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The Innovation Systems of Latin America and the Caribbean

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1. Introduction[1]

It is now widely recognized that we live in a knowledge-based economy; in fact, knowledge is the driving factor behind productivity growth. The share of knowledge-intensive sectors in the world economy's value-added and employment has been rising for a number of years. This trend is particularly pronounced in the developed countries, where by 1999 knowledge-based industries'[2] share of GDP was already above 50 percent, up from 45 percent in 1985 (OECD, 1999; OECD, 2000a). Furthermore, knowledge-driven innovation has become a decisive factor in the competitiveness of both nations and firms.

It is in this inescapable context that Latin America and the Caribbean have to compete with other nations of the world, and this is the challenge that technological innovation policies have to meet. This paper addresses the issues involved in upgrading the region's technological capabilities. The second section examines the worldwide structural tendency towards an economy where knowledge and learning processes play an increasingly important role and introduces the analytical framework to be employed in examining the issue of technological modernization in the region's countries. The third section analyzes the practices and institutions involved in technological modernization, i.e., the innovation systems, of Latin America and the Caribbean. Finally, the fourth section discusses selected innovation policy issues.

2. The Knowledge-and-Learning Economy

2.1 The Prevailing Trends in the World Economy

As suggested above, knowledge is now increasingly recognized as being at least as important as physical capital, raw labor-power, and natural resources as a source of economic growth. Recent structural changes in the world economy clearly reflect this. While the knowledge-intensive sectors have grown more rapidly than the overall economy and increased their share of GDP, the output and employment shares of agriculture, mining, and low-technology manufacturing industry continue to decline. The OECD economies spend more and more resources on the

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[2] Knowledge-based sectors are defined to include high- and medium-high-technology manufacturing industries and services such as finance, insurance, and communications.

production of knowledge. In 1999, investment in knowledge[3] represented 8 percent of OECD-wide GDP, a figure similar to investment in physical equipment.

Information and communication technologies (ICTs) constitute the backbone of the knowledge-based economy. A whole new technological system is emerging around them (Petit, 2000), mainly on the basis of their potential pervasiveness, i.e., their capacity to involve, organize, and be concerned with all kinds of operations and parts in a system of information flows, or in systems of production based on machinery. This potential for unprecedented pervasiveness implies that ICTs have the ability to penetrate all aspects of contemporary economic and social affairs (Vaitsos, 1996). Two features of the new technologies, the increasing miniaturization of microprocessors and the capacity to interconnect and therefore to monitor a host of different operations, seem to be at the root of their prominence.

The economic importance of information and communication technologies continues to grow. ICT intensity, defined as the ratio of ICT expenditures to GDP, is rising. In the OECD countries, it reached almost 7 percent on average in 1997 (OECD, 2000b). In non-OECD countries, ICT markets are growing at more than twice the OECD average and the largest markets (Brazil and China) are growing rapidly. ICT is also the area with the highest rate of innovation as measured by patents.[4] In addition, ICT is spurring many changes in the economy, including a whole host of innovation processes that help to make other sectors more productive. The services sector is by far the main purchaser of ICT equipment and its performance is being particularly affected by the uptake of ICT. Services sectors such as finance and business services lead in investment in ICT and have become highly innovative. Rapid growth in the use of the Internet and the emergence of electronic commerce have the potential to deeply transform a host of economic and social activities, but this potential is just beginning to be realized.

A powerful, albeit perhaps controversial, way of summarizing these trends is by means of Freeman's and Louça's (2001) hypothesis that the world economy is undergoing the fifth Kondratiev wave[5] since the English Industrial Revolution, an ongoing wave whose content they characterize as the computerization of the entire economy.

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[3] The OECD defines investment in knowledge as the sum of spending (both by firms and by the public sector in) R&D and software plus public spending in education.

[4] Of the overall growth in patents granted by the US Patent and Trademark Office over the 1992-1999 period, ICT accounted for 31 percent and the number rose by almost 20 percent annually.

[5] According to Freeman and Louça (2001), the four previous Kondratiev waves were: i) the water-powered mechanization of industry (from the 1780s through 1848); ii) the steam-powered mechanization of industry and

2.2 An Analytical Framework for the Knowledge-and-Learning Economy

Saying that knowledge plays an important role in production is, in a sense, a truism. Strictly speaking, every human activity requires some kind of knowledge to be carried out (or even attempted, for that matter). Even the hunting and gathering pursuits of our forefathers could not have been accomplished without knowledge. Nor could they have invented (or used) the simplest tool without knowledge. The claim that the modern economy is knowledge-based is relevant and noteworthy only because of the decisive role played by knowledge as an input, the density of knowledge flows, and the extent to which knowledge is both embodied in the goods and services produced and deployed in the production processes. From the standpoint of utilization of knowledge, the difference with past historical stages is certainly a difference of degree but of such a magnitude that what we are witnessing is arguably a qualitatively new production regime.

Nor is the idea that knowledge is important new to economic theory. Adam Smith referred to the new layers of specialists who, while being men of speculation, made important contributions to the production of economically useful knowledge. The nineteenth-century German economist List (1841) emphasized the infrastructure and institutions that contribute to the development of productive forces through the creation and distribution of knowledge. In the first half of the twentieth century, Schumpeter (1912, 1966) highlighted the role of innovation as a major force in competition.[6] In his view competitive behavior is primarily concerned with the search for new technologies which, for a time, are available to the innovative firm alone, transitorily bestowing on it the advantages of monopolistic rents. More recently, Arrow's (1962) seminal article explained some of the fundamental properties of knowledge relevant for economic analysis.

In the knowledge-and-learning economy as an object of theoretical reflection, the two key units of analysis are the firm and the national innovation system of the particular economy where the firm is located. The firm is the social locus where economically relevant technological innovation ultimately occurs. The national system of innovation is defined as the set of economic agents, institutions and practices that constitute, perform, and participate in relevant ways, in the processes of technological innovation. The firm as a creator and administrator of

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transport (from 1848 through 1895); iii) the electrification of industry, transport and the home, (from 1895 through 1940); and iv) the motorization of transport, war and the civil economy from 1940 to (presumably) the late 1970s.

knowledge and the national innovation system as providing the environment for, and many of the resources utilized in, firms' knowledge creation are the two building blocks of the analytical framework hereby proposed to understand innovation in modern economies.

2.2.1 Firms as Creators and Administrators of Knowledge

One possible point of departure towards a knowledge-based theory of the firm is Penrose's (1959) classic contribution. Penrose argues[7] that the modern corporate enterprise has to be viewed as an organization that administers a collection of human and physical resources. By far the most critical are human resources because they render services that can enable the firm to make unique contributions as a generator of higher-quality, lower-cost products. People contribute these unique labor services to the firm not merely as individuals but as members of teams who engage in learning about how to make the best use of the firm's productive resources. The firm is an innovative entity: what enables it to grow over time is the continual ability to utilize its unique pool of resources to generate new products and new unique capabilities. It is a unique social unit that can engage in learning that is both collective and cumulative.

Penrose's theory was the starting point and inspiration for the knowledge-based approach to the theory of the firm. At the heart of her approach[8] lies the idea that the primary role of the firm (and the essence of organizational capability) is the integration and creation of knowledge (Spender, 1996a, 1998; Grant, 1996; Tsoukas, 1996). This family of theories sees the firm as a body of knowledge residing in its structures of coordination and organizing principles (Nelson and Winter, 1982; Kogut and Zander, 1992, 1996; Fransman, 1995).

As is the case for all organizations, firms, when seen from within, are social systems of coordination (Lam, 1998). At first glance they appear as the loci where people with different types of professional and technical knowledge interact and combine to achieve collective results. Since any firm's capacity for learning and innovation is closely related to how knowledge is constituted, generated and utilized, it is important to incorporate into the analysis conceptual categories that can make sense of what goes on within a firm in terms of knowledge production and utilization. In this respect, knowledge-based theories of the firm have resorted to the distinction between explicit and tacit knowledge proposed by the twentieth-century Hungarian

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[6] The references to List and Schumpeter rely on OECD (1996a) and Cooper (1991).
[7] In summarizing Penrose's views I rely on Lazonick's (2000) penetrating analysis of her contributions.

philosopher Michael Polanyi.[9] The key to understanding the distinction is the fact that, as human beings living in society, we already have a pre-understanding of the social and natural world around us; an implicit knowledge that allows us both to move around our everyday activities and, in performing them, to relate to other people and the world of material objects. This implicit knowledge provides the background horizon within which we lead our everyday lives, including our lives as managers or workers in a firm or other social institution. Included in this knowledge are basic human skills such as how to walk and how to feed oneself; basic social, culturally acquired skills such as how to greet another person properly, or the ability to determine the appropriate distance at which to stand from another person when holding a conversation; or acquired skills such as how to swim, or how to handle a hammer; or a host of operational skills and know-how acquired through practical experience. It is a vast pool of knowledge that, for the most part, remains unarticulated and resists codification. The fact that much of this knowledge cannot be articulated means that, as Polanyi said, "we know more than we can tell."[10] In other words, a good deal of this implicit knowledge is knowledge we actually employ as we go about our daily activities without being conscious of our using it.

Explicit knowledge is, by contrast, that part of human knowledge that is specified as a deliberate object of our consciousness when we take an objectifying attitude towards the world and set out to describe and explain the phenomena around us. Explicit knowledge can be transmitted through the means of symbolic communication used by the species, that is to say, through verbal or written communication.[11] It can be codified and stored in blueprints, written rules, technical procedures, and recipes. It is the stuff of scientific and technical treatises.

The overwhelming importance of explicit knowledge for modern production is obvious, cannot be overemphasized, and needs no belaboring. Without the high degree of development of that subset of explicit knowledge codified in our body of science and technology we would have never had an industrial economy, let alone a digital economy. But what is the point of calling attention to tacit knowledge? Why is the latter relevant?

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[8] The account given here of the knowledge-based theories of the firm follows Lam (1998).

[9] Not to be confused with his brother Karl Polanyi, the economic historian well known for his important book *The Great Transformation*.

[10] See Polanyi (1966).

[11] Written communication includes not only traditional written texts but also blueprints, maps, computer programs, and the like.

