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Innovation systems and technological specialization in Latin America and the Caribbean

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Abstract

This paper examines the National Systems of Innovation (NSI) of Latin American and Caribbean (LAC) countries and attempts to assess their performances. Although it points out at a number of specific successes, overall, the region's NSI have evolved since their inception in the 1950s into weak entities. Science and technology institutions and organisations are not fully performing an enabling role; links and interactions between government support organisations, businesses and academia are tenuous; investment in intangibles and human capital is low; and, public policy is only partially effective. The main result of such weakness is that LAC countries' innovative performance has, as measured by the index of the technological specialisation (ITS) which relates the world's normalised shares of high- to low-tech exports, with the only exception perhaps of Mexico, remained stagnant or has fallen and has lost relatively to many countries that started at similar levels twenty years ago. © 1998 Elsevier Science B.V. All rights reserved

Keywords: National systems of innovation; Technological specialisation; Latin America; Caribbean countries; Technology policy

1. Introduction

Following World War II, the need to move from lower to higher value-added activities and to create employment, coupled with intellectual developments at the then United Nations Economic Commission for Latin America, led most governments in the region to introduce import substitution policies aimed at accelerating industrial growth through the production of manufactured goods for the local market. Initially, import substitution policies were quite successful in speeding industrialization. Between 1955 and 1975, the industry of Latin American and Caribbean countries (LAC) grew at an annual rate of 6.9%. The share of industry in total output grew from around 17.5% in 1950 to 24.6% in 1980. Most consumer goods and basic inputs such as glass, steel, paper, cement, basic chemicals, petrochemicals and vehicles were substituted, as were some simpler capital goods. Industry was unable, however, to compete successfully in international markets and to generate the foreign exchange needed to finance the progression towards producing more technically advanced goods. Growing foreign debt provided initial

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balance of payments relief, but by the early 1980s, LAC countries were no longer able to keep up with their payments. Since the early 1990s the region has been improving its exports and foreign payments position, but moving towards higher value-added products is proving as elusive as ever.

Much of the analysis of LAC's economic maladies has focused on the macroeconomic level. Lax monetary and fiscal policies, unrealistic exchange rates, macroeconomic mismanagement and instability and excessive government intervention have all been considered as key factors accounting for the dire international competitiveness of the region. Another strand of literature has focused on low rates of investment as the root cause of poor competitive performance (CEPAL, 1994a). [2]

While macroeconomic and investment factors played a role, in this paper we argue that technological variables had an equally significant role in accounting for the recent economic performance of LAC. This view contrasts with some current Latin American thought that contends that technology change is meaningless in a context of export growth and that long-term integration into the world markets can be achieved through sound macroeconomic policies and exports of natural resources or low-tech products.

Indeed, the underlying issue in this paper is that there are great complementarities for development between a sound macroeconomic policy, a high rate of investment coupled with efficient use of natural resources, and sustained technological change and innovation in terms of the ability to compete in *knowledge-intensive* or *high-technology* sectors (Krugman, 1979, 1981, 1987; Grossman and Helpman, 1991; Porter, 1990). The capacity to develop knowledge-intensive or high-tech sectors has been a central theme of an extensive body of literature on National Systems of Innovation (NSI). The introduction of new advanced products and processes, both locally and internationally, is seen by this literature as the result of the functioning and interactions of the institutions, organisations, investments and policies of the NSI.

The present paper is an attempt to assess LAC countries' NSI and international innovative performance in advanced industries/products. The paper is organized into five sections. Section 2 discusses the concept of NSI. Section 3 analyses the functioning of LAC countries' NSI. After reviewing some technology output indicators, Section 4 introduces the index of technological specialization (ITS) as an indicator of innovative performance and looks into LAC's long-run competitiveness in high-technology industries/products on the basis of this index. The paper ends with some conclusions in Section 5.

2. The National System of Innovation framework

The concept of National System of Innovation has been recently brought again into light by Freeman (1987) and has since been widely disseminated by Edquist (1997), Lundvall (1992), Nelson and Rosenberg (1993), Niosi et al. (1993) and OECD (1992). [3] Freeman (1987) defined the NSI as "the network of

[2] The proportion of investment in GDP fell from 24.2% between 1976–1982 to around 17% between 1983–1989 and to 16.6% in the early 1990s (CEPAL, 1994a). Between 1973–1993, the rate of growth of machine tool consumption, a key component of investment, was much lower in Latin America than in all the developing and developed world (Alcorta, 1995).

[3] The origins of the concepts can be traced back to List in the last century (Archibugi and Michie, 1995; Freeman, 1995). List pointed at the importance of knowledge, links between science and technology institutions and productive sector and foreign technologies for economic development. NSI ideas, although mainly restricted to formalised R&D and technical education, underlied most of the work of the Organization for Economic Cooperation and Development (OECD) on science and technology during the 1960s and 1970s (Freeman, 1995). Close personal ties between OECD and the Organisation of American States (OAS) meant that NSI ideas began to spill over into OAS's work on science and technology planning and more widely into the Latin American discussion on innovation (Sagasti, 1983). Indeed, a similar concept to the NSI was explicitly used in the Latin American literature and by policy makers as illustrated by Brazil's 1968–1969 national development plan which proposed the creation of a 'National System of Scientific and Technological Development' (Dahlman and Frischtak, 1993; Sagasti, 1983).

institutions of private and public sectors, whose activities and interactions initiate, import, modify, and diffuse new technologies'' (p. 1). Lundvall (1992) defined a NSI in terms of ''elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ..., either located within or rooted inside the borders of a nation state'' (p. 2). Nelson and Rosenberg (1993) conceptualised the NSI in terms of the set of institutions whose interactions result in firms designing and developing products and processes that are new to them.

While definitions are quite similar at face value, there are some differences in meaning, emphasis and use of the concept. One source of difference arises out of whether the NSI should encompass a well-defined specific science and technology set of institutions and organisations or should it be broader so that it includes production, marketing, finance or any other relevant body. Or, put in slightly different terms, what are the internal limits to the NSI? The second difference refers to the extent to which NSI are, in fact, 'national'. At one side of the spectrum, there are those that stress that globalisation and the increasing international links between scientists and diffusion processes are rendering the NSI a very open system and at the other are those that point out that differences in size and resource availability accompanied by common history, culture, language, laws and policies still reifies a NSI. To make diversity even wider, and matters more interesting, together with the issue of external geographical NSI delimitation there are the issues of whether and to what extent there are supraregional, regional or sectoral systems of innovation. The third contrast arises from the concept of innovation itself, with some authors focusing mainly on technological innovations while others having a broader understanding of innovation so as to include organisational and institutional innovations. A fourth variance emerges from the concept of systems with some viewing it as a simple aggregation of institutions or sectors while others pointing at the synergies that originate from their joint operation. Finally, differences emanate from the importance ascribed to each element in the system with some putting the accent on institutions, and certain kinds of them, and others on their relationships.

It would be pretentious to define NSI concepts and interrelations as a theory (Edquist, 1997). In addition to differences in approaches and emphasis there would seem to be too many variables and determinants at play and their precise interactions and causalities are difficult to establish. [4] Relationships are sometimes broad and diffuse and there is always the risk of being so general that everything and nothing is explained. A 'theory' of NSI would either be very ambiguous or could easily become tautological. Yet, Edquist (1997) also argued that NSI ideas can be of great help if they are seen not so much as a theoretical construct, not even of the appreciative type, but as a *conceptual framework* or ''a kind of 'wide trawl' intended to capture the processes of innovation, their determinants and some of their consequences (e.g., productivity growth and employment) in a useful way.'' (pp. 28–29). There are sufficient plausible common elements and understanding in the NSI literature to guide the interpretation of the key issues. And, through the refining and clarification of concepts and causalities the NSI framework could eventually graduate into theoretical status. [5]

The NSI framework, therefore, involves *institutions and organisations* (Edquist and Johnson, 1997; Galli and Teubal, 1997; Smith, 1997). Institutions are the rules and laws, established practices and common habits and routines that govern the behaviour of organisations and the individuals that conform them. Their main functions are to reduce uncertainty, regulate interaction and provide incentives. Arguably, the main NSI institution is the intellectual property protection regime. Organisations are the formalised structures or bodies that operate the NSI. They are the players or actors with predetermined roles within the innovation process, including basic and applied research; knowledge dissemination; invention; product and process research, design,

[4] As an anonymous referee pointed out, the main implication for empirical research of such variety of approaches, determinants and possible causalities is that it is difficult to identify clear guidelines as to what variables should be emphasised.

[5] Edquist (1997) also pointed out that NSI ideas are firmly rooted in evolutionary theories of technical change.

experimentation and development; and, new product commercialisation. Among others the organisations involved are schools and universities, industrial and government research laboratories, information providing and regulatory agencies or 'knowledge' infrastructure agencies and private and public firms.

Within organisations, however, firms play a central role in the NSI. It is they which are responsible for innovating. They must develop the competencies in product design and production, in overall management and assessment of consumer needs and in linking to upstream and downstream suppliers and distributors. It is they that must search, develop R&D 'routines' and further engage in the learning processes for innovation (Dosi et al., 1994; Nelson and Winter, 1982; Teubal, 1995).

