’s biodiversity, institutional research strength in the chemical and biological areas, and market dynamism in pharmaceuticals.
- **Energy research,** both fossil and renewable, in addition to the country’s deep-sea oil exploration capabilities, and in view of both the considerable knowledge in hydro systems and pent-up demand for gas-fired plants, and the emergence of diversified energy concerns.
- **ICT,** in view of the rapid growth of the domestic market and the entry of major producers, some of which are already committed to building local research facilities.
- **Aerospace technology,** with a focus on low-orbit satellites with commercial applications, and avionics.

Increasingly, researchers, government officials and industry recognise the importance of bringing research results to market in view of the deficit of economically useful by-products of research, in an environment where little
dialogue has taken place in the past between science institutions and industry. This situation is now changing but, more than simply a different mindset, the means must be present for change to occur. In particular, it will be necessary to:

- Organise sectoral innovation systems or networks involving science-based firms, research institutions, universities, among others, to facilitate the flow of knowledge, with commercial leadership assigned to those bearing financial responsibility for the project, and clearly defined roles for each of the agents involved. The new sectoral funds might be used to structure effective networks, by providing matching funds to research institutions and companies, investing in common facilities, including high-speed information links, connecting institutions and labs, science parks, and leading-edge companies.

- Promote science-based first movers as part of newly funded programmes. This may entail the supply of supportive infrastructure (science parks, advanced information facilities, management consulting, IPR counselling), private-led risk and other finance, and the movement of researchers on a secondment basis from institutions to firms and vice-versa. Universities and research institutes are the breeding grounds for such firms. Proximity to such centres, combined with adequate infrastructure and finance alternatives, are preconditions for the emergence of science-based entrants. Clustering economies of scale and scope, and remedying the dearth of science-based entrepreneurs, call for specialisation and concentration of investments.

- Promote expanded R&D efforts among a larger number of local firms. An open and competitive environment with a strong export orientation provides the basic incentives for firms to innovate. In addition, changes in the tax regime in line with countries which strongly differentiate between R&D and other expenditures, would be an important measure, providing a focal point for management and significant incentives to bias intra-firm resource allocation decisions. In fact, the potential positive impact of R&D on returns has not percolated down to most firms, even among those actually engaged in formal R&D activities. Often, not even R&D managers are able to convince management and shareholders that R&D pays and is a high-return activity for the firm. The development and diffusion of “user friendly” methods to measure the financial and economic impact of such activities are acquiring increasing relevance.
Finally, promote new programmes directed towards attracting knowledge-based FDI to add to or reinforce national competences. At the current stage, the challenge is to bring in mid-level (which can function as a precursor to) and advanced R&D facilities and programmes. A target of 3% of FDI flows directed at investment in R&D – equivalent to USD 0.6-1.0 billion annually – would be realistic within a three-year horizon, provided that the political and administrative forces of the Ministries of Science and Technology, Planning, Development and BNDES can be mobilised around this objective.
IV. CONCLUDING REMARKS

Brazil’s focused and large-scale efforts in science and technology date from the mid-1950s. In 1951, the National Research Council (CNPq) was founded, under the leadership of Admiral Álvaro Alberto, and with an initial preoccupation (justified in the aftermath of the war) centred on research and use of atomic energy. Since that time, the country has invested considerable resources in acquiring an institutional base and developing the human capital to create and disseminate knowledge.

In many ways, these efforts have paid off. The country is now doted with a large and relatively sophisticated scientific and technological base and, despite the many weaknesses of the innovation system, it is arguable that Brazil is on the threshold of crossing the knowledge divide. A combination of a growing awareness of the importance of knowledge in government and society, and the need for more effective use of existing resources, combined with recent successes in highly complex scientific and technological programmes, has demonstrated that high-productivity, frontier science is possible in the country, and that a supportive environment is gradually being put in place for leading-edge innovative firms.

Crossing the knowledge divide will require decisive actions on a number of fronts. In particular, political and economic resources must be mobilised on a scale sufficient to:

- Pursue sustained growth of income and employment, in the context of a stable macroeconomic environment, thereby providing the economic incentives for firms and individuals to accumulate physical and human capital.
- Reduce poverty and improve income distribution by bringing universal quality primary and secondary education and access to information to children and young adults.
- Improve the quality, productivity and effectiveness of institutional research and teaching through reforms which emphasise greater
autonomy and accountability of public universities and research institutions, and by attracting high-level human resources to frontier areas.