Two considerations may help to explain the role of tacit knowledge. The first is a very broad, general consideration: all production of explicit knowledge ultimately depends on the background horizon of pre-understandings and skills that constitute the content of tacit knowledge, in that the existence of those pre-understandings and skills and their operation as a living reality are *the constitutive condition* for explicit knowledge. The relationship between explicit knowledge and tacit knowledge is like that between an iceberg's tip and its submerged parts, which is a double relation. There is, first, the relation of the visible to the hidden. But second, and more importantly, there is the relationship between a (hidden) *supporting mass* and a much smaller (and visible) *supported element.* That the background of pre-understandings and skills we bring to bear on our everyday activities makes explicit knowledge possible can be seen in the particular field of the generation of scientific and technical knowledge, if one reflects on the myriad skills, habits, and pieces of unarticulated, implicit knowledge that (taken as a totality) make possible scientific and technological research as socially organized activities.

The second consideration is more specific and should be seen as an application of the first to the particular kind of social institution that the firm is. It has to do with the place of both explicit and tacit knowledge within the firm's stock and flows of knowledge. As to the former, it probably should go without saying that part of the knowledge available to a firm (and flowing through it) is certainly explicit knowledge deployed in research and development activities, in product and process design, in project formulation, in blueprints, and every type of scientific and technical rules and formulae, and embodied in the professional and technical qualifications of its managers, engineers and workers as well as in machines and other capital equipment.

Tacit knowledge, though, possesses two distinct characteristics. First, most of the skills acquired via "learning by doing" become tacit knowledge embodied in the workers. This knowledge is the practical know-how derived from "hands-on experience" or "on-the-job experience" and is highly valued in the labor market (since it is believed, and rightly so, that no university, whatever its prestige, can teach it). This particular type of *individual* tacit knowledge is an asset of both the worker and the firm.[12]

Second, and more importantly, the bulk of a firm's organizational knowledge has the quality of tacit knowledge. This is the *shared, collective,* form of tacit knowledge residing in a

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[12] A dramatic illustration of how important an asset can it be is the situation in which an experienced executive leaves a company to work with a rival company.

massive and complex weft of shared beliefs and implicit understandings held by the firm's members. This includes the firm's organizational routines, practices, and shared (but implicit) norms. To characterize this type of knowledge, Badaracco (1991) has proposed the term "embedded knowledge." He defines it as the organizational knowledge that cannot be owned in isolation by an individual. He likens it to the culture of the organization in that it exists in norms, attitudes and relationships among individuals and groups.[13]

When it comes to tacit knowledge, it is not possible to separate the knowledge from its carrier (Johnson and Lundvall, 2000). Desirable tacit knowledge can be accessed only by hiring people who possess it or through merger with other organizations that have incorporated it into their practical culture. This is the case, in particular, of the tacit knowledge embodied in the organizational routines and collective expertise of specific production, procurement, R&D, and marketing teams (Ernst and Lundvall, 1997). *It is the non-codified technological knowledge that differentiates firms* and that cannot be exchanged between them, as it is derived from, and tied to, the localized and collective learning experience of a given company through its own development of technological capabilities. While the explicit, encoded, component of technological knowledge may be traded between firms, the tacit component is the essence of firm-specific competitive advantage.[14]

To summarize, the claims made in the relevant literature are that: 1) studies of technological innovation and diffusion have increasingly identified tacit knowledge as a decisive component of the knowledge used in innovation (Rosenberg, 1976, 1982; Pavitt, 1987; Dosi, 1988; Senker, 1995; Howells, 1996); 2) tacit knowledge is fundamental for collective learning and organizational knowledge creation (Nonaka and Takeuchi, 1995; Spender, 1996b); 3) the growing complexity of technological systems and rapid change in the knowledge and scientific

[13] See also Cormican and O'Sullivan (2000).

[14] An empirical illustration can help understand the importance of tacit knowledge to a firm's (or group of firms') competitiveness. In discussing the highly innovative and successful clusters of enterprises of Jutland (Denmark) and Belluno (Italy), whose output and export growth in the period 1985-1998 was outstanding, Mytelka and Farinelli (2000) point out that "[O]f critical importance in the sustainability of the innovation process in Belluno and Jutland is the way in which (...), in both spectacle frame and furniture clusters, the industries have become tacit-knowledge intensive. In the former this is manifest in product design and marketing as well as in production. In the latter tacit knowledge accumulation is mainly centered in the production process and in the ability to manage a stable network of suppliers and clients." They add that "the tacit-knowledge nature of both industries (...) has served as the major barrier to entry for outsiders and potential newcomers. To that effect, they quote the chairman of the second biggest spectacle frame manufacturer in Belluno, Mr. Vittorio Tabacchi, who, in an interview with a well-known magazine, said that the engineers at his company modify the standard machines the company buys from outside and laughed at

base have made tacit knowledge ever more important in the process of learning and knowledge accumulation (Lundvall and Borras, 1997); 4) a particular kind of tacit knowledge, namely, the skills needed to handle explicit, codified knowledge is more important than ever in labor markets (OECD, 1996a);[15] and 5) *what is really significant about tacit knowledge is that it represents the principal source of sustainable competitive advantage* in today's changing and turbulent business environment (Winter, 1987; Hall, 1993 Grant, 1996; Lam, 1998).

2.2.2 National Innovation Systems

The second building block in the analytical framework of the knowledge-and-learning economy is the concept of the national innovation system. This concept has been proposed as a key element in the attempt to analyze how learning, knowledge creation, and innovation are organized in the modern national economies.[16] As stated above, we can initially define the national innovation system as the set of interrelated agents, institutions, and practices that constitute, perform, and participate in relevant ways in the processes of technological innovation. The agents in question are firm managers, university and industry researchers, engineers, technicians and workers in firms, policy makers, and research administrators. The institutions are 1) organizations such as the firms themselves; scientific and technological research centers; the universities; government bodies dealing with science and technology policy; and funding agencies involved in the financing of innovation; and 2) the norms and rules regulating innovation activities. The practices are the actual ways in which these agents and institutions operate and relate to each other in the generation (or dampening, if that is the case) of innovations.

Although it is still a matter of controversy in the literature, an appropriate way of delimiting a country's innovation system is by looking at it as centered in the production system, that is to say, by accepting the claim that what matters, in a fundamental way, are the actual practices of innovation carried out in firms. This means that, while the analysis of the formal institutions that are (legally or otherwise) assigned a role in innovation is the first indispensable

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the idea of asking the machine suppliers to modify the machines they sell him: "that would reveal his firms' secrets and allow them to fall in the hands of competitors."

[15] The OECD document's view is that "codified knowledge might be considered as the material to be transformed and tacit knowledge, particularly know-how, as the tool for handling this material."

step in understanding the national innovation system of a given country, the ultimate focus must be on the innovation that actually exists, wherever it is conducted, and on its impact on production processes at the firm level. The practices to be examined therefore include research activities conducted by firms; research activities carried out by both private not-for-profit institutions and public agencies, including universities; the requesting of patents by firms; the granting of patents by government; the introduction of new products; improvements of products that make them more attractive; the introduction of new production processes or the improvement of existing processes; the acquisition of new technologies via purchases of either patents or capital or intermediate goods (either in the domestic market or from foreign suppliers); reverse-engineering research either by firms or by research institutions; activities related to the adoption and adaptation of technologies developed by other agents; diffusion activities; training of people in the use of new technologies; the financing of research and development; and the formulation of science and technology polices by relevant governmental bodies. A thorough understanding of who carries out these practices, how they are they carried out, and with which results, is a key task in the study of a particular national innovation system.

But, of course, to understand the operation of a national innovation system it is not enough merely to have an inventory of the actual innovative activities performed. It is also necessary to grasp the linkages among the institutional actors involved in innovation. As the OECD (1997a) points out, "innovation and technical progress are the result of a complex set of relationships among actors producing, distributing, and applying various kinds of knowledge. The innovative performance of a country depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use as well as on the technologies they use" (p. 9).

The linkages in question can take the form of research partnerships between firms (including foreign firms); partnerships between firms and research institutes and/or universities; personnel exchanges; cross-patenting; purchases of equipment and other interactions between firms and equipment or input suppliers; interactions between firms and consumers (through, for instance, opinion surveys); and a variety of other interactions.

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[16] There is a vast literature on the concept of national innovation system. A relevant sample includes Freeman (1987, 1995, and 1997); Lundvall (1988a, 1988b, 1992a); Nelson (1988, 1993); Gu (1996); OECD (1997a); Boyer *et al*. (1997); Edquist (1997); and Lundvall and Maskell (1999).

The analysis of national innovation systems pays special attention to the investments in knowledge undertaken by the different actors within the system. These investments include expenditures in research and development; in education and training; in the purchase of existing technologies (in the form of patents, non-patented inventions, licenses, know-how, trademarks, drawing plans, and packaged software); in industrial design; and in the introduction of innovations into the market.

The systemic approach to innovation emphasizes flows of knowledge as much as investments in knowledge. Here, the focus is on mapping knowledge flows as a complement to measuring knowledge investments (OECD, 1997a). The flows in question include flows of both codified knowledge and tacit knowledge. The linkages mentioned above are, naturally enough, a fundamental source of both types of flows.

The flows of codified knowledge include those where the vehicles are scientific and technical publications; patents; new laboratory instruments; scientific and technical methodologies; new machinery and equipment.

The flows of tacit knowledge have as their main vehicle the movements of people throughout the system. As people follow the price (and other) signals coming from the labor market, they move between firms, or between non-profit institutions and firms, and carry with them their accumulated tacit knowledge (as well as stocks of codified knowledge at their command). Formal and informal contacts (even if short-term) between people also have the potential to generate flows of tacit knowledge.[17] Learning from other people's tacit knowledge normally depends on conversation, demonstration, and observation (OECD, 1996a).

Going back to the institutions involved in innovation, it is appropriate at this point to reiterate that the identification, description, and characterization of the formal organizations belonging to the national system is an indispensable step towards understanding the way it operates. What is required in this connection is an institutional mapping of the system under consideration. The resulting map must display, in a coherent manner, the different institution types and institutional levels. The institution types must be distinguished in accordance with the

[17] The OECD (1997a) study points out that, sometimes the specific knowledge transferred in such contacts is less important than the general approach to innovation and the competence in problem-solving that may be transferred through those contacts. The study adds "[T]he ability to locate and identify information and to access networks of researchers and personnel is a valuable knowledge asset. In most studies of technology diffusion, it is shown that the skill and networking capabilities of personnel are key to implementing and adapting new technology.

different functions they are designed to perform. In their study of the Norwegian innovation system, Orstavik and Svein (1998) used a policy-centered organizational map. I shall follow their classification with slight variations.[18] Seven groups of institutions can then be distinguished: 1) institutions laying down the general policy framework; 2) national governmental institutions responsible for (the different aspects of) the formulation and implementation of innovation policy; 3) institutions that facilitate and modulate innovation;[19] 4) institutions (other than the productive firms themselves) that finance innovation activities; 5) institutions (other than the firms) performing research and development; 6) institutions performing technology diffusion; and 7) firms (both private and state-owned).