Organisations *link and interact* in order to benefit from each other's knowledge and competencies (Lundvall, 1992; Galli and Teubal, 1997). Each organisation provides the NSI with specific kinds of knowledge, all of which are necessary for successful innovative performance. Universities provide scientific theory and engineering principles, laboratories bring in specifications on products, components and materials, firms supply knowledge on how components interact and user firms provide information on emerging technological opportunities and the performance of products. These interactions do not only involve markets but personal, professional acquaintances and institutional relations are important too. Interactions also result from the constant creation during the innovation process of tacit knowledge; i.e., the understanding of how techniques, methods, designs and processes work without knowing why (Foray, 1997; Senker and Faulkner, 1996). Tacit knowledge typically arises out of the complexity of the analyses involved and the constant resorting to experimentation and testing which characterises innovation. It cannot be easily codified nor transmitted in written form but through demonstration and discussion.

The key driver of the NSI is the level and efficiency of the *intangible investments* it undertakes (OECD, 1992). Intangible investments are outlays aimed at increasing the stock of knowledge other than through the purchase of physical assets. They include investments in technology, such as R&D expenditure and patents and licenses payments, and investments in education and training, in management techniques and support systems and in the formation of technological and commercial links with other organisations. Investment in intangibles is the main source of growth and knowledge accumulation of the NSI. Intangibles complement physical investments in the sense that they also contribute to establishing the conditions for creating productive resources, but unlike physical investment, technological outlays may not face decreasing returns.

Public policy, in turn, provides direction and coordination to the NSI (Dalum et al., 1992; Freeman and Soete, 1997; Galli and Teubal, 1997; Nelson, 1993). It is generally accepted that governments must support socially useful basic research that would have not been undertaken by the market because it may be too risky. But public policy's role in the NSI goes well beyond that. Because of the number and variety of institutions and organisations and of possible interactions, both market and non-market, it is necessary to introduce mechanisms that will coordinate them. Moreover, apart from their role in establishing and enforcing institutions, governments can impinge the NSI with a specific direction by setting priorities and providing incentives. The two main mechanisms for public policy are the funding of university or government research and programs directly supporting different aspects of the innovation process.

The outcome of the NSI is *cumulative* in that it results from the often slow and combined aggregation of the impact of institutions, organisations, intangible investments and public policy and their interactions (Lundvall, 1992). The output of the NSI can be measured in terms of indicators such as numbers of new products, share of sales derived from new products, patents, or a combination of them. Innovative performance, however, should not only be assessed through the use of quantitative changes in new products or patents as they do not fully reflect the extent of innovative activity, but also through the analysis of the distribution of technological activities or 'specialisation' across different sectors (Archibugi and Pianta, 1992). Technological specialisation indicators are particularly useful in identifying national areas of excellence, providing a qualitative assessment of aggregate performance and identifying the direction of future developments.

3. The functioning of LAC's national systems of innovation

3.1. The origins and evolution of the NSI

LAC's scientific and technological organisations had been established since the last century, although it is only in the 1950s that economy-wide research coordinating organisations emerged throughout the region. The National Institute for Scientific Research (INIC) was created in Mexico in 1950. INIC was the precursor of the Consejo Nacional de Ciencia y Tecnología (CONACYT), which is today in charge of defining Mexico's national policy for science and technology (Nadal, 1993). Its main objectives were to promote science and technology and to link scientific and technological research with productive activities. The Brazilian National Research Council (CNPq) was established in 1951 both to promote research in all areas of human knowledge and to prepare Brazil to use its mineral resources for the production of atomic energy (Dahlman and Frischtak, 1993). Argentina's National Council for Science and Technology was created in 1958 with the purpose of "promoting, coordinating and carrying out research both in applied and pure sciences" (p. 467 of Katz and Bercovich, 1993). Underlying the creation of these organisations were UNESCO's suggestions to create bodies formulating and implementing a comprehensive science and technology policy (Nadal, 1993).

During the 1960s and 1970s, LAC countries' NSI further developed their organizational structures. In most countries, the *head* of the system was the Ministry of Planning or the President's Office, supported by a Science and Technology Secretariat or a National Research Council. In Brazil, a Ministry for Science and Technology was eventually created. At ministry level, many countries established sectoral S&T units which, in turn, created or took control of specialized research institutes. In 1972, the Secretariat for Industrial Technology was established at Brazil's Ministry of Industry and Commerce. Its main activities included carrying out R&D programs, funding technological development, supplying technological information, administering a system of property rights, regulating technology transfer through the National Institute of Industrial Property (INPI), and acting as an executive secretariat to the industrial metrology, normalization and quality control center (Dahlman and Frischtak, 1993). Four years later, Cuba established a number of similar institutions aimed at regulating, disseminating and promoting invention, scientific and technical information, use of trade marks, automation, computing, medical technology and the sensible use of natural resources and the environment (Latin American Newsletters, 1983). These institutes were put under the command of the Cuban Academy of Sciences, which headed the system. During the mid-1970s, public universities, research institutes and specialized training centers were established throughout Latin America and brought under the general guidance of their sectoral S&T department and national S&T authority (Sagasti and Cook, 1987).

New intellectual property protection laws were also introduced during this period. In 1971, Brazil introduced an Industrial Property Code which specifies the patent, trademark, and trade secret regimes and in 1973 a Copyrights Law (Frischtak, 1990a,b). Brazilian patent regulations followed international conventions, although patents were not allowed or restricted in pharmaceuticals, chemicals and foodstuff on grounds of the social impact of these products and there was compulsory licensing and patent lapsing rules for patents that had not been used a period after being granted. Copyrights of written works, architectural or engineering designs, music, video and software were protected for between 25 and 60 years much in the way they are done internationally, but trade secrets protection only contemplated disclosure to competitors through 'unfair means', e.g., industrial espionage. Enforcement of intellectual property protection laws through courts was difficult because of long delays in bringing cases to trial, trivial monetary and criminal penalties and a generalised view by judges and the public at large that there is little to gain from stringent protection. In Mexico, a similar legal and enforcement framework was established in 1976 (Sherwood, 1990). Patents were restricted in a number of sectors, terms were shorter than those available internationally and faced compulsory licensing or lapsed if not used locally early on and penalties for infringement of property protection laws were small.

Together with the new organisational and institutional structure also emerged a different approach to policy. Concerns for science and technology were often explicitly incorporated into development plans. Specific science and technology plans, aimed at coordinating, institutionalizing and establishing long and short-term priorities for R&D, were also drawn in most countries (Oro and Sebastián, 1993; Wionczek and Márquez, 1993). Regulations, programs and policies established to implement plans were introduced and were similar throughout the region. In the early 1970s in Brazil, all foreign investors and technology transfer contracts had to be registered and restrictive clauses involving limits on exports, pricing guidelines, use of inputs, purchase of other technology or obligation to transfer to the seller improvements made by the buyer, were forbidden (Dahlman and Frischtak, 1993). Around the same years, Mexico established a Registry of Transfer of Technology, aimed at forbidding restrictive clauses and limiting the duration of technology transfer agreements (Nadal, 1993). Countries like Bolivia, Colombia, Ecuador, Peru, Venezuela and, initially, Chile, under the Andean Pact regional agreement, also set limits to profit repatriation by foreign investors and forced foreign investors to divest in favor of local ones after some years. Also during the early 1970s, Argentina, Mexico, Brazil and Venezuela started technological and human resource development programs in areas such as nuclear energy, telecommunications, petrochemicals, informatics, microelectronics, and biotechnology (Dahlman and Frischtak, 1993; Hobday, 1990; Nadal, 1993; Vaitsos, 1990a,b; Wionczek and Márquez, 1993).

The financing of programs was also begun around the same time and through comparable organisations. Brazil established FUNTEC, FINAME and FINEP to finance technological change. FUNTEC was a special fund created within the National Bank of Economic Development to finance training of specialized technical personnel. FINAME was aimed at funding the development of the local capital goods industry. FINEP financed feasibility studies and project development for investments in sectors and activities considered to be of priority (Bastos, 1993; Dahlman and Frischtak, 1993). In Mexico, CONACYT and the industrial technology development program FONEI started a risk-sharing program whereby they would contribute up to 50%, and could lend the remainder, of the cost of using R&D facilities at universities and government institutions. FONEI, in turn, also had a program, with World Bank resources, of funding or subsidizing R&D, technology assimilation and any technological development program in priority areas or which had special novelty characteristics (Vaitsos, 1990b).

In the 1990s, most of LAC countries' NSI changed in similar directions. Following the debt crisis of the early and mid-1980s, there has been a considerable reduction of state involvement in technological development. Sectoral priorities are no longer established by the state, they are instead left to the market, comparative advantage and profitability. S&T institutions have also been streamlined or eliminated, and previous attempts to develop indigenous technologies through public enterprises in telecommunications or informatics have ceased and firms privatized. Intellectual property protection laws have been strengthened by expanding the scope of patents to previously excluded products and increasing their duration and by introducing tougher penalties (Braga, 1993). Controls and regulations on technology transfer have been eliminated, including provisions that discriminate in favor of local firms, set domestic content requirements or limit the acquisition of foreign capital goods (Nadal, 1993; Vaitsos, 1990b).

There has also been a switch towards focusing what little effort was being made by the state towards the achievement of efficiency and competitiveness both by R&D institutions as well as by firms that could benefit from government programs. The Brazilian Program of Quality and Productivity (PBQP) was started in 1990 aimed at supporting industrial modernization on the basis of horizontal and sectoral subprograms. Measures include the development and diffusion of new managerial methods and new ways of organizing human resources, increasing the awareness and mobilizing firms to better quality and productivity, and the improvement of the articulation between government, university and industry. Quality and productivity programs for parts of the state's national and regional administration were also included (Bastos, 1993). In Mexico, the Center for Technological Innovation (CIT) was created within the National Autonomous University of Mexico (UNAM) with the aim of transferring industrial technology developed at the UNAM, researching on technology project management and ways to promote innovation, establishing training programs on innovation and innovation management, and providing technology-based consultancy services (Dini and Peres, 1994). In Venezuela, the Engineering Institute, aimed at providing engineering services to industry, was also created recently.