- Promote substantially greater engagement of domestic and foreign firms in R&D through the establishment of sectoral innovation networks, the provision of finance, facilities and fiscal incentives in line with international practice, and more active involvement of government agencies, particularly key ministries and BNDES, in attracting knowledge-intensive activities and players to the country.
Table A1. **Gross domestic expenditure on R&D (or S&T) as a percentage of GDP**

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Table A2. **GERD$^1$ by sector of performance in 1996 (or closest year)**

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<th>Higher education</th>
<th>PNP</th>
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$^1$ Gross Domestic Expenditure on R&D.

Table A3. **Number of researchers in head-counts and/or full-time equivalent (FTE)**

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Table A4. **Resident patent applications (RES) and inventiveness coefficient (INV)**

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<td>100 216</td>
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1. The inventiveness coefficient is the number of patent applications per 10 000 population.

NOTES

1. Country i and product j RCA is defined as \( \frac{X_{ij}}{X_i} / \frac{X_{wj}}{X_w} \); that is, the ratio of country i’s exports of product j over its total exports, over world exports of product j over world total exports. The higher that ratio, the stronger the country’s revealed comparative advantage in that product.

2. In the period 1990-97, for example, among the ten highest growth exports (with average growth rates above 12.5% per annum), eight were in the middle-high- to high-technology category, including the top three. Other high-growth products included certain textiles and garments, as well as vegetable oils, fats and related commodities. Despite revealing comparative advantage in these product groups, Brazil has continued to lose market share.


4. Equally importantly, a number of international firms operating in Brazil are progressively localising knowledge-intensive activities in the country, whether in terms of R&D&E, management or other value-critical functions (mostly in transport material, as in the case of Fiat, GM and VW, which have important testing facilities in the country and are engaged in developing local designs), but also in telecommunications equipment and software, where players such as Siemens, Ericsson and Motorola, have decided to set up research facilities, mostly clustered in the Sao Paulo’s Campinas region. See *Gazeta Mercantil*, 25 January 2001, p. C3.

5. According to the Brazilian Census Bureau (Instituto Brasileiro de Geografia e Estatística – IBGE).

6. Unless otherwise noted, data used on this and the following page are taken from IBGE’s national household surveys.

7. Simulation results by Marcelo Néri, head of the Centre for Social Policies of the Fundação Getúlio Vargas, showed that a combination of 4% annual income growth over five years and a 10% reduction in inequality – quite plausible for a country with such high and persistent levels of concentration – would reduce the proportion of the poor from 29.3% (49.7 million) to 15.8% (26.8 million) by the end of the period. See Valor, 6 March 2001.
8. See Portero (2000), except for Brazil.


10. Brazil has experienced rapid growth in the number of Internet hosts (668,000 or 39.3 per 10,000 inhabitants by end-2000, compared to 74,458 in 1996, a 8.5-fold per capita increase). Still, at 3.93 per 1,000 inhabitants, it compares unfavourably with the penetration rate in the OECD area, which stood at an average of 81.5 in October 2000. See OECD (2001).

11. By comparison, Mexico’s penetration rate was 37.3; Argentina’s 39.2; Chile, 54.1; Spain’s 22.1; and the United States, 406.7. See Ministry of Science and Technology (2000a).

12. The restrictions affect both public and private institutions. According to the Sindicato dos Estabelecimentos de Ensino of the municipality of Rio, a relatively wealthy region, in early 2001 only 60% of private schools had “computer labs”; that is, used computers for classroom purposes, as opposed to a projected 95% three years ago. The alleged reasons are the financial constraints facing schools’ investments in equipment and pay for services.


14. Indeed, it is arguable that the issue of access to information becomes, to a point, subsidiary, since facilitating access, no matter how positive a step it is, contributes little to the spread of knowledge. Without education, information has a limited economic impact.

15. Brazil’s HDI progress cannot be discounted: 0.639 in base year 1975, 0.674 in 1980, 0.687 in 1985, 0.706 in 1990, 0.739 in 1997 and 0.747 in 1998.