While in its actual operation the national innovation system is rooted in the production system, its fundamental capabilities and resources are ultimately dependent on the human-resource development system and its institutional core, the education system. The human-resource development system is the main determinant of labor-force quality. Competence, skills, resourcefulness, inventiveness, cooperation habits, flexibility, and a sense of independence and responsibility are all qualities that, if present in the labor force, strengthen firms' ability to innovate and compete. Their supply crucially depends on the human-resource development system. This implies that in examining the web of relations that constitute a national innovation system, it is very important to trace the connections between the system's actual operation at the level of firms and R&D institutes, on one hand, and the strengths and constraints flowing from the educational system, on the other.

If national economies are not closed systems, there is no reason to see national innovation systems as closed systems either. They are actually fully open systems.[20] As pointed out in OECD (1997a), globalization of industry and internationalization of production, research, and other firm activities means that international knowledge flows are on the rise. There is an

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Investment in advanced technology must be matched by this '*adoption capability*' which is largely determined by the qualifications, overall tacit knowledge and mobility of the labor force" (p. 18, italics are the OECD's).

[18] The main departure from the Orstavik's and Svein's proposal is the inclusion of financial institutions as a separate category. In their proposal financial institutions are subsumed under the category of policy-formulating-and-implementing institutions.

[19] Orstavik and Svein propose to collect under this heading, besides the Patent Office, the standard-setting and quality-certification agencies as well as agencies in charge of intellectual property issues and metrology services. The supervisory agencies that take care of the public interest, such as those that set standards for health, work-place safety, and the environment are also included in this category. Generally speaking these latter agencies set minimum standards for products and processes, thus influencing firm behavior and technology development and use.

[20] This point is forcefully made by Ernst (1999).

increased openness of national innovation systems to such knowledge flows as those involved in the purchase of foreign technology embodied in capital and intermediate goods, foreign patents and licenses; or in technical consultancy services, foreign direct investment, and internationally co-authored technical and scientific publications; or in the international mobility of scientists, engineers, and other qualified personnel.[21]

While the theoretical import of the national-innovation-system concept lies in the help it provides to understand the systemic determinants of innovation, its practical import resides in the fact that an empirically sound analysis of the national innovation system of a particular country can be a powerful diagnostic tool for identifying its weaknesses and limitations and therefore the focal areas that policymaking must address and public policy help to transform. The diagnosis should start by analyzing all parts of both the economy and the human-resource development system that contribute to competence-building and innovation.[22] It should additionally focus on the linkages and synergies (or lack thereof) among the different parts of the system, and it should try to recognize the nodal points of knowledge creation and innovation. It should also identify both the crucial learning-stimulating linkages and the missing linkages or interactions whose absence lowers the economy's innovation performance.[23] Such a diagnosis can assist in pinpointing mismatches within the system, both among institutions and in relation to government policies, which may be thwarting technological development and innovation.

3. The National Innovation Systems of Latin America and the Caribbean

Even the most cursory examination of innovation systems in developing countries shows that major differences between them and the national innovation systems of the developed countries. At first glance, it would appear as though the differences were purely quantitative. In the developing countries the number of people involved in innovation is smaller. There are fewer institutions, and they are less developed. Investment in R&D as a percentage of GDP is lower.

[21] International mobility of qualified personnel goes hand in hand with the development of knowledge-and-learning-based economies. One way in which a particular national innovation system can overcome the constraints imposed by its national human-resource development system is by appealing to the international market. This seems to be a factor in the case of the Silicon Valley cluster. The Valley is a "hodgepodge of different nations: almost a third of the region's scientists and engineers are Asian-born; and Indians and Chinese created 27% or more of the more than 4,000 information companies founded between 1991 and 1996." See Ernst (1999).
[22] In what follows I build on Johnson and Lundvall (2000) and OECD (1997a).
[23] For instance, as pointed out by Johnson and Lundvall (2000), having excellent universities and good academic training is of little relevance if linkages to firms are missing.

The number of patents is smaller. Many firms do not have R&D departments, and so on. What must be understood, however, is that these quantitative differences are the expression of a deeper divide. Innovation systems in developing countries are *qualitatively different*. The root of the difference is historical. When developing countries reached political independence, the economic and technological race among nations had long since started and a technological and productivity gap was already entrenched. Right from the moment of their birth, the new nations faced the daunting task of catching up with the advanced countries. The innovation systems of latecomers trying to catch up cannot but be qualitatively different from the leaders': *they are handicapped systems*.[24]

In order to characterize the region's national innovation systems, I present in Section 3.1 a brief historical overview of the determinants of the firms' innovation practices. The two following sub-sections attempt to characterize the general type of innovation system that resulted from, and is evolving out of, those historical determinants. Part 3.2 focuses on the actual practices of innovation through assessing whether the region is catching up with or falling behind the world's innovation leaders. Part 3.3 examines the formal organizational aspects of the innovation systems' institutional component.

3.1 A Brief Historical Overview of the Region's Innovation Systems.

3.1.1 Innovation Systems in the Import-Substitution Era

By the 1950s, when the first governmental organizations in charge of defining science and technology policies in Latin America were created, the national innovation systems, in the sense of actually existing bodies of innovation practices being carried in the modern sectors of the economy, had been already operating for about two decades, at least in those countries that responded to the Great Depression with a push toward industrialization.[25] Roughly speaking, it

[24] Nonetheless, national innovation systems in developing countries *are not irreparably handicapped*, in the sense that some human beings unfortunately are.

[25] The empirical claim underlying this comment is that in the Latin American countries that started to build their own manufacturing industry in the 1920s and 1930s (or, more generally, before the 1950s), industrialization itself meant the constitution of actual innovation systems given substance by the innovations practices intrinsic to any industrialization process. They were, however, innovation systems that lacked a formal, organizational component in the form of governmental organizations in charge of policy making, coordination of research institutions and activities, funding of research and provision of complementary services. This empirical claim rests on the theoretical claim that *there may exist innovation systems where the organizational aspect of the institutional component (as different from the aspect of norms and other rules of the game) is practically non-existent, or any case, scarcely developed*. Innovation systems are constituted by the institutions having to do with innovation and

can be said that the pre-1950 period was a formation period in an almost geological sense of the word. In the 1950s, the national systems in the largest countries took a more definite institutional shape with the creation of governmental science and technology agencies.[26] During the 1940s and 1950s,[27] a vast array of public-sector enterprises and R&D laboratories were established. By the 1960s, the national innovation systems of the import substitution era had matured and were fully operating. Close to 80 percent of R&D was financed by the public sector and performed by the public laboratories and engineering departments of state-owned enterprises. These activities constituted the core of the national innovation system. Public agencies concerned with agriculture, nuclear energy, mining, fisheries, and forestry were also established in those years. The state-owned enterprises and the other public agencies thus constituted the first (and dominant) component of the national innovation systems. The three other components were local subsidiaries of the multinational corporations, domestically owned large industrial firms (very frequently the property of large conglomerates), and family-owned small- and medium-enterprises (SMEs).

The domestic subsidiaries of multinational enterprises, which arrived in large numbers in the second half of the 1950s and throughout the 1960s, found it necessary to adapt to local conditions the production routines and organizational know-how that had been originally created for a different environment. Many of them created local engineering departments and supplier development programs geared to the needs, operational scale and organizational patterns of the host countries. Many of these firms became focal points for the diffusion of technology, in the process setting up the local quality control standards and efficiency parameters employed afterwards throughout the national production structure. The firms belonging to the large domestic conglomerates, mostly engaged in raw-material-processing industries, also developed their own technological base. Their main focus was on process-engineering technologies that allowed them to adapt and marginally to improve production techniques brought from abroad and embodied in the capital goods they purchased. The SMEs were mainly established in the

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the practices of innovation, with the latter being the only indispensable component. Thus in the relatively rare event that a given system is, as it were, organization-less that does not make it any less of a system, provided that a more or less coherent set of innovation practices is carried out by the firms in the productive system itself. All in all, in this discussion there is still another theoretical assumption, namely, that, *strictu senso*, the concept of innovation system is not applicable to pre-capitalist economies (although, no doubt, *there was* innovation in such economies).

[26] The National Institute for Scientific Research (INIC) was created in Mexico in 1950; the National Research Council (CNPq) was established in Brazil in 1951, and Argentina's National Council for Scientific and Technical Research (CONICET) was created in 1958.

production of consumer non-durables, such as textiles, apparel, footwear and other leather goods, and the like. Many of these firms started with *ad hoc* production facilities and second-hand machinery, copying product designs that lagged one or even two decades behind the international technological frontier. They gradually developed their own engineering departments and started to produce their own technical know-how.

The general policy framework was given by the import-substitution model of industrialization whose components are well known: tariff protection, direct state intervention in the production structure (mainly through the establishment of state-owned enterprises), and more or less close regulation of the private sector. In the mid- and late-1960s, this model brought about high GDP growth, high levels of industrial expansion, a sustained rise in productivity, and an increase in the share of manufactured goods in total exports. Eventually, however, this model also produced serious disincentives to innovation, extended rent-seeking behavior, and a political economy where protectionist interests posed major obstacles to reform and further modernization.

3.1.2 The Liberalization Era: Innovation Systems in Transition

Trade liberalization made imported capital goods less expensive, thus inducing their substitution for locally produced equipment. This means that foreign technology, embodied in imported capital goods, was made cheaper. The downside was that the domestic capital goods industry suffered a major setback.[28] In addition, lower prices for imported intermediate inputs induced domestic firms to increase their demand for these inputs, reduce the demand for inputs produced by local sub-contractors and suppliers and cut down on the number of parts and components they manufacture themselves. Many firms found that they no longer needed in-house design capabilities, as they can now proceed on the basis of imported parts and components. Responding to the same incentives, domestic subsidiaries of transnational corporations have significantly reduced the number of products they produce locally and are searching for production specialization and for new forms of integration into the global production programs of their parent companies. They are also finding that adaptive, in-house engineering efforts are no longer needed, as products have become more standardized worldwide. They have also

[27] In what follows, I rely on Katz (1999).

reduced their domestic input content, tending now to resemble more assembly plants of imported parts and components than integrated manufacturing facilities. In short, *innovation through imports rather than through domestic R&D seems to be a widespread response*.