3.2. The technological infrastructure

LAC seems to be facing acute general and technological infrastructure deficiencies. There are severe limitations with the regions' general physical infrastructure. Although there are variations per country, LAC's roads, energy and water supply, ports and telecommunications infrastructure, apart from having to cope with very high rates of population growth and unsatisfied demand, have deteriorated considerably due to lack of investment in the late 1980s. Privatization of public services does not seem to be solving the problems of underinvestment, at least in the short run. Indeed, the main immediate effect of privatization has been large increases in the prices of main utilities.

The innovation support organisations are also flawed. A recent evaluation of industrial technology research institutes in LAC summarized in Machado (1993) found that although there were some exceptions industrial research organisations were facing a number of problems, many of which had intensified as a result of recent efforts of macroeconomic stabilization and liberalization.

One of the key problems was that research and services provided were not matched to demand. Finding the right *services-mix* is exceedingly difficult because organisations must keep a balance between satisfying the precise demands of their clients and *keeping an eye* on the technologies of the future and research being done elsewhere (Goldman, 1994). But, by and large, Latin American industrial technology organisations have not been able to keep such a balance. Most entities did not have deep knowledge of advances in technology in their field nor were actively seeking partners, domestically or abroad, that could provide such information. Many research centres were not even aware of public domain technological information and had no experience in reverse engineering and copying which were in great demand by small and medium firms. Research programs are determined on the basis of what the government or individual researchers want and not as a result of a study of what industry needs. There is little consultation with the private sector. There have been recent attempts at commercializing the output of industrial institutes but usually this amounts to establishing a marketing department or hiring public relations personnel, not on understanding clients' demands. Indeed, none of the eight industrial organisations reported by Machado (1993) had ever made a customer satisfaction survey. There are few examples of successful technology transfer from research centres to industry. Often industrial support organisations have become mere rubber-stamp certification agencies.

Another major limitation is the lack of organisational flexibility (Machado, 1993). Industrial support organisations in Latin America are normally organized on rigid functional lines which emphasize vertical progression within the administrative hierarchy, allocate clear lines of responsibility, are based on secrecy and lack of information sharing and make position within the hierarchy and not knowledge the source of authority. The result is that organisations lose their problem solving capabilities, their capacity to establish and operate with purpose-built teams, their ability to communicate and react quickly to private sector and external environment demands, and to use available resources efficiently.

Human resource availability needs to be improved. With the exception of INTEC and the Fundacin Chile in Chile, most of the industrial support organisations in Latin America have a low ratio of professional permanent to temporary staff and very high turnover of professional staff which does not allow for research and organisational continuity. In addition there is a high ratio of support to professional staff adding to the bureaucratic nature of many institutes. There is a total absence of wage, recruitment, promotion and training policies leading to professional frustration and low moral.

In recent years industrial support organisations are also facing severe financial restrictions as a result of fiscal retrenchment. In those organisations that have successfully moved towards self-financing, this has been done at the expense of eliminating what little independent long-term research and development projects they had. Less successful ones are struggling to make ends meet and are being forced to reduce personnel, normally the most capable, and to sell equipment. Some organisations are increasingly dependent on foreign financial assistance.

3.3. Interactions between organisations

The evidence regarding the way parts of the innovation system interact with each other in LAC is limited and fragmented. Regarding the interaction between local users and producers of technology, research in Brazil shows a very successful experience in developing the close cooperative long-term relationship between financial institutions and manufacturers of banking automation equipment (Cassiolato, 1992; CEPAL, 1990; Frischtak, 1991). In the mid-1980s, a number of finance companies decided to automate their operations to increase their competitiveness and because of the high inflation rates of the Brazilian economy required *real time* transactions to avoid losses due to rapidly changing prices. It involved creating a totally integrated computing, accounting and cash-point system, a tall order as this had never been tried before. To do so, both financial and computer companies undertaking the project had to be totally transparent to each other, develop very specific channels and codes of communication and interaction between them and collaborate closely in the design, testing and implementation of the system. After several years of work the task was completed and the Brazilian banking informatics system is recognized as second to none within the industry. It would have not been possible to achieve this had it not been for the uniqueness of the relationship developed between computer companies and financial institutions.

While more examples of this kind can be found, the overall picture is very different. In Colombia, buyer–supplier relationships in most sectors are characterized by antagonism and withholding of information. Reports made by Monitor (1994, 1993) for Colombia and Bolivia point out an historically uncooperative relationship between textiles and apparel manufacturers or an interaction between slaughter houses, tanneries and manufacturers of leather products where information is simply not circulated at all. Colombian flower producers, which require to rapid transport of fresh flowers to the US and European markets, cannot export them because airlines do not want to make available facilities for fresh products. Another study by Alcorta et al. (1997) on technological collaborations in MERCOSUR concluded that there are few technological collaborations between firms of the region and between them and foreign firms. Those collaborations that have emerged are marketing agreements or related mainly to the mechanical engineering industry. On the whole, evidences tend to confirm the view of CEPAL (1990) that there is little interaction between firms in LAC.

Another area of potential linkages is between universities and businesses. Here too the experience is not all that positive despite some recent attempts to improve the situation. According to Plonsky (1993), who summarized a number of studies on university–enterprise cooperation, and Peres (1994), during the import-substitution period there was little interest to cooperate between LAC universities and firms because protected market conditions did not require firms to innovate and universities did not depend financially on the business sector but on the state. Hence, the choice of research was independent of business needs. Over the years the rift between both grew, making it ever so more difficult to link. Since the 1990s a number of modes of cooperation such as transfer offices, university companies, joint programs and projects and national organizations to promote integration between university and industry have emerged. But the evaluation of Velho et al. (1997) on the impact of these attempts in MERCOSUR countries conclude that while they have been well-received by the 'starved-of-funds' academic community, this has not been the case with business which continues to have its own agenda in terms of technological advance. Hence, most programs have had limited success.

3.4. Investment in innovation

3.4.1. Aggregate expenditure in R&D

One of the main characteristics of LAC's system of innovation is its very low level of aggregate expenditure in R&D. Total expenditure in R&D in the region amounted to US$2.9 billion or 0.63% of world expenditure in 1990 (Table 1). As percentage

Table 1
R&D expenditure

	1980	1985	1990	1992[a]
As Percentage of GDP				
World Total	1.85	2.22	2.55	1.76
Developed countries	2.22	2.62	2.92	2.38
Eastern Europe				1.03
Developing countries	0.52	0.54	0.64	0.62
Latin America and Caribbean	0.44	0.43	0.40	0.37
Africa[b]	0.28	0.25	0.25	0.45
Other[c]	0.65	0.68	0.85	0.68
Million US Dollars				
World Total	208,370	271,850	452,590	428,580
Developed countries	195,798	258,834	434,265	371,950
Eastern Europe				7020
Developing countries	12,571	13,016	18,325	49,610
Latin America and Caribbean	3635	3062	2860	3930
Africa[b]	1081	921	1139	1810
Other[c]	7855	9033	14,326	43,870
Structure (%)				
World Total	100.00	100.00	100.00	100.00
Developed countries	93.97	95.21	95.95	86.79
Eastern Europe				1.64
Developing countries	6.03	4.79	4.05	11.58
Latin America and Caribbean	1.74	1.13	0.63	0.92
Africa[b]	0.52	0.34	0.25	0.42
Other[c]	3.77	3.32	3.17	10.24

[a]In purchasing power parity terms.
[b]Only Sub-Saharan Africa until 1990.
[c]Includes China and Middle East in 1992.
Source: Data for 1980–1990 from UNESCO (1994) and data for 1992 from UNESCO (1996).

of GDP, LAC's expenditure fell from 0.44% in 1980 to 0.40% in 1990. During the same period developed countries' R&D ratio over GDP rose from 2.22% to 2.92% while that of other developing countries, including 'tigers' and 'potential tigers,' grew from 0.65% to 0.85%. [6] Brazil's expenditure in R&D over GDP, which is the second highest in the region after Cuba, is only slightly higher than the average for non-African, non-LAC developing countries (see Table 2).

3.4.2. Human resources for R&D

Between 1980 and 1990, the number of R&D scientists and personnel engaged in R&D increased by 87.5% and LAC had the highest number of R&D scientists and engineers per million population in the developing world. Yet, the expenditure per head in LAC is much lower than other non-African developing countries and only 12% higher than that of African countries (Table 3). Assuming an average monthly wage of US$800 per scientist and engineer in developing countries and of US$4000 in developed countries a non-African, non-LAC scientist has left around US$17,750 to spend in materials, support staff and equipment, a developed country scientist

Table 2
R&D and S&T expenditure by country (percentages of GDP)

	Early 1980s	Early 1990s
Argentina (R&D)	0.47	0.30[a]
Bolivia (R&D)	0.07	0.10[c]
Brazil (S&T)	0.72	0.91[f]
Chile (R&D)	0.41	0.71[a]
Colombia (S&T)	0.10	0.50[a]
Costa Rica (S&T)[e]	0.14	0.50[b]
Cuba (R&D)	0.72	0.93[d]
Dominican Republic (R&D)	0.35	n.a.
Ecuador (R&D)	0.13	0.16[c]
El Salvador (R&D)	0.10	0.16[d]
Guatemala (R&D)	0.08	0.15[d]
Honduras (R&D)	0.10	0.20[b]
Jamaica (R&D)	0.10	0.03[d]
Mexico (S&T)	0.44	0.48[b]
Nicaragua (S&T)	0.25	0.40[b]
Panama (R&D)	0.16	0.08[c]
Paraguay (R&D)	0.12	0.29[c]
Peru (R&D)	0.30	0.22[d]
Trinidad and Tobago (R&D)	0.10	0.08[d]
Uruguay (R&D)	0.22	0.59[b]
Venezuela (S&T)	0.34	0.47[b]

[a]Data for 1994.
[b]Data for 1991.
[c]Data for 1990.
[d]Data for the late 1980s.
[e]Data for the early 1980s include only public sector expenditures.
[f]Data for 1995.
Sources: INOVA (1997), Oro and Sebastián (1993), Peres (1994), and UNESCO (1994).