16. Most Latin American countries have HDIs classified in the middle range, with the exception of Argentina (0.837), Chile (0.826), Uruguay (0.825) and Haiti (0.440). Costa Rica, at 0.797, is very close to becoming a high HDI country.


18. Although it is clear that Brazil seems to be under-spending in primary and secondary education relative to comparator countries, in private discussions with Carlos H. de Brito Cruz of Unicamp and Fapesp, it was pointed out that the country is over-spending in university education, insofar as public
university budgets (both state and federal) include both university hospital expenditures and resources allocated to pay university personnel pensions (each of which accounts for roughly between one-fifth and one-third of the total budget).


21. According to the Ministry of Labor and Employment (MTE) cadaster for the year 2000, individuals hired by industry in that year had on average 6.8 years of schooling, with 11.7% having less than four years, and 8.5 % having university training.

22. The notion of productivity differentials between private and public subsystems should be treated with caution, insofar as measures usually look at incoming students per university staff/professor. However, if the focus were on outgoing students, the differences between public and private institutions would remain, but would be significantly lower. Moreover, despite the rapid growth in the number of professors with graduate degrees in private universities (as they attempt to conform to the 1996 legislation – Lei de Diretrizes e Bases da Educação), data from INEP (Instituto Nacional de Estudos e Pesquisas Educacionais), show that, as of 1999, federal and state universities still employed significantly more qualified faculty than private and philanthropic institutions. Among the former, 67% and 61% of professors had Masters’ and doctoral degrees, while among the latter, this was the case for only 44% and 38% of faculty (the legislation requires a minimum of 33%). The differences were even more pronounced in the proportion of full-time faculty with graduate degrees: 89% and 85% vs. 29% and 23%, respectively.


24. The propensity to export of MNCs located in Brazil (at 12.2%) is not significantly different than that of those in India (8%), China (12%) or Japan (13%), but remains well below the ratios for MNCs located in France (32%), Chinese Taipei (35%), Finland (39%) and Malaysia (42%), among others. See UNCTAD, *World Investment Report*, 2000.

25. It is telling that among the factors favouring entrepreneurialism in the GEM survey, education and training was the one which contributed least in Brazil relative to other factors.

26. Data from Anprotec (Associação Nacional de Entidades Promotoras de Empreendimentos de Tecnologias Avançadas). The number of incubators
experienced a strong boost after 1994, at which time there were just 19 units in the country. This coincided with a period of macro stability and economic recovery. The growth in the number of incubators goes hand in hand with expansion, with demand for spots being driven by commercially successful experiences, integrated support. They are fast becoming a focal point for venture capitalists. Cietec, hosted by the University of S. Paulo, is expected to expand from 15 to 134 units by end 2001, while the acclaimed incubator at Rio’s Catholic University will increase from 24 to 50-60 spots.

27. Data from CNPq (National Research Council) and Anprotec.


29. The Parque Tecnológico Alfa, in Santa Catarina, is an ongoing concern, housing both incubated and larger companies on its premises. It has an emphasis on software and IT technologies, taking advantage of a strong engineering programme at the university, dynamic internal markets of major local companies (telecommunications and electrical utility firms), and a highly entrepreneurial and organised community. In Rio, clustered around the Federal University (with 38,000 students and 350 undergraduate and graduate courses), a technology park (Parqtec) is being set up to host 120-150 SMEs, including those currently incubated at Coppe (the university’s highly regarded graduate engineering programme), in addition to new laboratories in telecommunications (for Embratel), oceanography (for Petrobras), and taking advantage of the proximity of a number of research institutions. The Federal University of Pernambuco, with 1,700 professors, 20,000 undergraduates and 6,000 graduate students, has been an important nexus of collaborative efforts with the productive sector, deriving close to USD 35 million from contract work (over six times as much as four years ago in nominal terms – BRL 65 million vs. BRL 10 million), organised by the Office for Technological Integration (Intec). Although the university has undertaken significant collaborative efforts in areas such as chemistry, pharmacy and life sciences, a major undertaking is in IT technology, the so-called Digital Port, a technology park which is expected to attract by end-2002 approximately 100 companies, incubate an additional 70 graduate and 180 software engineers, and train 3,500 professionals, with the engagement of major companies such as Siemens, Motorola, Microsoft, among others. The Port will include a venture capital fund (Fundo de Capital de Risco) and a human capital fund (Fundo de Capital Humano), the latter providing matching funds (on a one-to-one basis) to companies’ training programmes. It is expected that the contribution of IT to Pernambuco’s economy will grow from the current 6% to 10% by 2002.