The privatization of public enterprises has led to the closing down of their R&D and engineering departments. The new operators are modernizing the domestic infrastructure of telecommunications, energy, and similar sectors through imports of capital equipment and technological know-how. Telecommunications is a particular sector where privatization has made it possible for a number of countries in the region to reduce the technological gap vis-à-vis the international leaders. Significant increases in labor productivity and in the digitization of the telecommunications infrastructure are some of the positive accomplishments.

The structural reforms were carried out at the same time that a profound technological transformation centered on high technology was taking place in the developed world. A significant part of the capital goods whose price has been reduced by import liberalization now involves computer-based technologies that make it possible to organize production in "real time," thereby reducing inventories as well as the length of the production cycle. The automobile industry in the region's more advanced countries epitomizes this trend and its consequences. Large auto producers completely have overhauled their production organization strategies, moving quickly to incorporate computer-based technologies that allow them to reduce downtime. This has pushed the final assembly plants into a much higher degree of integration with the first tier of suppliers and contractors. Since most first-tier suppliers are now foreign-owned companies, which are also the auto companies' suppliers in their home market, this has spelled doom for a number of local suppliers that had previously carried out a significant amount of domestic R&D efforts.

In short, trade liberalization, privatization and, in some cases, their compounded effects, seem to have brought about a fair amount of creative destruction: a partial closing of the technological gap in a few countries and in a few sectors, though strategic ones, at the expense of the loss of a certain amount of local R&D capabilities. The change in the incentive structure has enhanced the role played by foreign firms and external sources of know-how in the region's national innovation systems.

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[28] And so have the engineering departments of domestic firms that used to perform technological research and other tasks aimed at extending the life cycle of their capital equipment.

3.2 Towards a Characterization of the Region's National Innovation Systems: The Actual Practices

This section aim to answer a central question, namely, how is the Latin American and Caribbean region doing in the technological race? The section's answer is that *the region is progressing in absolute terms but falling behind in relative terms*. In the process of examining the empirical evidence that supports this claim, the section introduces, step by step, the main features that characterize the region's national innovation systems from the standpoint of the actual practices of innovation being carried out.

3.2.1 Low-Output and Low-Effort Innovation Systems

Warner (2000) created a standardized measure of innovation, the Innovation Index,[29] and calculated the Index values for a large number of countries. He found that all Latin American countries in the sample[30] have a negative Innovation Index value (see Table 1). The average value of the Index for the Latin American countries is –0.99, which, to be seen in perspective, must be compared to the value for the two most innovative countries, the United States and Finland, (2.02); to the average value for the industrialized countries (0.89), and for the East Asian countries (-0.25). It is also instructive to make the comparison with two countries, Ireland and South Korea, that arguably are successfully catching up with the leaders. These countries' Innovation Index values are, respectively, 0.49 and 0.33.

[29] The Index values for every country are built on the basis of the answers given by business executives to questions about inputs to innovation; outputs of innovation; ratings of the quality of the scientific research institutions, and of higher education and the teaching of mathematics and science in schools; and about whether the country has incentives in place to encourage innovators.
[30] There are no Caribbean countries in the sample.

Table 1. Innovation Index for Selected Countries

Country	Innovation Index
United States	2.02
Finland	2.02
Germany	1.66
Switzerland	1.62
Japan	1.59
Israel	1.55
Sweden	1.52
France	1.36
Denmark	1.25
Netherlands	1.20
United Kingdom	1.08
Belgium	1.00
Austria	0.99
Singapore	0.98
Canada	0.85
Taiwan	0.81
Iceland	0.80
Australia	0.78
Norway	0.61
Ireland	0.49
New Zealand	0.45
Korea	0.33
Luxembourg	0.32
Italy	0.25
South Africa	0.03
Spain	0.00
Hong Kong SAR	-0.04
Costa Rica	-0.21
Slovak Republic	-0.27
Malaysia	-0.33
Russia	-0.34
Hungary	-0.35
Chile	-0.43
China	-0.49
Brazil	-0.52
Portugal	-0.56
Turkey	-0.57
India	-0.62
Poland	-0.64
Czech Republic	-0.66
Mauritius	-0.69
Vietnam	-0.72
Mexico	-0.76
Egypt	-0.77
Greece	-0.83
Jordan	-0.84
Philippines	-0.92
Ukraine	-0.93
Bulgaria	-0.94

Table 1, continued	
Country	**Innovation Index**
Thailand	-0.94
Argentina	-0.95
Zimbabwe	-1.07
Colombia	-1.10
Peru	-1.16
Indonesia	-1.18
Venezuela	-1.22
Ecuador	-1.31
El Salvador	-1.35
Bolivia	-1.84

Source: Warner (2000).

Indeed, from the standpoint of their output, Latin American and Caribbean innovation systems do not seem to be catching up with those of advanced countries. Table 2 shows the relative share of eleven groups of countries and China in world innovation output, measured by patents in both the European Patent Office (EPO) and the US Patent and Trademarks Office (USPTO).[31] The Latin American and Caribbean region's aggregate share in both patent offices was 0.2 percent in 1995. The comparison with the shares of South Korea (0.65 percent) and Ireland (0.14 percent), which are not shown in the table,[32] makes it evident that the region's innovation output is not catching up with the leaders'. The hypothesis is strengthened when one considers how the share of a leading Latin American country, Mexico, in EPO patents evolved throughout the 1990s. Mexico's share increased from 0.02 percent in 1990 to 0.03 percent in 1996. By contrast, South Korea's went up from 0.19 percent in 1990 to 0.65 percent in 1996 and Ireland's rose from 0.11 percent to 0.14 percent. Thus from the standpoint of both share size and growth, the performance of a leading Latin American country cannot rival either of the two reference countries.

[31] The table is taken from Barré (1998), p.26.
[32] The shares for Ireland and South Korea are for 1996 and for EPO patent applications only. They are taken from OECD(1999).

Table 2. Innovation Output Measured in Patents

	European patents		US patents	
	1995 (%)	1995 (base 1990 = 100)	1995 (%)	1995 (base 1990 = 100)
Western Europe	47.4	91	19.9	78
Central and Eastern Europe	0.4	101	0.1	43
Commonwealth of Independent States	0.4	113	0.1	59
North America	33.4	125	51.5	108
Latin America	0.2	204	0.2	122
Arab States	0.0	101	0.0	135
Sub-Saharan Africa	0.2	96	0.1	78
East Asia	16.6	87	27.3	108
China	0.1	152	0.2	118
India and Central Asia	0.0	103	0.0	160
South-East Asia	0.0	165	0.0	126
Oceania	1.3	163	0.6	84
World total	**100.0**	**100**	**100.0**	**100**

Source: Barré (1998).

The same picture emerges from Table 3, which shows information about the patents granted by the USPTO between 1977 and 1996. The table shows two important things. First, the total share of the four Latin American countries with the largest numberss of patents granted by the Office (Mexico, Brazil, Argentina, and Venezuela), taken as group (0.143 percent), was, in 1990-1996, smaller than the share of any one of the (arguably) successful[33] countries (which in this table are represented by Taiwan, South Korea, and Hong Kong) taken separately. This comparison suggests that Latin American countries' innovation systems are not generating the innovation output needed for successful catching up. Secondly, while the share of the Latin American group increased in the 1990s with respect to the 1980s (0.079 percent), this increase only allowed them to recover the share they had previously held in the 1970s. By contrast, the reference countries (which, taken separately, all had shares smaller than the Latin American group in the 1997-1982 period) steadily increased their share through the succeeding periods, and by the mid-1990s all of them (again taken separately) had shares greater than those of the

[33] Successful, that is to say, at catching up.

Latin American group taken together. The conclusion that Latin American and Caribbean innovation systems are not up to the task of catching up seems, again, inescapable.

Table 3. Ownership of US Patents

	Patents granted during					
Year	**1977-82**	**share**	**1983-89**	**Share**	**1990-96**	**Share**
Taiwan	382	0.10	2292	0.24	11040	1.43
South Korea	70	0.02	580	0.06	5970	0.77
Israel	641	0.16	1507	0.16	2685	0.35
Hong Kong	272	0.07	633	0.07	1416	0.18
South Africa	491	0.12	699	0.07	787	0.10
Mexico (M)	245	0.06	289	0.03	314	0.04
Brazil (B)	144	0.04	212	0.02	413	0.05
China	7	0.00	142	0.01	353	0.05
Argentina (A)	130	0.03	135	0.01	187	0.02
Singapore	17	0.00	65	0.01	337	0.04
Venezuela (V)	51	0.01	122	0.01	192	0.02
India	56	0.01	96	0.01	204	0.03
East and Central Europe	3444	0.87	2417	0.25	1317	0.17
M+B+A+V	570	0.14	758	0.08	1106	0.14
Total	393629	100.00	959368	100.00	772927	100.00

Source: Kumar (1997).

Another measure of relative performance throws light on the issue. Table 4 shows the invention coefficient[34] for a sample that includes fifteen Latin American countries, two Caribbean countries, and three developed economies (Canada, Spain and the United States).[35] Taking 1998, the year for which there are data for most countries in the sample, the invention coefficient for the three developed economies ranges from 6.8 (Spain) to 50.1 (United States). The coefficient values for the Latin American and Caribbean countries range from 0.1 (for Panama and Paraguay) to 3.8 (Uruguay). The mean is 2.0. What the difference between the first and second sets of coefficients says about the relative speeds of expansion of new technological knowledge in the two types of countries is consistent with the view that the Latin American and Caribbean countries are falling further behind rather than catching up with the leaders.

[34] The invention coefficient is defined as the number of patent applications by residents per 100,000 inhabitants.
[35] The data are taken from Red Iberoamericana de Indicadores de Ciencia y Tecnología (2000).