[6] Latin America and the Caribbean includes all countries in the region. G7 includes Canada, France, Germany, Italy, Japan, United Kingdom and United States. *Tigers* comprises of Hong Kong, Korea, Taiwan and Singapore. *Potential tigers* encompasses China, Indonesia, Malaysia and Thailand. European Newly Industrialized Countries (NICs) include Ireland, Greece, Portugal, Spain and Turkey.

Table 3
R&D scientists and engineers

	1980	1985	1990	1992[a]
Number				
World Total	3,920,754	4,402,867	5,223,614	4,334,100
Developed countries	3,452,128	3,834,251	4,463,798	2,367,400
Eastern Europe				738,300
Developing countries	468,626	568,616	759,816	1,228,400
Latin America and Caribbean	86,901	125,395	162,930	158,500
Africa[b]	51,324	56,761	73,081	258,400
Other[c]	330,401	386,460	523,805	811,500
Structure (%)				
World Total	100.00	100.00	100.00	100.00
Developed countries	88.05	87.09	85.45	54.62
Eastern Europe				17.03
Developing countries	11.95	12.91	14.55	28.34
Latin America and Caribbean	2.22	2.85	3.12	3.66
Africa[b]	1.31	1.29	1.40	5.96
Other[c]	8.43	8.78	10.03	18.72
Per Million Population				
World Total	824	920	1000	779
Developed countries	3038	3267	3694	2601
Eastern Europe				1783
Developing countries	144	158	189	264
Latin America and Caribbean	242	312	364	341
Africa[b]	111	106	117	368
Other[c]	136	145	178	264
R&D Expenditure per Scientist and Engineer				
World Total	53,145	61,744	86,643	98,886
Developed countries	56,718	67,506	97,286	157,113
Eastern Europe				9508
Developing countries	26,825	22,891	24,118	40,386
Latin America and Caribbean	41,829	24,419	17,554	24,795
Africa[b]	21,062	16,226	15,585	7005
Other[c]	23,774	23,374	27,350	54,060

[a]Data for R&D expenditure for scientist and engineer is measured in purchasing power parity terms.
[b]Only Sub-Saharan Africa until 1990.
[c]Includes China and Middle East in 1992.
Source: Data for 1980–1990 from UNESCO (1994) and data for 1992 from UNESCO (1996).

and engineer around US$49,286 while a LAC scientist would only have US$7954. Thus, the very low ratio of scientific publications accounted for by LAC scientists (1.3% of the world total in 1985) (CEPAL/UNESCO, 1992).

3.4.3. The structure of R&D

The distribution of R&D resources is also not conducive to technological upgrading. Around 80% of total expenditure is funded by the government, most of which goes to universities (Table 4). The equivalent figure for OECD countries is 43%, for 'tigers' is 36% and for European NICs is 44%. Privately funded R&D expenditure is around 25%, half of what the private sector finances in other regions (CEPAL/UNESCO, 1992).

Moreover, unlike developed and other developing countries which focus most of their R&D expenditure efforts on manufacturing, LAC spends mainly in primary products or primary-products related industries. By the mid-1980s, only 12% of total R&D expenditure by Brazil was in the manufacturing sector, while 55% was in natural resources and agriculture, and 33% in services. For Argentina in the late-1980s, R&D expenditure in manufacturing was

Table 4
R&D by source of funds (percentages)

	Year	Government	Private	Foreign	Others	Total
Argentina	1992	85	8	2	5	100
Brazil	1982	67	20	5	8	100
Brazil[a]	1995	69	22		9	100
Chile	1988	70	18	3	8	100
Chile	1992	87	13			100
Colombia	1990	65	35			100
Costa Rica	1986	92		8		100
Cuba	1992	100				100
El Salvador	1992	47		53		100
Guatemala	1988	37	10	17	36	100
Honduras	1991	23	48	29		100
Mexico	1984	85	15			100
Mexico	1991	77	23			100
Nicaragua	1987	81		19		100
Peru	1984	48	27	21	4	100
Trinidad and Tobago	1984	91	4	3	1	100
Venezuela	1992	100				100

[a]Others includes state-owned firms.
Source: INOVA (1997), Oro and Sebastián (1993), UNCTAD (1993), and OECD (1994).

only 4%, while in natural resources and agriculture, and in services it amounted to 64% and 33% respectively (UNESCO, 1994).

Very little is spent by LAC in experimental development as compared with other regions. In Argentina in 1992, only 6% of the total R&D expenditure was in experimental development. In Mexico in 1989, the same type of expenditure was 34%. By contrast, OECD countries, 'tigers' and European NICs spent 59.5%, 48.5% and 41.2% respectively in 1988–1990 (UNESCO, 1994; CEPAL/UNESCO, 1992).

3.4.4. Enterprise investment in innovation

LAC firms invest little in innovation. The small participation of the private sector in aggregate R&D expenditure financing discussed above is a first indication of such conduct. But there are other indications too. Perhaps the best indication is the research of Matesco (1993, 1994) on the technological effort of Brazilian firms. Being Brazil the most technologically advanced economy in the region, the study should give an indication of the upper limit in innovation effort. The research was based on the 1985 economic census and focused on 59,994 enterprises selling over US$40,000 per year. These enterprises employed 4.8 million people and had overall sales that year of US$199.1 billion.

The main conclusions were that only 3.5% of firms have any R&D expenditure, out of a total of 2117 firms. Within them there were 89 public enterprises of which 17 were innovators. R&D expenditure was concentrated on the largest firms and amounted to 0.4% of total sales. The average expenditure over sales for the whole sample was 0.08%. That same year the average R&D expenditure over sales by USA, French and German firms had been 3%. Half of the firms that had any expenditure in R&D were in mechanical engineering and chemicals. Only 413 firms made any payment for technology transfer, amounting to a total of US 30 million. On the whole, with very few exceptions, firms were not interested in improving their innovative capabilities and the majority of firms had no innovative capacity at all.

Dahlman and Frischtak (1993) reached similar conclusions for Brazil. They found that firms declaring R&D expenditure in their income tax returns fell from 1050 in 1976–1977 to 780 in 1981–1983, but recovered to 1095 in 1985. R&D expenditure over net revenue increased from 0.2% in 1983 to 0.4% in 1985. Expenditure was highly concentrated in state enterprises (62.6%), with eight firms accounting for more than 50%. Only about 25 private industrial groups were responsible for an additional 17.4% of expenditure. They conclude that Brazilian producers are basing their market position on extensive exploitation of natural resources and reliance on low-wage labor rather than on the quality and productivity of labor itself and the introduction of new or better products.

A series of similar studies were conducted in Venezuela (Pirela, 1993; Pirela et al., 1991a,b; CEPAL, 1994a). The studies approached a sales and employment stratified sample of 113 firms in the chemical and petrochemical industry both in 1988 and 1992. The studies found that around 40% of the firms had no knowledge of technological, commercial, organizational, or accounting problems. One-fourth of the firms felt these issues were not important. Two-thirds of the firms had made no change between 1988 and 1992 despite major macroeconomic adjustments in the economy. The studies conclude that there is no *technological culture* among Venezuelan firms. [7]

A third study on innovation in LAC was conducted by Waisbluth et al. (1992). The study has the particularity that it focused on innovative firms and, within them, on the most innovative as the sample was selected from firms that applied for an international innovation award offered by the Spanish government. One hundred firms were selected for the contest and an in-depth research out of 137 applicants and 800 *contacts* for the whole of Latin America and Spain. Usually, an innovative firm was local, exported between 8–15% of total sales, sold around US$3.2 million of which 50% was said to be associated to innovation, spent 4% of its sales in R&D, employed 66 people of which 8 were in R&D and 31% were professionals, and was 25 years old.

[7] Other studies reported in CEPAL (CEPAL, 1994a) point out that Brazilian, Mexican, Chilean and Venezuelan firms in industries like garments and textiles have not adapted their *technological conduct* to the more liberalized and competitive environment that LAC is facing at the moment.

Two-thirds of the firms developed their own product while the rest adapted foreign products or licensed them abroad. More than 23% were in the food and health sector, 18% in machinery, 16% in chemicals, 16% in software and telecommunications, 6% in energy and electricity and 9% in others. The study also provided data about the typical Latin American firm as compared with the typical Latin American *innovative* firm. While the former spent 0.2% of sales in R&D and US$13 per worker in training, employed less than 5% of professionals, exported less than 8% of its production in 1991 and its sales grew 2% in 1989–1991, the latter spent 3.9% of sales in R&D and US$272 per worker in training, employed 31% of professionals, exported 16% of its production in 1991, and its sales grew 16% in 1989–1991.