31. The Cenatecs are industry-supported centres which cover a broad spectrum of sectors, ranging from automotive, chemicals and petrochemicals, IT, to shoes, leather, furniture, construction and food. They provide a mix of services, ranging from education and training to technical assistance. The “Dial Technology” is a demand-driven service offering immediate and over-the-phone support and on-the-spot technical assistance, to micro enterprises and SMEs. It originated at the S. Paulo University in 1991 and has been replicated by a number of other institutions and industry associations over the last few years.

32. Data from Ministry of Science and Technology and CNPq. See www.mct.gov.br.

33. These data are taken from the fourth CNPq Census (published in the “Diretório dos Grupos de Pesquisa”), which provides an estimated 80%+ coverage of the relevant universe. Compared to 1993, the date of the first Census, there has been a more than two-fold increase in the number of institutions (224 vs. 99), research groups (11 760 vs. 4 404), researchers (48 781 vs. 21 541), and doctorate holders (27 662 vs. 10 994). Even taking into account an enlargement of the total coverage, the differences suggest a substantial gain over a seven-year period. Brito (2000) argues that there is a significant undercount of the number of researchers. According to his estimates, there are some 77 861 scientists and engineers performing R&D in the country. This estimate seems to be rather on the high side, depending, of course, on how restrictive a definition of R&D one uses and whether one accepts Brito’s premise that all full-time professors are by definition engaged in R&D (which seems unlikely given the nature of the university system).

34. Data drawn from the Institute for Scientific Information, “National Science Indicators”, and MCT.

35. For an alternative view which emphasises the important aggregate gains in Brazilian science based on the significant increase in the numbers of papers published internationally in science citation indexed journals, see Brito (2000). He argues in his comments to this paper that, on a per dollar basis (abstracting from PPP considerations), Brazilian science – on the basis of more recent figures of publications alone, approximately 200 000 for the United States and 10 000 for Brazil – would be twice as effective as the US effort. Clearly, this discussion requires more detailed information than is currently available.

36. In part, the results derived from a patented method Orestes, originally developed in 1997 in the Belo Horizonte unit of the Fundação Oswaldo Cruz, by E. Dias Neto, a biochemist working on his dissertation under Andrew Simpson, an emigré UK scientist who has played a critical role in genomic research in Brazil, as a means of arriving at the centre of the genes (the
protein-producing genetic material) of the *Schistosoma Mansoni*, responsible for schistosomiasis, and later applied to the human genome (with collaboration of oncologist R. Bretanni, Director of the Ludwig Institute in S. Paulo) for the Cancer Genome project. The country is second as being second only to the United States in its effort to map the genes associated with cancer.

Just as the BRGene consortia was readying itself by acquiring 25 MegaBace 500 DNA analysis sequencing systems, 35 MegaBACE 1000 systems were bought by the Hangzhou Genomics Institute, a subsidiary of Beijing Genomics Institute, to deepen its work in the human genome, and focus on sequencing superhybrid rice and on the genome of pigs (in collaboration with the Danes). According to the president of the international division of APBiotech, the manufacturer of the equipment, Brazil, China, Korea and Israel are perceived as emerging powers in the area of genetic sequencing. See *Gazeta Mercantil*, 22 January 2001.

Among the institutions involved in RioGene are the Federal University (the medical biochemistry and the biophysics institutes), the Northern State University (UENF), the University of the State of Rio, Embrapa Agrobioló gia, the National Institute of Cancer (INCA), the National Institute of Pure and Applied Math (INPA) and the National Lab for Scientific Computation (LNCC), the leading institution in bioinformatics (which will offer a Master’s and PhD programme in the area).