Table 4. Invention Coefficients in the Americas and Spain (Patent applications by residents/100,000 inhabitants)

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Argentina	2.9	2.9	1.5	2.3	2.0	1.9	3.1	2.3	2.4	-
Bolivia	0.3	0.6	0.6	0.4	0.4	-	1.3	-	-	-
Brazil	4.7	4.4	3.5	4.2	3.7	4.5	4.5	-	-	-
Chile	1.2	1.8	2.4	2.5	3.0	2.3	2.5	3.0	2.9	3.1
Colombia	-	0.2	0.3	0.4	0.3	0.4	0.2	0.4	0.2	-
Cuba	1.7	1.9	1.1	1.1	1.1	0.9	0.8	1.0	1.2	1.0
Ecuador	-	-	-	0.1	0.3	0.6	0.6	0.7	0.8	-
Guatemala	0.1	0.1	0.1	0.1	0.1	0.1	-	-	-	-
Jamaica	0.2	0.2	0.2	0.4	0.2	0.3	0.1	0.4	-	-
Mexico	0.8	0.7	0.7	0.6	0.6	0.5	0.4	0.4	0.5	0.5
Panama	0.3	0.2	0.3	0.8	0.5	0.6	1.2	0.1	1.2	0.4
Paraguay	-	0.1	0.1	0.4	0.3	0.2	0.1	0.1	0.1	0.3
Peru	-	-	-	0.1	0.1	0.1	0.2	0.2	0.1	-
Tr. and Tob.	1.4	2.0	1.0	2.3	1.0	1.9	0.8	1.3	-	-
Uruguay	6.1	5.9	7.3	5.4	3.8	4.3	3.6	4.3	3.8	2.6
Venezuela	1.3	1.2	1.0	0.9	1.0	1.2	0.8	1.4	0.3	-
Canada	9.2	8.0	11.3	14.2	10.5	10.4	11.2	14.0	16.0	-
Spain	5.9	5.7	5.5	5.8	5.8	5.5	6.1	7.5	6.8	7.2
United States	36.3	34.9	36.2	38.8	41.2	47.2	40.3	45.0	50.1	-
Lat. Am and Caribb.	2.3	2.2	1.8	2.0	1.9	2.1	2.2	2.1	2.0	2.0

Source: RICYT (2000).

Still another measure of relative performance tells very much the same story. Table 5 shows the value of a GDP-weighted innovation index built by Barré (1998).[36] There is such a gap between the index values for Western Europe, North America, and the East Asia Group, on one hand, and Latin America, on the other, that any comment seems to be redundant.

[36] For each group of countries, the index is calculated through the following steps: i) calculate NE and NU defined, respectively, as the ratio of the number of European and US patents granted to the particular group of countries divided by the GDP of that group of countries; ii) calculate WE and WU defined, respectively, as the number of total European and US patents divided by world GDP; iii) To calculate the GDP-weighted Index of European patents, take the ratio of NE to WE; iv) To calculate the GDP-weighted Index of US Patents, take the ratio of NU to WU. See Barré (1998), p. 27.

Table 5. GDP–Weighted Innovation Index

	European patents	US patents
Western Europe	213	89
Central and Eastern Europe	25	7
Commonwealth of Independent States	10	3
North America	150	232
Latin America	2	2
Arab States	1	0
Sub-Saharan Africa	7	5
East Asia	145	239
China	1	1
India and Central Asia	1	1
South-East Asia	0	0
Oceania	104	46
World total	100	100

Source: Barré (1998)

An indication as to whether the innovation systems of Latin America and the Caribbean are closing the gap or falling further behind should be their innovation performance in the area of information and communication technology (ICT), the kind of technology that is leading the way in the emerging technical paradigm. One would expect that a national innovation system on the way of successfully catching up with the leaders should exhibit an increasing innovation output in ICTs.

Table 6. Innovation in Information and Communication Technology Patents Granted by USPTO

Country	Share of ICT patents in total	
	1992	1998
Canada	5.8	14.7
Mexico	2.6	2.9
United States	8.8	18.4
Australia	4.8	8.0
Japan	14.1	21.0
Korea	28.8	23.4
New Zealand	3.3	11.7
Austria	2.7	5.8
Belgium	4.1	9.3
Denmark	6.4	3.1
Finland	6.0	29.0

Table 6, continued		
Country	**Share of ICT patents in total**	
	1992	1998
France	8.7	13.3
Germany	4.2	6.7
Ireland	14.2	24.4
Italy	4.0	7.4
Netherlands	10.2	16.6
Norway	4.5	5.1
Spain	4.8	6.6
Sweden	7.3	16.8
Switzerland	3.4	5.7
United Kingdom	9.1	15.9
European Union	6.2	11.0
Total OECD	9.5	17.6

Source: OECD (1999).

For most Latin American countries there is no information available as to the ICT share of patents in total patents. However, there is an indirect way of assessing how the region as a whole is doing. Table 6 shows, for the OECD countries, the share of ICT patents in total own-country patents granted by the USPTO in 1992 and 1998. As is well known, most of the countries in the OECD are ICT leaders themselves, and hence forging ahead, countries keeping up with the leaders, or, alternatively, successfully catching up. Mexico is currently the only country of the region that is an OECD member, and the share of ICT patents within the total of patents granted by USPTO to Mexico did increase between 1992 and 1998. The share absolute increase is a small 0.3 percent. By contrast, most countries increased their ICT patent shares substantially. It is of special interest to focus on Ireland and South Korea, as they represent the paradigmatic "catchers up." By 1992, South Korea already held by far the highest share of ICT patents (28.8 percent) in the OECD countries. In 1998, this share went down to 23.4 percent, which, of course, is still one of the highest. Ireland represents, in a more transparent manner, the performance of an innovation system successful in catching up. In the six-year period under consideration, the country's share of ICT patents grew by 72 percent. It is really difficult to make the case that Mexico, with a far smaller share and growing, moreover, at a much slower pace, is catching up. The meaning of this for the Latin American and Caribbean region as a whole is obvious, once account is taken of the fact that Mexico is a leading innovator when compared to the rest of countries in the region.

Table 7. Shares of High-Technology Exports in the OECD Market, 1997-1994 (Percentages)

Year	Lat. Am. and the Caribb.	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	50.3	5.6	5.3	4.0	70.0
1993	4.7	50.6	5.8	6.1	4.1	71.3
1994	4.8	50.4	5.9	6.6	4.0	71.7

Source: Alcorta and Peres (1995).

The conclusion is also supported by the information provided in Table 7. The table shows how the shares of high- and medium- technology exports[37] to the OECD market from Latin America and the Caribbean[38] and from four East Asian countries (Hong Kong, Singapore, South Korea, and Taiwan) evolved during the period 1977-1994. While the East Asian countries have steadily increased their share, the Latin American and Caribbean countries increased theirs only from 5.2 percent in 1977 to 6.2 in 1984. Thereafter, the region steadily declined to its lowest value in 1991 (4.4 percent) and partially recovered the lost ground between 1992 and 1994. The net result is a decrease in the share. This is hardly the expected performance of national innovation systems on the way to catching up.

It is still true, however, that the Region is progressing in *absolute* terms. Table 2 above, for instance, shows that the number of Latin American patents in the EPO grew by 104 percent (that is to say, more than doubled) between 1990 and 1995, and the number in the USPTO rose by 22 percent. Table 3 shows that the number of patents granted by USPTO to residents of

[37] For a listing of the industries classified as high- and medium-technology industries by the OECD, see OECD (1999), Annex 1, p. 106.

[38] *All* countries in the region were included.

Argentina, Brazil, Mexico, and Venezuela, taken together, increased from 570 in the period 1977-1982 to 1,106 in 1990-1996. Table 8 shows that of the total amount of exports from the Latin American and Caribbean region to the OECD market, the share of those that are high-technology goods increased almost fivefold between 1977 and 1994. Table 9 shows that the total number of patents granted in the Latin American countries grew from 8,190 in 1990 to 10,517 in 1999. Both the number of patents granted to residents and the number granted to non-residents grew steadily throughout the decade. In particular, the number granted to residents grew 35.6 percent.

The region's meager innovation output cannot but be related to the innovation effort made by the countries. Table 10 shows the expenditure on science and technology as a percentage of GDP for the same group of sixteen Latin American and Caribbean nations, and for Canada, Spain, and the United States.[39] With the exception of Brazil, Costa Rica, and Cuba, countries where the indicator is higher than Spain's and (particularly in the case of Cuba) reasonably close to Canada's, the effort made by the Region (relative to GDP) seems to fall short of what is needed.

[39] The table is taken from Red Iberoamericana de Indicadores de Ciencia y Tecnología (2000) with some minor changes.

Table 8. High-Technology Exports as a Share of Total Exports to the OECD Market, 1977-1994

Year	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	25.4	56.3	51.2	25.4	36.7
1994	26.5	56.7	53.3	26.5	37.1

Source: Alcorta and Peres (1995).

Table 9. Patents Granted by National Patent Offices in Latin America

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Argentina										
Residents	249	87	114	612	451	198	342	292	307	-
Non-Residents	510	316	549	2835	1663	805	1449	936	1382	-
TOTAL	759	403	663	3447	2114	1003	1791	1228	1689	-
Brazil										
Residents	464	341	254	378	417	526	938	-	-	-
Non-Residents	2891	2138	1568	2271	2052	2134	1663	-	-	-
TOTAL	3355	2479	1822	2649	2469	2660	2601	-	-	-
Chile										
Residents	101	85	63	38	51	42	41	20	45	70
Non-Residents	540	511	405	277	164	179	230	67	58	156
TOTAL	641	596	468	315	215	221	271	87	103	226
Colombia										
Residents	-	35	35	53	95	87	44	58	19	-
Non-Residents	-	390	213	227	595	278	326	447	418	-
TOTAL	-	425	248	280	690	365	370	505	437	-
Costa Rica										
Residents	5	5	10	4	1	3	3	-	-	-
Non-Residents	1	5	2	2	10	20	4	-	-	-
TOTAL	6	10	12	6	11	23	7	-	-	-
Cuba										
Residents	50	50	39	48	33	15	19	42	34	46
Non-Residents	9	11	10	3	10	5	13	18	5	31
TOTAL	59	61	49	51	43	20	32	60	39	77
Ecuador										
Residents	-	-	1	3	2	5	7	5	18	-
Non-Residents	-	-	59	62	23	82	129	362	291	-
TOTAL	-	-	60	65	25	87	136	367	309	-
El Salvador										
Residents	5	4	1	3	5	1	7	1	5	8
Non-Residents	7	2	23	62	74	60	0	5	60	12
TOTAL	12	6	24	65	79	61	7	6	65	20
Guatemala										
Residents	4	3	4	1	0	0	-	-	-	-
Non-Residents	69	110	63	18	38	3	-	-	-	-
TOTAL	73	113	67	19	38	3	-	-	-	-
Jamaica										
Residents	1	1	2	2	5	2	0	1	-	-
Non-Residents	20	10	1	2	1	3	23	20	-	-
TOTAL	21	11	3	4	6	5	23	21	-	-
Mexico										
Residents	132	129	268	343	288	148	116	112	141	120
Non-Residents	1487	1231	2892	5840	4079	3390	3070	3832	3078	3779
TOTAL	1619	1360	3160	6183	4367	3538	3186	3944	3219	3899
Nicaragua										
Residents	-	17	5	2	53	30	39	33	-	-
Non-Residents	-	0	0	0	2	2	0	5	-	-
TOTAL	-	17	5	2	55	32	39	38	-	-

Table 9, continued										
Panama										
Residents	6	9	7	6	2	7	7	3	12	1
Non-Residents	29	32	34	20	62	73	31	49	97	63
TOTAL	35	41	41	26	64	80	38	52	109	64
Paraguay										
Residents	-	4	3	4	5	4	-	-	-	6
Non-Residents	-	62	30	22	59	49	-	-	-	84
TOTAL	-	66	33	26	64	53	-	-	-	90
Peru										
Residents	-	-	-	10	15	9	7	7	6	-
Non-Residents	-	-	-	104	221	267	174	174	132	-
TOTAL	-	-	-	114	236	276	181	181	138	-
Uruguay										
Residents	61	76	42	43	54	39	9	16	18	38
Non-Residents	101	114	16	139	55	27	20	49	84	106
TOTAL	162	190	58	182	109	66	29	65	102	144
Venezuela										
Residents	63	73	26	299	365	180	76	62	24	-
Non-Residents	724	520	483	1804	2873	2195	1195	684	751	-
TOTAL	787	593	509	2103	3238	2375	1271	746	775	-
Latin America										
Residents	1207	929	882	1847	1837	1294	1659	1596	1609	1637
Non-Residents	6983	5605	6451	13686	11980	9569	8356	8347	8115	8880
TOTAL	8190	6534	7333	15533	13817	10863	10015	9943	9724	10517

Source: RICYT (2000).