The empirical literature in the region has provided a few clues as to why there is little investment in innovation by firms. One set of explanations arises from a number of interviews in Chile, Jamaica, Mexico and Venezuela by Macario (1995). The interviews were aimed at examining competitive behavior following liberalization and macroeconomic adjustment. They suggest that firms in these countries when confronted with a critical situation are likely to react by emphasizing commercial and financial solutions, not technological ones. The reason for this is that there is a much larger managerial capacity in commercialization and financial areas because most of the training received by top managers is in these areas. Hence, managers tend to see problems in the light of their experience and training and find solutions along those lines. A reduction in sales or profitability would not be seen, for instance, as a problem of poor product performance or deficient production technology but of, for instance, poor marketing or high debt–equity ratios. Sometimes the assessment of the problem is correct, but not always.

A related explanation is lack of knowledge of the importance of innovation and its main elements. For instance, it may not be known that it is crucial to invest in developing human capital both at managerial and at other levels of the company. Pérez (1994) pointed out that the new forms of management require that workers and staff are no longer treated as a cost but rather as a resource. But this new approach to labor and training is not widely embraced in LAC as only few firms train their staff (CEPAL/UNESCO, 1992). Training of managers in the adequate fields may also be necessary.

A third set of explanations focuses on the lack of medium- and long-term vision. Pirela (1993) and Pirela et al. (1991a,b) argued that local entrepreneurs do not have the capacity and possibilities to engage in medium and long term planning required to invest in innovation either because of lack of information about the future or because of the lack of clear and stable rules which are crucial for long range planning. It becomes very risky for firms under these conditions to commit themselves to long and complex learning processes and to the large sums of money that they sometimes entail.

A final explanation refers to entrepreneurship. According to the study on the 100 innovative firms mentioned above, the main motivation to innovate did not come from highly expected returns, competition pressures, or government incentives but from the entrepreneur's own interest in developing new products, gain prestige or create an inventive environment (Waisbluth et al., 1992). Interestingly enough, these motivations cut across all innovative firms except Spanish ones which were motivated much more by competition than by any altruistic drive or value.

3.5. Human capital formation

It is quite apparent that education and training play a pivotal role in technological change and growth of NSI. Yet, despite early successes in raising the educational level of LAC population and some useful experiences in vocational training, of late LAC does not seem to be forming the level, quality and variety of human resources required for technological upgrading.

Over the last 30 years LAC has steadily increased the number of pupils at school. Although there are some significant variations between countries the share of pupils enrolled in primary education as percentage of pupils in their respective enrollment age grew from 58% in 1960 to 88% in 1990, the share of pupils enrolled in secondary education as percentage of pupils in their respective enrollment age grew from 15% in 1960 to 56% in 1990, while the share of pupils in higher education as percentage of pupils in their respective enrollment age grew from 3% in 1960 to 19% in 1990. This was achieved during a period of fast growth in the number of pupils (CEPAL/UNESCO, 1992).

Improvements in enrollment have been, however, at the expense of the quality and efficiency of education (CEPAL/UNESCO, 1992; Haddad et al., 1990; Labarca, 1995). Students in LAC, particularly in lower-income countries, are learning less than students in developed countries, 'tigers' or 'potential tigers' as measured by mathematics and sciences scores for pupils of similar age. There is also evidence that the knowledge gap is large and has been increasing in recent years. Expenditure per pupil averaged between 1970–1988 US$1758 in the UK, US$3520 in the US, US$4197 in Sweden and US$2344 in Japan (Labarca, 1995). In Turkey in 1984 the expenditure in a primary school pupil was US$816. Expenditure in secondary and tertiary pupils was even higher (Haddad et al., 1990). Argentina's average expenditure in 1990, the highest in the region, was US$349. The performance of other indicators of quality of education such as teacher/pupil ratios, number of hours in class and failure ratios are also poor. One out of every two pupils has to repeat a year during primary education in LAC while the equivalent ratio is only 2% in advanced countries. Typically, a LAC pupil attends between 700–900 hours of classes per year while in Europe this figure amounts to 1200 hours, and in Korea and Japan to 1400 hours. The curriculum used, particularly in secondary education, is outmoded and rigid, focusing almost exclusively on the massing of data, i.e., the *encyclopedia* approach, rather than on the development of rational and critical thought and practical experience and is woefully detached from the demands of both tertiary education and the labour market (Labarca, 1995).

The public university system, which expanded significantly during the 1950s through to the early 1970s by opening new departments and disciplines, introducing an academic career and stimulating research, is increasingly delivering lower-quality education due to falling living standards of academic staff and excessive politicisation and bureaucratization of universities (CEPAL/UNESCO, 1992). Partly this has been compensated by the emergence of private universities and non-university higher education institutions but this has meant that the focus of tertiary education has shifted mainly towards commercial sciences and away from engineering. In addition, or perhaps as a consequence of the shift towards commercial sciences, research and development, which is mainly carried out in LAC at public universities and related research centers has become concentrated in medical sciences and social sciences and humanities (see Table 5).

Despite the success of vocational training schemes, especially those provided by public institutions with close ties with the private sector like SENAI in Brazil, SENA in Colombia and SENATI in Peru, it has not been possible to extend them widely. Again the private sector has stepped in to cover some of the most obvious gaps but the apparent need far exceeds supply. At the end of the 1970s, around 4% of the Brazilian and 12% of the Venezuelan workforce had attended a course in a public training institute; but, by 1987 only 2% of LAC workforce had attended to one of these courses, meaning that a LAC worker only gets two weeks outside training every 50 years (CEPAL, 1994b; CEPAL/UNESCO, 1992).

3.6. Public policy

Several weaknesses in public policy have also become evident. The first is the lack of clarity in objectives in Latin America's innovation system. Perhaps this is better shown in the foreign investment and technology transfer regime. According to Dahlman and Frischtak (1990, 1993) for the last thirty years, Brazilian foreign investment and technology transfer policy's rationale was that foreign firms were using technology payments as a form of remitting profits and not so much to develop a local technological capability. Indeed, during the 1970s there was an intense academic and policy debate on how investment and technology payments were being used as a means of surplus extraction. It followed that the government imposed strict financial controls and external payments regulations on technology payments and profit remittances. These controls may have had the effect of discouraging foreign companies to transfer their most up-to-date technology. A weak domestic property protection regime made it even less worthwhile to transfer more advanced tech-

Table 5
Scientists and engineers engaged in R&D by field of science and technology (percentages)

	Argentina	Chile	Costa Rica	Cuba	Ecuador	Guyana	Mexico	Nicaragua	Peru	Uruguay	Venezuela	Korea	Spain	USA
	1988	1984	1992	1992	1990	1982	1984	1991	1981	1987	1989	1992	1990	1983
Natural Sciences	41	26	19	14	23	73	27	25	14	45	32	19	24	46
Engineering and technology	13	15	7	18	19	9	15	18	4	8	15	45	16	21
Medical Sciences	15	27	25	24	7	n.a.	18	11	6	12	12	20	19	16
Agricultural Sciences	9	10	28	3	27	5	13	32	43	9	18	12	11	9
Social Sciences and Humanities	20	22	14	30	23	14	27	13	14	17	15	n.a.	30	9
Other Fields	2		7	11	n.a.				19	9	7	4		
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: UNESCO (1994) and Oro and Sebastián (1993).

nology because of the risks of copy or imitation. Furthermore, the restrictive nature of a trade policy aimed at promoting a local capital goods industry had the effect of limiting the adoption of advanced technologies even more. Hi-tech industry development was in turn hampered by market reserve limitations which impeded entry to these industries.

A policy that had a clear focus on technological development and not so much on balance-of-payments considerations would have put far less emphasis on financial and payments controls and would have had a more balanced approach to industry and technology import-substitution. Although some technology transfer regulations included provisions to ensure a degree of local absorption, most of these were difficult to put into practice and, much more so, to enforce. A policy focusing on technological development would have also put more emphasis in developing practical mechanisms that ensured local diffusion of the more advanced foreign technologies.

A second related weakness refers to the lack of priorities in technology policies. One of the striking features of Latin America's innovation system is the great number and variety of ad-hoc institutions, programs and policies it is based upon, which in turn mesh with a great number and variety of institutions, programs and policies developed with other purposes. In addition, during the 1980s many Latin American countries started technology development programs in microelectronics, new materials, biotechnology and other frontier areas even though they where no way near to using, let alone producing, the technologies they were allegedly promoting. Hence it is not clear which elements of the system perform a useful function. Katz and Bercovich (1993) pointed out that in Argentina, there are many overlapping research programs, research groups that are just *empty boxes*, and institutions that do not have the minimum critical scale in terms of experimental equipment or qualified personnel required to attain worthwhile results.

Frischtak (1990a) added that a key problem with Brazilian attempts to develop an electronics industry was the lack of specialization. He points out that the industry was exceedingly diverse as it spanned through many subsectors. This diversity and fragmentation did not allow firms to concentrate their limited technological, marketing and financial resources in a smaller set of key products that could have been competitive in international markets and would have allowed them to reap economies of scale. Indeed, the lack of firm, industry and intra-industry specialization seems to be one of the major limitations to Brazil's industrial development.

Another major public policy weakness was its complexity and detail. Peres (1994, 1997) pointed out that industrial and technological policy in LAC tended to cover all aspects and details that were seen as involved in achieving a particular objective. This approach to policy implied that whenever there was a new policy initiative a myriad of laws and regulations had also to change, an extremely cumbersome process. In 1984, Mexico introduced PRONAFICE, the National Program for Industry Promotion and Foreign Trade, aimed at reducing external vulnerability and creating employment through trade specialization, promotion of technological modernization, regional and industrial organization restructuring, and improved coordination between agents. Although the program was somewhat successful in promoting a better relationship between government and industrial firms, it ran into problems two years later, and was scrapped in the late 1980s, because its full implementation involved, among others, setting up or strengthening 76 policy instruments, 33 laws, 66 decrees and 175 presidential resolutions, a total of 274 regulations.