One institution which in many ways represents the country’s long-term commitment to research in health care and related areas is the 100-year old, 3 200-staff Fundação Oswaldo Cruz (Fiocruz), a leading centre for tropical disease research and teaching, which co-operates with over 26 countries in research and technological development. Fiocruz is currently undertaking over 1 200 projects in research, development and production for public health programmes of drugs (sometimes in partnership with pharmaceutical companies such as Merck, Novartis, among others), vaccines (it produces 170 million doses per year, while the S. Paulo based Instituto Butanta – a leading institution – adds another 70 million, thus combined supplying 75% of domestic needs), testing kits, among others. Fiocruz is currently leading projects in the genetic sequencing of human parasites, with the support of the World Health Organization, having started with the Chagas Disease *Trypanosoma Cruzi* and schistosomiasis’ *Schistosoma mansoni*, to be followed in 2001 with the protozoa *P. falciparum*, responsible for malaria.

It is estimated that Brazil produces 1.2% of world’s scientific output, twice the share of a decade earlier, although with significant variations according to areas – in structural biology, for example, this share would be just 0.3%. See the interview of R. Meneghini, Director of LNLS’s Center for Structural Molecular Biology, *Gazeta Mercantil*, 20 February 2001. Further, the
number of graduating PhD students is in the order of 5 000 yearly, comparable with OECD countries such as Switzerland and Italy. In any case, patent activity is inconsistent with both scientific resources and results, as well as industry R&D allocations. This results partly from the high costs of patenting; and partly to a culture which has yet to focus on intellectual property rights.

41. The China-Brazil satellite development and launching programme utilises Chinese launching vehicles (Long March rockets). The programme, which has been recently extended, has absorbed an estimated total of USD 400 million, with China’s contribution in the order of 70%, and Brazil contributing the remainder.

42. Among the time-reducing tools employed by Embraer are a centre for virtual reality, a knowledge-based engineering (KBE) system making use of artificial intelligence and capable of drastically shrinking the development cycle for certain parts and components (in one instance, reducing the cycle from 200 to just 20 days), specially designed numerically controlled machines which will increase the level of automation in the assembly of aircraft structures from 15% to 80%, among others.


46. According to the Instituto de Economia Aplicada (IPEA), “Boletim de Conjuntura”, January issue, GDP growth is expected to reach 4.6% this year, with a Central Bank inflation target of 4%.

47. These projections are part of a January 2001 IMF report on the Brazilian economy.

48. Central Bank data.


50. A broad measure of the cost of capital is the interest spread of Brazilian bonds over US T-bonds of the same duration. In early January 2001, long-term (30-year) Brazilian Government bonds had a spread of 805 basis points, while Mexican papers of an even higher maturity (36 years) were 418 basis points above Treasury. For short-term papers, the respective spreads were 535 vs. 366 basis points, although Brazilian bonds’ maturity was considerably shorter than Mexico’s (2004 and 2008, respectively). At the same time, real interest rates (so-called basic or Selic rates) in early 2001
were approximately 10.9% (while the financial intermediation wedge implies significantly higher rates to producers and consumers), an improvement over those of a year earlier (13.2%), but still above the rates practised in most countries with stable, low-inflation economies. Term or investment credit markets are still thin, with finance concentrated in BNDES, the country’s well-regarded development bank, with a post-stabilisation addition of instruments issued by “triple A” companies (mostly debentures).

51. Driven by the fiscal requirements of macro stability, the country’s total tax burden stood at 31.6% of GDP at end-2000, a historical record (in the last 50 years, total taxation as a proportion of GDP increased from 14.4% in 1950, to 17.4% in 1960, 26% in 1970, 24.5% in 1980 and 28.8% in 1990), considerably above other industrialising countries (which ranged from 17.9% in Korea and 19.9% in Chile to 22% in Malaysia in 1990), while generally inconsistent with the quality of services provided by the state. In addition, the present taxation system introduces substantial distortion, penalising production and investment in general, as well as low-income consumers, while providing limited relief to innovating or knowledge-intensive companies.