Table 10. Expenditure on Science and Technology as a Percentage of GDP, 1990-1999

Country		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Argentina	STA	0.33	0.34	0.36	0.43	0.44	0.49	0.50	0.50	0.51	0.54
	R&D	-	-	-	-	-	-	0.42	0.42	0.42	0.47
Bolivia	STA	-	-	-	-	-	-	-	0.58	0.54	0.55
	R&D			0.37	0.39	0.39	0.37	0.33	0.32	0.29	0.29
Brazil	STA	1.23	1.20	1.04	1.20	1.35	1.26	1.29	-	-	-
	R&D	0.58	0.59	0.48	0.61	0.74	0.87	0.91	-	-	-
Chile	R&D	0.51	0.53	0.58	0.65	0.66	0.65	0.66	0.65	0.62	0.63
Colombia	STA	-	-	-	-	0.62	0.67	0.70	0.65	-	-
	R&D	-	-	-	-	0.37	0.39	0.41	0.41	-	-
Costa Rica	R&D	0.73	1.05	1.23	1.42	1.23	1.25	1.13	-	-	-
Cuba	STA	1.13	1.11	1.65	1.56	1.47	1.43	1.26	1.33	1.49	1.69
	R&D	0.72	0.65	1.13	0.93	0.82	0.77	0.61	0.70	0.87	0.83
Ecuador	STA	-	-	-	-	-	-	0.18	0.23	0.22	-
	R&D	-	-	-	-	-	0.08	0.09	0.08	0.08	-
El Salvador	STA	-	-	-	-	0.30	0.30	0.30	0.30	0.84	-
	R&D	-	-	-	-	-	-	-	-	0.08	-
Mexico	STA	0.28	0.33	0.32	0.37	0.41	0.35	0.35	0.42	0.47	0.41
	R&D	-	-	-	0.22	0.29	0.31	0.31	0.34	-	-
Nicaragua	STA	-	-	-	-	-	-	-	0.14	-	-
	R&D	-	-	-	-	-	-	-	0.13	-	-

Table 10, continued											
Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	
Panama	STA	0.63	0.67	0.63	0.71	0.72	0.76	0.85	0.92	0.87	-
	R&D	0.38	0.38	0.34	0.36	0.37	0.38	0.38	0.37	0.33	-
Peru	STA	-	-	-	0.18	0.42	0.68	0.74	0.67	0.75	-
	R&D	-	-	-	-	-	-	-	0.06	-	-
Trinidad & Tobago	STA	-	-	-	-	-	-	0.33	0.36	-	-
	R&D	-	-	-	-	-	-	0.13	0.14	-	-
Uruguay	R&D	0.25	0.15	0.19	0.07	0.14	0.28	0.28	0.42	0.23	0.26
Venezuela	STA	0.37	0.39	0.49	0.47	0.39	0.48	0.29	0.33	-	-
Canada	R&D	1.45	1.51	1.56	1.60	1.65	1.62	1.57	1.59	1.61	1.50
Spain	R&D	0.85	0.87	0.91	0.91	0.85	0.85	0.87	0.86	0.89	0.90
United States	R&D	2.62	2.69	2.61	2.49	2.39	2.48	2.52	2.55	2.59	2.67

Source: RICYT (2000). STA stands for Science and Technology Activities.

3.2.2 Qualified Human Resources Are Both Insufficient and Underutilized

The human resource development system in the Latin American and Caribbean countries imposes serious constraints upon their innovation systems. Table 11 shows the number of researchers per thousand people in the labor force for fifteen regional countries, and for Canada and the United States. Again, the differences between the countries in the region and the small sample of developed countries speak for themselves. Although the stocks of human resources in science and technology (relative to the size of their population) in Argentina, Chile, and Cuba are relatively strong, the general picture is confirmed of a gap that does not seem to be closing.

Table 11. Researchers per Thousand in the Labor Force

Country		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Argentina	HC	-	-	-	1.99	2.45	2.57	2.62	2.69	2.75	-
Bolivia	HC	-	-	-	-	-	-	-	0.38	0.39	0.38
Brazil	FTE	-	-	-	-	-	0.67	-	-	-	-
Chile	HC	1.20	1.24	1.25	1.18	1.21	1.26	1.30	1.32	1.37	1.35
Colombia	HC	-	-	-	-	-	-	0.45	0.46	0.47	-
El Salvador	HC	-	-	-	-	0.10	0.10	0.09	0.09	0.20	0.20
Mexico	HC	-	-	-	0.55	0.68	0.74	-	-	-	-
Nicaragua	HC	-	-	-	-	-	-	-	0.29	-	-
Panama	HC	-	0.38	0.38	0.63	0.65	0.67	0.84	0.78	0.78	-
Trin.&Tob.	HC	-	-	-	-	-	-	-	0.66	-	-
Uruguay	HC	-	-	-	-	-	-	-	-	-	1.80
Venezuela	HC	-	-	-	-	-	-	-	-	0.45	-
Canada	FTE	4.63	4.74	5.02	5.25	5.46	5.58	-	-	-	-
United States	HC	-	-	-	14.52	-	13.67	-	13.75	-	-
	FTE				7.47	-	7.31	7.77	8.17	-	-

Source: RICYT (2000). HC stands for Head Count, and FTE for Full Time Equivalent.

The human resource development system is not the only culprit and not even the main culprit of this situation, as it only explains the supply side of the problem. There is also a demand side. The labor market, which transmits the demands for R&D professionals coming from the productive system, is the other determinant factor. The productive system has systematically de-emphasized knowledge investment and technological innovation as major tools for profit-making. Generally speaking, the universities produce more researchers than the amount demanded by the productive system, which entails under-utilization of a key human-capital resource.

Results from surveys in two countries (Colombia and Uruguay) illustrate the *low utilization of qualified human resources in broad segments of firms*, which is a major handicap for the purposes of innovation. Table 12 shows the average number of qualified professionals employed by Colombian firms according to size and according to whether they are international-caliber, national-caliber, or potential innovators. What is striking about these figures is that they show the low level of qualified human resources employed in most categories of Colombian firms. With such a low level of human capital utilization, the ability to innovate is bound to be seriously impaired. Table 13, showing the percentage of Uruguayan firms in three size categories and in the total sample that do *not* employ either engineers or technicians, underscores the same point.

Table 12. Average Number of Qualified Professionals in the Production Department of Colombian Firms

Firm Size (by number of employees)	**Type of Firm**			
	International – caliber	National – caliber	Potential Innovators	Does not Innovate
20-49	1.1	0.8	0.3	0.3
50-99	4.4	1.6	3.0	1.0
100-199	8.6	3.5	3.1	2.3
200+	42.5	14.9	2.6	3.4
Total	17.5	4.5	1.6	0.8

Source: Sutz (1998).

Table 13. Percentage of Uruguayan Firms that do not Employ Technically Qualified Personnel

Lack of:	**Firm Size** (by number of employees)			
	20-49	50-99	100+	Total
Engineers	73.8	50.3	22.5	45
Graduated technicians	72.7	53.4	32.6	50
Non-graduated technicians	28.8	19.8	20.8	22.5

Source: Sutz (1998).

3.2.3 Actual Innovation Tends to be Informal

Sutz (1998) reviews the results of surveys conducted in six Latin American countries.[40] Combining the results, she draws several conclusions regarding the region's national innovation systems. First, when a broad definition of innovation[41] is used, 63.6 percent of firms in the surveys had introduced some type of innovation. A second feature is the *informality of innovation in many firms*, defined as the carrying out of actual innovations in companies that do not have a formal internal structure in charge of R&D. The conclusion that there is such a phenomenon is derived from a comparison between the percentage of firms that reported having introduced innovations (63.6 percent) and the percentage that had a formal R&D department (15.7 percent). Another aspect of this informality is that management in many firms did not know how much the firm was spending on R&D. In Uruguay, more than 60 percent of the firms declared not knowing how much were they spending on R&D. In Mexico, the percentage was 71.4 percent. In Venezuela only 8 percent of the firms provided data about their R&D expenses.

3.2.4 Linkages Are Weak and Knowledge Flows Limited

The aforementioned set of surveys also allows the observer an approximation to the type and intensity of the knowledge flows circulating in the region's innovation systems. When asked about the source of their innovation ideas, 13.4 percent of the firms in the Colombian survey

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[40] The six countries were Argentina, Chile, Colombia, Mexico, Uruguay, and Venezuela. Information about the main characteristics of the surveys and their results can be found in CIESU (1987), CONACYT (1998), Durán *et al*. (1998), INDEC (1998), INE (1996), OCEI-CONICYT (1998), and Sutz (1998).