There was also a tendency to increase the scope of plans, programs and instruments to such an extent that they became very difficult to implement. Brazil's industrial and technological policies focused at the level of the industrial sector during the 1950s and 1960s, moved towards more comprehensive industry-specific policies and programs in the 1970s and to even more detailed schemes targeting whole production chains, including technology and marketing-related aspects. The *New Industrial Policy* launched in 1988 was to affect not only the main activities of a specific industry, but also its suppliers of raw materials, components, production and technology services, capital goods and any other activity that affects each industry's competitiveness. The view was that targeting only specific industries might be insufficient because of the linkages between firms and industries. The upshot was that policies could not be applied because they needed a massive administrative, planning and coordinating capacity that was beyond the Brazilian government's capability (Peres, 1994).

Finally, technology organisations and public policy and their beneficiaries are rarely assessed. Although programs and policies are often discontinued or replaced this is normally not the result of a, thorough or otherwise, evaluation. There is no tradition of public policy assessment in LAC and changes occur more often than not due to changes in overall policy direction or due to changes in specific ministries than from any learning from past mistakes or successes. Indeed there are a number of policy success stories whose experiences do not seem to be informing today's policies. In Brazil, the cases of Usiminas, an integrated steel producer; Embraer, a public enterprise manufacturing small commercial and training planes; and Metal Leve, a thriving piston manufacturer and exporter, and the role government institutions played in their success have been thoroughly documented (Dahlman and Frischtak, 1990, 1993; Dahlman et al., 1987). Dini and Peres (1994) have also found effective combinations of government research centres and universities and technologically dynamic private firms in three regions of the state of São Paulo: Campinas—computing, electronics and telecommunications; São Jose dos Campos—aeronautics, electronics and defense; and São Carlos—optics, new materials, precision mechanics and fine chemicals. There are other examples of successful combinations also in Mexico, Venezuela and Chile (Dahlman et al., 1987; Dini and Peres, 1994).

There is also no tradition of demanding tangible results from policy beneficiaries (Alcorta, 1993; Peres, 1994). Much of the debate on industrial and technology policy in Latin America is being carried out in terms of protectionism as opposed to free trade. Yet the evidence in the case of successful countries shows a much more complex picture. It shows that internationally successful firms can operate in extremely protected markets or with heavy initial subsidies provided they are subject to strict performance criteria. One such criteria is participation in international markets because of the fierce competition that is normally encountered. But, this is not necessarily the only performance criteria. Other criteria such as level of investment in R&D or patenting could be used particularly in non-tradable sectors or for those in which the learning process is exceedingly long.

4. The performance of LAC's national systems of innovation

4.1. The traditional innovation output indicator: patents

One of the most widely used indicators of innovative performance is patents. The use of patents as an indicator of output of the NSI is based on the fact that they are given in recognition for the production and disclosure of knowledge with potential industrial application and that time series and comparative data is readily available (Basberg, 1987; Soete, 1981). However, because of differences in national patent legislation and criteria for granting patents, the number of patents granted in the US is normally used for international comparisons.

Data on US patents granted between 1977 and 1986 shows that the share of patents owned by G7 countries' inventors accounted for around 92% of total patents between 1977 and 1989 falling slightly to 91.6% between 1990–1996 (Kumar, 1997). More than 2.1 million patents were granted to all countries over the twenty year period. Patents granted to inventors from *tiger* countries rose from 0.19% between 1977 and 1982 to 0.38% between 1983–1989 and to 2.32% between 1990–1996. Patents granted to China have also been rising from a negligible level up to the late 1980s to 0.05% between 1990–1996. In Mexico, Brazil, Argentina and Venezuela's case, the LAC countries with the largest number of patents granted in the US the trends are more erratic, with the four countries accounting for 0.14% of total patents granted in 1977–1982, falling to 0.07% in 1983–1989 but then rising to 0.13% in 1990–1996.

It is clear from the above data that LAC innovative performance is negligible either in absolute terms or as compared with developed countries and some other developing countries. Furthermore, in recent years LAC has lost significantly to *tiger* economies and may soon fall behind China. Nonetheless, it must be stressed that patent indicators are only partial indicators of innovative performance as not all inventions or innovations are patented nor all patents are innovations. US patent costs may discourage inventors, especially in developing countries, to file for a patent (Kumar, 1997). It is therefore necessary to complement patent data with other indicators of innovative performance that may reflect better the achievements, or lack of them, of LAC economies.

4.2. The index of technological specialisation

Attempts to measure innovative performance of LAC have generally focused on the technological content the regions trade flows by examining the composition of high-tech exports in total exports, changing international market shares or revealed comparative advantage indicators for specific high-tech industries or product groups (Dahlman and Frischtak, 1993; Guerrieri, 1994). [8] High-tech products have a number of features that make them good proxies for the technological capability and innovative performance of a country (Guerrieri and Milana, 1995; Nelson, 1993). These include the use intensive scientific and research and development inputs, steep learning curves and significant dynamic economies of scale, widespread upstream and downstream externalities and oligopolistic or monopolistic profits.

While the use of indicators based on high-tech products seems to be useful, most of the approaches to assess technological performance mentioned above have the shortcoming that they do not simultaneously relate performance in high-tech industries to the performance in other industries. Moreover, changes in the trade structure from low- to high-technology products in each individual country or region does not take into account changes in the level and composition of world trade. The share of high-tech products in any country's own export structure may be very different from that country's share in the world market for high-technology products. Thus, the need for an indicator that takes the changing level and composition of world trade into account.

One way to cater for this need is the index of technological specialization. It depicts how much any particular country or region *adapts* its relative high to low-tech products trade structure to changing patterns of world trade in high and low technology products. The ITS is defined by:

$$\mathrm{MS}_i^H = \frac{\sum_{j \in H} X_{ij}}{\sum_{j \in H} X_j} \qquad \mathrm{MS}_i^L = \frac{\sum_{j \in L} X_{ij}}{\sum_{j \in L} X_j}$$

$$\mathrm{ITS}_i = \frac{\mathrm{MS}_i^H}{\mathrm{MS}_i^L}$$

where, i stands for countries or regions, j stands for SITC product groups (three-digit), MS stands for share in the world market, H is the set of high-technology SITC product groups, L is the set of low-technology SITC product groups. X_{ij} is the value of exports to the world from country or region i in SITC product group j, X_j is the value of exports to the world from all countries in SITC product group j.

The ITS shows (see Appendix A for method and sources of data), from a dynamic perspective, how a country's relative market shares in high and low technology change. For the ITS, values as well as changes are meaningful. A value below (above) one indicates that a country's export share in high-technology markets is bigger (smaller) than its export share in low-technology markets. An increasing (decreasing) value for the ITS along time indicates a movement towards a relatively higher (lower) market shares in high-technology markets.

The ITS is an indicator of a country or region technological specialization in exports and does not reflect the technological specialization of the whole production structure. A country may develop technological capabilities in non-tradable areas or in potentially tradable products which are mainly oriented towards the domestic market. Nevertheless, to the extent that a country has strong domestic technological capabilities they should be reflected in its exports, at least in the long run. Moreover from a policy point of view, in the context of the current export oriented strategy of LAC, countries must focus on sectors where those local technological

[8] Similar studies for European countries include Dalum (1992), Dalum et al. (1988), Fagerberg (1992), and Guerrieri and Milana (1995).

Table 6
High- and medium-tech exports as share of country grouping total exports to OECD, 1977–1995 (percentages)

	Latin America and the Caribbean	G7	Tigers	Potential tigers	European NICs
1977	5.7	44.4	21.3	2.9	19.4
1978	6.5	45.1	23.7	3.8	20.6
1979	6.5	44.4	24.8	4.8	22.5
1980	6.5	45.1	25.9	4.8	23.1
1981	6.5	45.9	27.0	5.7	24.2
1982	7.4	47.1	28.1	6.5	24.8
1983	9.1	48.5	30.6	7.4	25.4
1984	10.7	50.2	32.0	7.4	26.5
1985	12.3	52.4	33.3	8.3	27.5
1986	14.5	53.9	35.1	9.1	28.1
1987	17.4	54.5	37.9	10.7	29.1
1988	18.7	54.8	39.8	13.0	29.6
1989	19.4	54.8	41.5	16.0	31.5
1990	19.4	55.0	42.9	18.0	33.3
1991	20.6	55.2	44.8	20.0	35.1
1992	23.1	55.9	47.4	22.5	36.3
1993	25.2	56.3	51.2	25.3	36.7
1994	26.9	57.0	56.3	28.7	37.9
1995	27.4	56.8	58.6	31.1	38.3

Source: CANPLUS database of ECLAC (1997).

capabilities translate into significant shares in the world market. This is what the ITS intends to show.[9]

4.3. The technological specialisation of LAC

4.3.1. Export structure and market shares

Table 6 presents the share of high and medium-tech exports in total exports to the OECD for several regional groupings in 1977–1995. Medium-tech exports are included because they involve a measure of advanced technological capabilities. For simplicity we will refer to all of them as high-tech products.

[9] The ITS is not a Revealed Comparative Advantage Index (IRCA) although it is closely associated with it, (Balassa, 1965). The main difference is that while the ITS relates high- to low-technology products normalised by the world share of trade in each category of products the IRCA relates the share of exports of a specific commodity within a country relative to the share of that commodity in total world exports. The former is a product index while the latter is a country index.