52. When this approach was first tested, in the city of Campinas in 1995, out of total of 550 street children, only 70 remained on the streets two years later. Since then, many such programmes have been implemented at both city and state levels. At the federal level, the expanded Bolsa Escola, uses bank branches, post offices and lottery houses to distribute cash which is accessible on a monthly basis using a magnetic card given to the family. It is worth noting that mothers have control over the cash received, on the premise that they tend to make wiser spending decisions than other family members. For a brief description, see de Souza (2001). Critics of the Federal programme emphasise the relatively small amounts distributed in its expanded version, noting the trade-off between scope and effectiveness. See Gazeta Mercantil, 17 April 2001, p. A-10.

53. A telling example is that of Embraer, one of the companies with the highest excess demand for engineers in a given specialty in the country. Currently employing 11 000 workers (of which approximately 1 500 engineers, mainly graduates from the highly regarded Air Force Technological Institute – ITA), it is expected to grow to 15 000 within four years. In the short term, Embraer is hiring 300-350 aeronautical engineers, approximately 150 from Eastern Europe and the remainder trained in a new USD 5.8 million (2001 budget), 18-month (permanent) programme, which will train engineers from other specialities into aeronautical sciences. Out of 2 000 candidates, 165 will enter the programme, which requires fluent English and a 25-28 age bracket. See Valor, 8 February 2001, p. A12, and Gazeta Mercantil, 8 February 2001 and 9 March 2001.
54. The Brazilian Government recently commissioned a low-cost machine from the Department of Computer Sciences of the Federal University of Minas Gerais, which unveiled a prototype to be mass-manufactured and marketed for BRL 500 each, according to newspaper accounts. Many in the industry are sceptical of the ability to reach such cost levels even after gaining scale, and the commercial viability of what is basically a connection machine, which has been tried and failed in other markets (with both PCs and TVs). See Valor, 2-4 February 2001, and O Globo, 31 January 2001.

55. According to IDC, computer sales in Brazil reached 3.1 million in 2000, a 40.9% increase over the previous year.

56. It has been shown that the consumption of durables among the middle, lower middle and working classes is basically determined by the size of the instalment rather than by the price of the good itself or other variables.

57. By end-1999, only 3.2% of public primary schools and 10% of secondary public schools were connected to the Internet., according to the Ministry of Education. See MCT (April 2000).

58. The Fust (Fundo de Universalização de Sistema de Telecomunicações) will raise approximately USD 500 million in 2001, and will focus on the telecommunication needs of the education and health sectors.

59. The programme will present a challenge to telecom operators, who will need to link schools to the Net, while only 164 municipalities – the economically better off – have points of access to the main Internet backbones, the rest being condemned to use slow telephone lines and pay long-distance rates. According to the draft tender documents, operators would need to provide 9 100 connections at 64 kbs, 2 900 at 128 kbs and 1 220 at 256 kbs., all dedicated circuits with direct links to the backbone. It is questionable if this will be feasible within such a short period.

60. Thus, for example, 15 Embraer suppliers of small metal-based parts and components are co-operating to upgrade technology and export to countries which are Embraer’s US and European risk partners in new and existing projects, with the sponsorship and active involvement of the regional directorate of the Centro da Indústria do Estado de S. Paulo (CIESP). See Gazeta Mercantil, “Por Conta Própria”, 31 January - 6 February 2001, p. 3.

61. In the oil industry, for example, ONIP – a public-private initiative – has been instrumental in improving the information flows and co-ordination between the many new players which entered the country with the end of the Petrobrás monopoly in exploration and transport of oil and gas, and the tendering out of exploration both on the continental shelf and on land, and local firms which for the last 20 or so years have been active in Petrobrás’ Procap deep-water oil exploration programmes, among others. ONIP itself
has been patterned after the perceived success of Norway and the United Kingdom in developing suppliers and subcontractors for the North Sea oil works.

62. A recent example is Firjan’s (Rio’s Industrial Federation) industrial residues and waste exchange, which has effectively linked innovators in environmental technologies and waste-producing industries.

63. See Gazeta Mercantil, 5 February 2001. Three years ago, the Laboratório Nacional de Luz Síncroton (LNLS) in Campinas became the first research institution to adhere to the new “social organisation” format, by signing a management contract with government. The record suggests both substantial efficiency gains and improved results, with the combination of greater autonomy and accountability.
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