[41] There are several more or less strict definitions of innovation and innovators. According to the strict definition, to be accepted as such an innovation requires international recognition. An innovator in the broad sense is a firm that carries out an innovation that gets recognition in the local market. A potential innovator is a firm that attempted but was unable to bring about an innovation.

attributed them to universities and 7.4 percent to public-sector research institutes. However, 45 percent of the firms belonging to the category of international-caliber innovators, and with 50-100 employees, credited universities as one source of innovation ideas and 43 percent credited public research institutes as another such source. But when the firms resorted to outsourcing of innovation, the universities and public research institutions were the least employed counterparts. In Mexico only 6 percent of firms had established cooperation agreements with universities and only 4.9 percent had done so with public research institutes. Moreover, many firms declared that those agreements were "irrelevant." The Mexican survey also makes it possible to look at the knowledge flows between domestic firms and foreign actors. In the small percentage of cases in which cooperation agreements were signed with universities, only 10 percent of those agreements were with foreign universities. When agreements were signed with clients, the percentage of foreigners was 40 percent. When agreements were signed with suppliers, the percentage of foreigners climbed to 44 percent. And, finally, when the agreements were signed with firms of the same conglomerate or group, 50 percent were foreign firms. In the Venezuelan survey, 43 percent of firms reported signing cooperation agreements. Only 3.5 percent of these agreements were with universities and only 4.5 percent with public research institutes. In Chile, 31.8 percent of firms acknowledged having received innovation ideas from universities and 16.2 percent from public research institutes; 25 percent of the firms surveyed actually signed contracts with universities; and 14 percent with public research institutes. In Uruguay, 27.2 percent of the firms had cooperation agreements with public institutions (including both universities and public research institutes); 10 percent of those were with the main public university.

The main conclusion is obvious: *the linkages and hence the knowledge flows between firms and research institutions (including universities) are weak.* Among the modalities of interaction between the firms and their environment, they are the least frequent.

Firm-to-firm flows have a variable weight in different countries. In Colombia 60 percent of the firms reported having carried out some type of joint innovation with client firms. In Chile that percentage is 48 percent. In Uruguay only 10.5 percent of firms have sought technological advice from other firms, and in Venezuela only 10 percent reported having had technical links with other firms.

It is important to point out, however, that, in any case, *the whole set of external interactions was not assigned a crucial role by the firms themselves. Most firms pointed out that the principal source of new ideas was their own personnel.*

Blum (1995) reviews several surveys about innovation practices in, and innovation capabilities of, Mexican firms. In a survey of 142 firms from the chemical sector, which included small, medium, and large firms, she finds a *"potentially important" but underutilized capacity* for R&D and engineering. Innovations, both product and process, amounted to fewer than five every two or three years, and very few had carried out ten innovations or more per year. This group of firms did not show any evidence of being engaged in cooperation agreements and other forms of alliance with other firms to lower the cost of R&D. There were very few collaborative relations between these firms and universities and research institutes. Only 19 percent have any kind of cooperation with research centers.

Another interesting result from the Mexican survey of chemical firms relates to entrepreneurs' perceptions of the obstacles they face to a higher innovation performance. A report on these perceptions, complemented by information from a survey of Ecuadorian firms, is presented in Appendix 1.

Blum draws additional information from two other sources, namely, Mexico's 5,071-firm National Survey on Employment, Salaries, Technology, and Training, carried out in 1992; and 3,500-firm SECOFI-NAFIN Survey on Technological Capabilities of Mexican Firms, carried out in 1993.

Some noteworthy results from the first survey are as follows. First, medium-size firms made the greatest R& D effort, devoting 0.9 percent of their income to that end (the average for all firms was 0.6 percent). Second, only 2.4 percent of manufacturing establishments used new technologies. The rest used either mature or obsolete technologies; 64 percent of the firms using new technologies were micro-enterprises. Technology transfer payments amounted, on average, to 2.5 percent of total income. Micro-enterprises made the biggest effort in this area, spending 3.9 percent of their income on purchases of technology. Technology transfers were made mainly from other Mexican companies.

Two results are of special interest in the SECOFI-NAFIN survey. First, firms were classified in accordance with the results as competitive, if their activities incorporated advanced technologies and exhibited high productivity; "in transition," if they had machinery that was

already used when purchased; and backward, if they used obsolete equipment. On one hand, 57 percent of large firms and 45 percent of medium-size enterprises were classified as competitive. On the other, micro- and small-enterprises constituted the majority of the two other groups. Second, as far as strategic alliances are concerned, only 8.2 percent of firms had entered into such arrangements,[42] which, again points to the limited extent of knowledge flows in the innovation system.

All this evidence and testimony points to the existence of *a limited and faulty articulation both among firms and between the business sector, on the one hand, and universities and research institutions, on the other, as another of the defining characteristics* of the region's national innovation systems. Since the firms, the universities and the other research institutions are decisive components of the innovation system, this leads to the conclusion that *the core institutions of the system are poorly articulated.*

3.2.5 Firms Are Not the Central Loci of R&D Efforts

Unlike most developed countries, where the dominant component of the nationwide innovation effort is located in the business sector (see Table 14), in Latin American and Caribbean innovation systems the dominant component is the public sector. Table 15 shows that for the entire decade of the 1990s more than 60 percent of S&T expenditures was made by government and less than 30 percent by the business sector. However, if the assumption is accepted that the desirable pattern is the one prevailing in the developed countries,[43] the ongoing trends in the region are positive, as the share of the business sector within total R&D spending has been increasing and the share of government has been declining.

Table 14. Total R&D Expenditure by Source of Funds (Percentage)

	Industry		**Government**		**Other sources**	
Country	1990	1998	1990	1998	1990	1998
European Union	52.3	53.9	40.9	36.9	6.8	9.2
United States	54.0	66.7	40.8	29.8	3.5	4.0
Japan	77.9	73.4	16.1	19.7	6.0	6.8

[42] Only 5.5 percent of micro-enterprises; 12.1 percent of small enterprises; 15.1 percent of medium-size companies; and 17.5 percent of large companies had entered into alliances with other companies.
[43] That the developed countries' pattern is the desirable one is supported by the modern literature on technical change. See especially Cooper (1994) and Nelson and Winter (1982).

Table 15. Expenditure on S&T by Financing Sector (percentage)

Country		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Argentina											
Government	STA	-	-	-	52.7	44.7	45.5	46.3	41.0	42.8	-
Business Enterprise	STA	-	-	-	23.5	28.1	27.7	28.0	27.3	27.4	-
Higher Education	STA	-	-	-	19.3	22.1	21.8	20.3	26.3	24.5	-
Private Non-profit	STA	-	-	-	0.9	1.6	1.5	1.7	1.8	2.2	-
Foreign	STA	-	-	-	3.6	3.5	3.5	3.7	3.6	3.0	-
Bolivia											
Government	R&D	-	-	-	-	44.2	37.0	30.0	25.0	24.0	24.0
Business Enterprise	R&D	-	-	-	-	5.0	17.0	24.0	20.0	20.0	20.0
Higher Education	R&D	-	-	-	-	16.7	12.0	12.0	26.0	27.0	30.0
Private Non-profit	R&D	-	-	-	-	24.0	22.0	22.0	19.0	18.0	16.0
Foreign	R&D	-	-	-	-	10.0	10.0	10.0	10.0	10.0	10.0
Brazil											
Government	STA	72.4	71.8	70.7	70.6	65.4	64.1	64.9	64.0	-	-
Business Enterprise	STA	22.3	22.7	22.9	24.1	30.5	31.8	30.9	31.8	-	-
Higher Education	STA	5.3	5.5	6.3	5.4	4.1	4.2	4.2	4.1	-	-
Private Non-profit	STA	-	-	-	-	-	-	-	-	-	-
Foreign	STA	-	-	-	-	-	-	-	-	-	-
Government	R&D	71.5	70.9	69.5	69.4	67.3	59.1	57.2	-	-	-
Business Enterprise	R&D	23.9	24.5	24.7	26.2	29.7	38.2	40.0	-	-	-
Higher Education	R&D	4.7	4.6	5.7	4.4	3.0	2.7	2.8	-	-	-
Private Non-profit	R&D	-	-	-	-	-	-	-	-	-	-
Foreign	R&D	-	-	-	-	-	-	-	-	-	-
Chile											
Government	R&D	67.0	67.9	58.7	64.2	69.2	71.2	69.5	67.9	66.3	64.3
Business Enterprise	R&D	15.7	15.1	22.6	18.6	14.1	12.2	16.6	19.5	21.1	21.5
Higher Education	R&D	10.9	9.1	10.9	8.9	9.4	9.7	7.5	6.0	5.7	7.3
Private Non-profit	R&D	-	-	-	-	-	-	-	-	-	-
Foreign	R&D	5.5	7.9	7.8	8.3	7.3	6.8	6.4	6.6	7.0	6.8
Colombia											
Government	STA	-	-	-	-	75.4	75.0	74.7	73.3	-	-
Business Enterprise	STA	-	-	-	-	13.0	13.4	13.7	14.2	-	-
Higher Education	STA	-	-	-	-	6.4	7.9	8.4	9.5	-	-
Private Non-profit	STA	-	-	-	-	5.2	3.7	3.2	3.0	-	-
Foreign	STA	-	-	-	-	-	-	-	-	-	-
Government	R&D	-	-	-	-	77.0	74.0	73.0	70.0	-	-
Business Enterprise	R&D	-	-	-	-	8.2	10.0	11.3	13.0	-	-
Higher Education	R&D	-	-	-	-	8.3	11.8	12.0	14.0	-	-
Private Non-profit	R&D	-	-	-	-	6.5	4.2	3.7	3.0	-	-
Foreign	R&D	-	-	-	-	-	-	-	-	-	-
Costa Rica											
Government	R&D	33.1	52.0	58.8	64.7	55.7	49.8	53.4	-	-	-
Business Enterprise	R&D	11.9	7.6	8.2	8.0	11.1	20.2	17.4	-	-	-
Higher Education	R&D	19.4	14.6	12.1	9.9	15.4	13.9	14.8	-	-	-
Private Non-profit	R&D	0.9	0.6	2.1	2.2	3.1	3.3	4.5	-	-	-
Foreign	R&D	34.7	25.1	18.8	15.2	14.8	12.8	9.9	-	-	-