Between 1977 and 1995, G7 countries export structure shifted away from natural resources, natural resource-based and labor-intensive manufacturing products towards automotive products, aircraft, computers and pharmaceutical and specialized chemicals. Japanese exports of automobiles, computers, electrical machinery and other electronic equipment were a significant contribution to the change in export structure and more than compensated for a relative reduction in high-tech exports by European and North American G7 countries (Mortimore, 1995).

'Tigers' have also seen an improvement in the share of high-tech product exports in their total exports, shifting from textiles, clothing, footwear and toys towards automatic data processing and telecommunications equipment and consumer electronics. The 'tigers,' which began with a similar share of high-tech exports as European NICs in the late 1970s had, since 1993, more than half of their exports accounted for by high-tech products and they should, at the present rate of change, have the same structure of exports as G7 countries by the end of this century.

The export structure of 'potential tigers' is also shifting towards high-tech products, albeit at even faster rates than the 'tigers'. From exporting primary agricultural and petroleum products they are now exporting automatic data processing and telecommunications equipment and consumer electronics.[10] Starting from the lowest share of high-tech exports in total exports of all regional groupings, 'potential tigers' shift towards high-tech products has been ten-fold and by 1994 they had an export structure more geared to high-tech exports than their LAC competitors.

The share of LAC's exports of high-tech products has also risen significantly over the years, from 5.7% in 1977 to 27.4% in 1995. Although still far from G7 countries and 'tigers,' technological upgrading, as shown by the change in the export structure, has been faster than in the G7 and European NICs. From specializing in petroleum and petroleum products, coffee and metals, the region is now producing motor vehicles and their components and electrical

[10] China's technological specialization shift has been from petroleum products towards garments, footwear, toys and travel goods.

Table 7
Country grouping export shares to the OECD, 1977–1995 (percentages)

	Latin America and the Caribbean	G7	Tigers	Potential tigers	European NICs	Total
1977	5.2	44.9	3.3	3.2	2.2	58.8
1978	5.1	45.9	3.4	2.9	2.4	59.7
1979	5.1	45.5	3.4	2.9	2.4	59.3
1980	5.3	45.0	3.5	3.1	2.4	59.3
1981	5.5	45.1	3.7	3.3	2.4	60.0
1982	5.9	46.2	4.1	3.4	2.5	62.1
1983	6.1	47.3	4.6	3.4	2.6	64.0
1984	6.2	48.5	5.0	3.4	2.7	65.8
1985	5.7	50.4	5.3	3.2	3.0	67.6
1986	5.1	51.7	5.8	3.1	3.2	68.9
1987	4.7	52.5	6.2	3.1	3.5	70.0
1988	4.6	52.3	6.4	3.4	3.6	70.3
1989	4.6	52.1	6.1	3.6	3.7	70.1
1990	4.5	51.7	5.8	4.0	3.9	69.9
1991	4.4	51.2	5.5	4.5	4.0	69.6
1992	4.5	50.6	5.6	5.3	4.0	70.0
1993	4.7	50.6	5.8	6.1	4.1	71.3
1994	4.9	50.0	5.9	6.7	4.1	71.6
1995	5.0	49.9	5.8	6.8	4.3	71.8

Source: CANPLUS database of ECLAC (1997).

distribution equipment. This achievement, however, has also to be assessed against a backdrop of falling overall export shares (see Table 7).

4.3.2. Patterns of technological specialisation

Table 8 presents estimations for the ITS for 1977–1995. Several conclusions meet the eye. First, although G7 countries are the most specialized in high-tech export to the OECD, they have been persistently losing ground, as this fast-growing market is taken over by producers from other regions. Between 1977 and 1995, the ITS fell by 23% for G7 countries. Second, 'tigers,' 'potential tigers,' and LAC have increasingly stepped in the high-tech arena, albeit it is only the 'tigers' that have been able to compete successfully in high-tech products. Third, the 'potential tigers' and LAC's ITS is similar, although that of the 'potential tigers' started from a much lower base, and is catching up with that of European NICs.

In the face of the previous figures, the technological performance of LAC does not seem to be all that worrying. LAC is losing out with regards to 'tigers' and may do so also with regards to 'potential tigers,' but it is closing the gap on G7 countries and European NICs. Indeed, LAC competes in the same product groups as the latter, which may mean that some of LAC gains may have been at the expense of European NICs. Yet, there are still several causes for concern.

To begin with, although falling, primary products still constitute a large proportion of LAC exports. In 1993, around 1/3 of LAC exports to OECD were accounted for by primary products. Furthermore, the revealed comparative advantage index for primary products in LAC increased from 1.48 in 1977 to 2.19 in 1993. After more than 50 years of industrialization, LAC is still heavily specialized in primary products. By contrast, developing Asian economies' natural resource exports decreased from over 50% in 1980 to 16.5% in 1993 (Mortimore, 1995). If one considers primary products together with manufactures based on natural resources, the drop in the case of Asian economies is even higher.

Table 8
Index of technological specialization, 1977–1995

	Latin America and the Caribbean	G7	Tigers	Potential tigers	European NICs
1977	0.16	2.17	0.74	0.09	0.67
1978	0.17	2.14	0.80	0.11	0.69
1979	0.18	2.17	0.87	0.13	0.74
1980	0.18	2.14	0.93	0.14	0.80
1981	0.19	2.22	0.96	0.15	0.83
1982	0.20	2.19	0.96	0.16	0.80
1983	0.23	2.13	0.98	0.17	0.77
1984	0.24	2.08	0.97	0.17	0.74
1985	0.26	1.99	0.91	0.16	0.68
1986	0.29	1.90	0.89	0.16	0.64
1987	0.32	1.82	0.93	0.19	0.62
1988	0.34	1.80	0.99	0.23	0.63
1989	0.35	1.78	1.05	0.27	0.67
1990	0.35	1.77	1.09	0.32	0.72
1991	0.38	1.76	1.16	0.36	0.77
1992	0.42	1.77	1.26	0.41	0.79
1993	0.45	1.73	1.41	0.45	0.78
1994	0.47	1.71	1.66	0.52	0.78
1995	0.48	1.67	1.80	0.55	0.79

Source: CANPLUS database of ECLAC (1997).

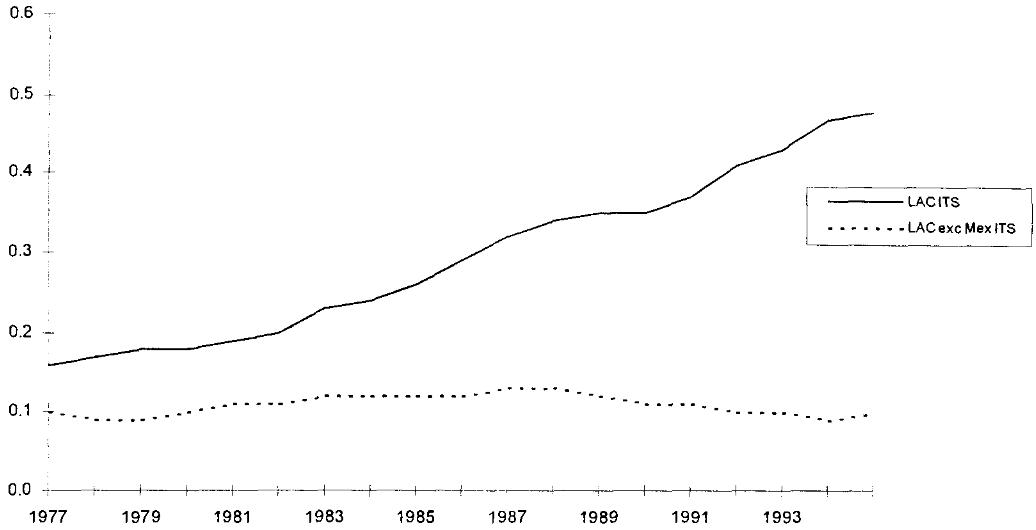

Fig. 1. Latin America and the Caribbean ITS, 1977–1995.

Secondly, and perhaps more importantly, the technological performance is quite different if Mexico is removed. Because of NAFTA membership, Mexico has preferential access to the US market. In addition, Mexico has had successful export-processing zones in its northern border for a number of years. Both export-processing zones and NAFTA membership have attracted significant industrial investment aimed basically at the US market, an advantage that not all of LAC has. [11]

Fig. 1 shows the performance of the ITS without Mexico. There are significant differences between the indexes with and without Mexico, reaching up to four times in recent years. Further note that without Mexico, the ITS remains flat for the 18-year period of analysis at around 0.10. This index is similar to that of the 'potential tigers,' when they started their technological upgrading in 1977.

In Mexico, only a few products, such as vehicles and vehicle parts, electrical distribution equipment and apparatus, combustion engines, TVs and telecommunications equipment, account for the expansion of trade in high-tech products. Their share increased from 9.2% of total exports to OECD in 1980 to 31% in 1993. Except for vehicles and car engines, most of these are produced mainly in the export processing zones. Only weak linkages are built to the domestic economy and even in the case of the vehicle industry, which is based in *mainland* Mexico, earlier stronger linkages with local specialized suppliers seem to be waning (Capdeville et al., 1995). [12]

The innovative performance of the other LAC countries is in sharp contrast with Mexico's. Argentina, Brazil and the Caribbean, which showed an increase in their ITS in the 1980s, fell behind to levels well below those of 'potential tigers' by the early 1990s (Table 9). For Caribbean, as well as for Central America, export processing zones account

[11] Mexico is also an OECD member, but OECD import data for 1977–1995 that we use in this paper do not include Mexico.

[12] Needless to say, weak linkages are always preferable to no linkages. Also, export processing schemes although perhaps *exploitative* in terms of labor regulations, safety and social security, sometimes create employment that would not have been created otherwise. They may contribute to the accumulation of human capital, even if it were only of the lower skills type. It would seem that a key challenge for public policy would be to make these processing zones more integrated to the local economy and regulations. Often export processing zones schemes have been seen by governments as second-rate industrialization and, in the case of Mexico, it has been located so far from *domestic* industrial centers that it is difficult to reap any of the externalities that may arise from them.

Table 9
Index of technological specialization, 1977–1995

	Argentina	Brazil	Caribbean countries	Central America	Chile	Colombia	Mexico	Peru	Venezuela
1977	0.12	0.22	0.09	0.09	0.01	0.03	0.50	0.02	0.03
1978	0.09	0.25	0.07	0.08	0.02	0.02	0.60	0.01	0.01
1979	0.11	0.25	0.06	0.08	0.01	0.02	0.58	0.01	0.01
1980	0.14	0.27	0.06	0.07	0.01	0.02	0.50	0.01	0.01
1981	0.17	0.29	0.07	0.08	0.01	0.03	0.43	0.02	0.01
1982	0.16	0.29	0.10	0.07	0.01	0.04	0.43	0.02	0.01
1983	0.13	0.29	0.13	0.08	0.01	0.03	0.49	0.02	0.01
1984	0.10	0.29	0.15	0.07	0.01	0.02	0.55	0.02	0.01
1985	0.08	0.29	0.13	0.06	0.01	0.01	0.66	0.02	0.01
1986	0.08	0.32	0.10	0.04	0.01	0.01	0.78	0.02	0.01
1987	0.07	0.32	0.08	0.04	0.01	0.01	0.97	0.02	0.01
1988	0.08	0.33	0.07	0.04	0.01	0.01	1.06	0.02	0.01
1989	0.08	0.32	0.07	0.04	0.01	0.01	1.13	0.03	0.02
1990	0.09	0.30	0.08	0.04	0.01	0.01	1.18	0.02	0.02
1991	0.09	0.27	0.08	0.04	0.01	0.01	1.29	0.03	0.02
1992	0.10	0.25	0.08	0.05	0.01	0.01	1.44	0.03	0.02
1993	0.09	0.23	0.09	0.05	0.01	0.01	1.57	0.02	0.02
1994	0.09	0.22	0.09	0.05	0.01	0.01	1.60	0.02	0.02
1995	0.07	0.23	0.09	0.05	0.01	0.01	1.62	0.02	0.02

Source: CANPLUS database of ECLAC (1997).

for their relatively higher ITS. The ITS of other LAC countries stagnated throughout the whole period at extremely low levels.

Furthermore, a closer view of the components of LAC high-tech products without Mexico reveals not only that LAC performance in high-tech products is stagnant but that it has switched towards their lower end in terms of technological competence. Fig. 2 shows the trends in the ITS separating between high and medium-tech products. From a technological specialisation that was relatively geared to high-tech products in the late 1970s, e.g., aircraft, telecommunications equipment and early industrial and consumer electronics, LAC excluding Mexico had moved by the mid-1990s to a specialisation pattern where medium-tech products are predominant. These products are manufactured mainly in the mechanical engineering and transport equipment industries. In Argentina and Brazil, for instance, the ITS for the more advanced high-tech products fell from 0.12 and 0.27 respectively in 1979 to 0.9 and 0.13 respectively in 1994. The ITS for the less advanced or medium high-tech products remained at around 0.10 in Argentina and rose from 0.24 in 1979 to 0.33 in 1994 in Brazil.

In sum, LAC technological performance has been modest. Except for the Mexican export processing zones and vehicle and mechanical engineering industry, LAC has very little more to show in terms of technological upgrading and internationally competi-

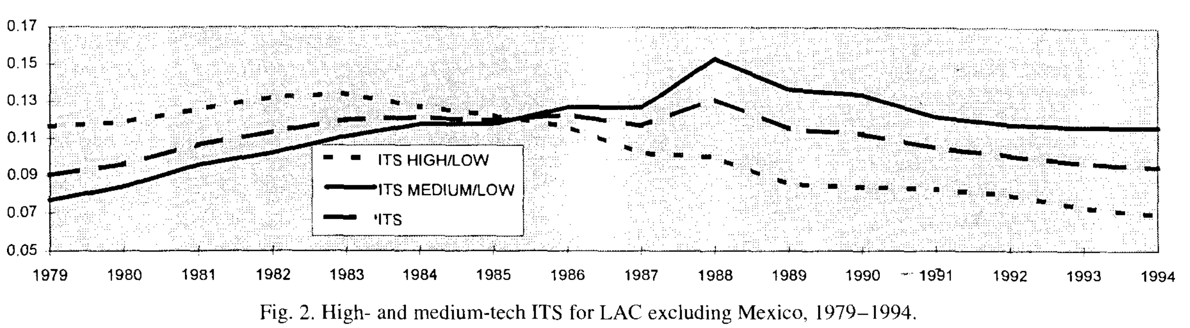

Fig. 2. High- and medium-tech ITS for LAC excluding Mexico, 1979–1994.

tive high-tech industries. Rather, the pattern of specialization in trade has returned to, if not remained in, primary products and low-tech manufactured goods. This is true even after macroeconomic stabilization was achieved in the early 1990s as there is no significant difference in the trends prior or after stabilization.

5. Concluding remarks

LAC's innovation systems have developed into weak entities. Although, emerging with great potential at the end of the 1950s and 1960s, and expanding considerably during the 1970s, they have since not been able to consolidate into an effective promoter of technological upgrading and innovation. There are significant specific accomplishments in policy making, institutional development and education and training but it has not been possible to replicate them throughout the system. The upshot has been that the output of LAC's innovation systems has also been modest. Again, although there are a number of significant examples of successful performance by and large, patenting for instance, has been negligible. And, perhaps more importantly, the innovative performance of LAC's innovation systems, with the only exception perhaps of Mexico, as measured by the ITS, is low in absolute terms and has lost relatively to many countries that started at similar levels twenty years ago. Furthermore, LAC exports are relatively less geared today to the most technologically advanced products than what they were in the mid-1970s.

It is true, of course, that there is no need for a region or country to produce or excel in all high-tech products. Nelson (1993) pointed out that there does not seem to have strong empirical support for the view that countries are at an advantage or disadvantage if they have or do not have high-tech firms and that transnational corporations have increasingly to collaborate with other firms and share their high-tech knowledge to pay for the high R&D costs. Yet, it is also true that all countries that are internationally competitive in some high-tech products have enjoyed continuous growth. They do not always grow as fast in the short-run as other countries, but they are certainly not stagnant and in any case they are creating the conditions for subsequently sustained productivity and output increases. The intrinsic advantages of high-tech products have already been pointed out. From a growth and development perspective, while efforts to manufacture the range of high-tech products may not be warranted, a combination of high, low or labour-intensive and natural resource-based products which in the long-run switches towards a relatively higher share of high-tech products, without attempting to produce all of them, would seem to be 'wise'. Labour- and natural resource-intensive pathways to growth are always limited by the availability of natural and human resources and decreasing returns whilst strategies based on the continuous use of knowledge do not seem to face such constraints. As for technological collaboration, as pointed out earlier, there is little cooperation from abroad with LAC firms, except perhaps for marketing agreements. For cooperating LAC firms must first have the knowledge to share.

Whatever one's view on the need for high-tech products for growth and development, however, it must not be forgotten that LAC's innovative performance in high-tech products is not only not improving but seems to be worsening. And, coming back full circle to the Latin American debate on the causes for the poor international competitiveness of the region, this has not been the exclusive result of macroeconomic maladies or low investment.

Appendix A. The method and data sources

To estimate the index of technological specialization, the Competitive Analysis of Nations (CANPLUS) database of ECLAC (1997) was used. The CANPLUS is a database and software of foreign trade statistics built on the basis of the United Nation's COMTRADE statistics of three-digit Standard International Trade Classification (SITC, second revision). It has entries for 239 three-digit product groups and 89 countries for 1977–1995.

The *international market* or *world market* is the imports of the 1990 member countries of the OECD on grounds that it is a demanding market for which there exists reliable, consistent and up-to-date information. Given that in this paper, we develop an index to evaluate technological performance, it is particularly important to focus on high-quality markets as it is the case for the OECD ones. Consumers in high-quality markets have higher income, face more alternatives regarding their consumption bundles and have more experience to determine the quality of goods than consumers in low-quality markets. As Nelson (1993) pointed out "if firms do not compete on world markets they do not compete strongly." (p. 512).

A country's degree of competitiveness in any particular product group is determined by CAN-PLUS on the basis of its market share of the OECD market (Mandeng, 1991; Mortimore, 1995). Market shares are calculated as three-year moving averages. Classification into high-tech and low-tech industries has been done on the basis of an adaptation of a previous classification developed at ECLAC (CEPAL, 1993). It consists of classifying the 239 Standard International Trade Classification (SITC, revision 2) product entries on the basis of OECD's industry-based research and development intensity ratios. In this paper high-tech products includes OECD's high and medium R&D intensity manufacturing products while low-tech consists of low R&D manufacturing goods and primary products.

Classifying products according to technological intensity is not without risks. Available export data does not allow to determine the degree of domestic content of those exports. Exports from highly integrated national economies are treated in the same way as exports from less integrated ones. This situation is particularly acute in the case of economies where export processing zones have minimal integration with the domestic production structure. In LAC, this may be the case of the Caribbean, Central America, and Mexico.

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