Table 15, continued											
Country		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Cuba											
Government	STA	71.4	78.2	71.2	75.5	72.8	73.5	69.3	62.0	54.2	63.6
Business Enterprise	STA	28.6	21.8	28.8	24.5	27.2	26.5	29.0	35.9	42.0	33.4
Higher Education	STA	-	-	-	-	-	-	-	-	-	-
Private Non-profit	STA	-	-	-	-	-	-	-	-	-	-
Foreign	STA	-	-	-	-	-	-	1.7	2.1	3.9	3.0
Government	R&D	55.1	63.0	57.8	58.7	51.8	50.5	52.8	51.7	51.6	58.9
Business Enterprise	R&D	44.9	37.0	42.2	41.3	48.2	49.5	47.2	48.3	48.4	41.2
Higher Education	R&D	-	-	-	-	-	-	-	-	-	-
Private Non-profit	R&D	-	-	-	-	-	-	-	-	-	-
Foreign	R&D	-	-	-	-	-	-	-	-	-	-
Ecuador											
Government	R&D	-	-	-	-	-	39.8	79.7	80.1	90.6	-
Business Enterprise	R&D	-	-	-	-	-	32.5	-	-	-	-
Higher Education	R&D	-	-	-	-	-	-	-	-	-	-
Private Non-profit	R&D	-	-	-	-	-	4.9	0.4	0.4	0.5	-
Foreign	R&D	-	-	-	-	-	22.9	19.9	19.5	8.9	-
El Salvador											
Government	STA	-	-	-	-	50.0	47.0	47.0	47.0	19.5	-
Business Enterprise	STA	-	-	-	-	35.0	35.0	35.0	35.0	0.5	-
Higher Education	STA	-	-	-	-	5.0	7.0	7.0	7.0	68.5	-
Private Non-profit	STA	-	-	-	-	-	-	-	-	2.5	-
Foreign	STA	-	-	-	-	10.0	11.0	11.0	11.0	9.0	-
Government	R&D	-	-	-	-	-	-	-	-	51.9	-
Business Enterprise	R&D	-	-	-	-	-	-	-	-	1.2	-
Higher Education	R&D	-	-	-	-	-	-	-	-	13.2	-
Private Non-profit	R&D	-	-	-	-	-	-	-	-	10.4	-
Foreign	R&D	-	-	-	-	-	-	-	-	23.4	-
Mexico											
Government	R&D	-	-	-	73.4	63.6	66.2	66.8	71.1	-	-
Business Enterprise	R&D	-	-	-	14.3	19.0	17.6	19.4	16.9	-	-
Higher Education	R&D	-	-	-	8.9	7.7	8.4	8.1	8.6	-	-
Private Non-profit	R&D	-	-	-	1.2	0.6	1.1	2.2	0.9	-	-
Foreign	R&D	-	-	-	2.3	9.1	6.7	3.5	2.5	-	-
Panama											
Government	STA	-	59.3	63.3	62.6	65.1	63.6	61.3	64.4	56.3	-
Business Enterprise	STA	-	0.3	0.2	0.2	0.7	0.9	1.5	0.5	-	-
Higher Education	STA	-	2.3	2.4	5.3	5.0	4.6	4.7	4.5	11.2	-
Private Non-profit	STA	-	0.5	0.5	0.6	0.9	0.8	2.5	3.4	2.6	-
Foreign	STA	-	37.6	33.6	31.3	28.4	30.1	29.9	27.2	29.9	-
Government	R&D	-	35.4	39.7	41.5	44.2	44.5	42.2	44.6	40.2	-
Business Enterprise	R&D	-	0.5	0.4	0.5	0.6	0.5	2.2	0.7	-	-
Higher Education	R&D	-	0.4	0.5	1.0	1.0	0.9	1.0	1.0	2.5	-
Private Non-profit	R&D	-	0.9	1.0	1.2	1.1	1.1	1.8	1.3	1.3	-
Foreign	R&D	-	62.8	58.4	56.0	53.1	52.0	52.8	52.4	56.1	-
Uruguay											
Government	R&D	15.0	23.9	13.8	8.7	6.1	6.1	18.4	38.7	10.8	9.4
Business Enterprise	R&D	58.0	1.9	75.4	79.2	87.6	31.1	30.4	32.4	37.8	35.6
Higher Education	R&D	27.0	72.7	-	-	-	50.3	40.9	26.3	48.5	47.1
Private Non-profit	R&D	-	-	-	-	-	-	-	-	-	-
Foreign	R&D	-	1.4	10.8	12.1	6.2	12.5	10.3	2.4	2.9	7.9

Table 15, continued											
Country		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Venezuela											
Government	STA	47.5	43.6	53.6	50.5	43.3	46.2	32.0	31.5	-	-
Business Enterprise	STA	37.3	42.2	33.1	31.8	36.4	30.2	44.6	44.8	-	-
Higher Education	STA	15.2	14.2	13.3	17.7	20.3	23.6	23.4	23.7	-	-
Private Non-profit	STA	-	-	-	-	-	-	-	-	-	-
Foreign	STA	-	-	-	-	-	-	-	-	-	-
Latin America											
Government	STA	69.3	68.9	67.6	68.1	63.2	62.2	62.9	61.8	61.4	61.5
Business Enterprise	STA	21.5	21.6	22.0	22.4	27.8	28.5	28.3	28.6	28.6	28.5
Higher Education	STA	7.6	7.8	8.4	7.7	6.8	7.4	7.0	7.8	8.2	8.2
Private Non-profit	STA	0.5	0.6	0.6	0.5	0.5	0.5	0.6	0.5	0.6	0.6
Foreign	STA	1.1	1.2	1.4	1.3	1.8	1.5	1.3	1.2	1.2	1.2
Government	R&D	66.5	66.3	64.8	65.7	62.6	57.8	56.9	56.7	56.6	56.6
Business Enterprise	R&D	22.1	22.1	22.6	23.0	26.7	31.8	33.3	32.4	32.6	32.6
Higher Education	R&D	8.8	8.8	9.5	8.6	7.4	7.8	7.3	8.7	8.5	8.6
Private Non-profit	R&D	0.8	0.8	0.9	0.8	0.7	0.6	0.8	0.6	0.7	0.7
Foreign	R&D	1.8	1.9	2.1	2.0	2.7	2.0	1.7	1.6	1.5	1.5
Canada											
Government	R&D	36.2	35.5	35.0	33.3	30.2	28.3	27.2	25.6	25.1	24.4
Business Enterprise	R&D	40.2	40.0	41.2	43.3	45.3	46.5	46.6	48.2	48.7	49.2
Higher Education	R&D	11.5	11.9	11.8	10.7	10.0	10.5	10.1	9.7	9.7	9.8
Private Non-profit	R&D	2.5	2.7	2.3	2.6	2.6	2.5	3.0	3.0	2.9	2.8
Foreign	R&D	9.6	9.9	9.7	10.1	11.9	12.2	13.1	13.5	13.6	13.8
Spain											
Government	R&D	45.0	45.7	50.2	51.6	52.4	48.0	48.0	47.8	42.7	-
Business Enterprise	R&D	47.4	48.1	43.7	41.0	40.3	44.5	45.5	44.7	49.8	-
Higher Education	R&D	-	-	-	-	-	-	-	-	-	-
Private Non-profit	R&D	0.8	0.6	0.6	1.0	1.0	0.8	1.0	0.7	0.8	-
Foreign	R&D	6.8	5.6	5.5	6.4	6.3	6.7	5.5	6.8	6.7	-
United States											
Government	R&D	41.5	38.7	37.8	37.5	37.0	35.5	33.3	31.6	29.4	27.5
Business Enterprise	R&D	54.8	57.5	58.4	58.4	58.8	60.6	62.9	64.5	66.6	68.5
Higher Education	R&D	2.1	2.1	2.2	2.2	2.3	2.3	2.2	2.3	2.4	2.4
Private Non-profit	R&D	1.6	1.6	1.7	1.8	1.8	1.7	1.6	1.6	1.6	1.6
Foreign	R&D	-	-	-	-	-	-	-	-	-	-

Source: RICYT (2000). STA stands for Science and Technology Activities

3.2.6 The Region's National Innovation Systems Are Open

National innovation systems in Latin America and the Caribbean are open systems. This has profound implications in terms of knowledge and resource flows.

First, inflows of foreign technology are a major source of innovation. These inflows take three main forms, namely, 1) inflows associated with foreign direct investment; 2) imports of capital goods and intermediate goods, and 3) technology transfers carried out by means of purchases, on the part of domestic agents, of disembodied technology in the form of intellectual and property rights materialized in patents, licenses, know-how, and technical assistance. The

importance and magnitude of the first two types of flows for the region's economies are well known. Table 16 illustrates the importance of the third source.

Table 16. Technology Transfers to Western Hemisphere Countries as Measured by Receipts in Originating Countries

	Receipts by USA in million of dollars		Receipts by France in million francs		Receipts by Japan in 100 million Yen	
	1986	**1995**	**1985**	**1995**	**1986**	**1992**
All Countries	**7,511**	**25,456**	**8,523**	**10,833**	**2,241**	**3,777**
Developed Countries	**6,797**	**21,327**	**6,271**	**8,987**	**1,081**	**1,882**
Share in total	***90***	***84***	***74***	***83***	***48***	***50***
Argentina	26	128	25	42	3	9
Brazil	25	311	17	18	38	22
Chile		26	8	9		
Mexico	109	414	42	52	13	24
Venezuela	15	93	65	25		
Other Western Hemisphere	96	184	6	2	11	12
Latin America	**271**	**1,156**	**163**	**148**	**65**	**67**
Share in total	***3.6***	***4.5***	***1.9***	***1.4***	***2.9***	***1.8***

Source: Kumar (1997).

Second, foreign economic agents established in the region are major actors in domestic innovation processes. This is tellingly illustrated by the patent data in Table 9: non-residents own an overwhelming majority of the patents granted by domestic patent offices in the region. In 1999 the percentage of patents owned by non-residents was 84.4 percent for the region as a whole.

Third, the region constantly loses a portion of its most qualified human resources through emigration to the industrialized countries. This is a well-known feature of the relationship between developing and developed countries.[44] And it is a systemic feature in that powerful market and other structural forces make it all but inevitable. There are no precise figures on the

[44] Some figures cited by Meyer and Brown (1999) give a rough idea about the quantitative proportion of the phenomenon. According to one estimate, 825,000 skilled immigrants entered the United States and Canada between 1960 and 1987. According to another, only half of the foreign students receiving a doctorate or post-doctorate in the United States return to their native country within two years. In the case of the S&T sector, graduate studies (or, even more generally, university studies) constitute a *de facto* major channel for migration. According to the SESTAT data base of the National Science Foundation, the United States science policy and funding agency, in 1995, the number of people who had science and engineering degrees or who worked in science and engineering occupations in the United States and were of foreign origin was 1,434,000. Over 72 percent of these were originally born in a developing country. Moreover, the higher the diploma attained, the bigger the proportion of the foreign-born population. Of those having a doctorate 23 percent are not citizens born in the United States. This proportion is even higher in some key areas such as engineering and computer sciences.

number of Latin American and Caribbean scientists and engineers living and working in the developed world, but Cetto and Vessuri (1998) report estimates according to which between 40 and 60 percent of all Argentine, Chilean, Colombian, and Peruvian researchers live and work outside their home countries. Meyer and Brown estimate that the total number of scientists and engineers originally from a developing country and working in R&D in the European Union, Japan, and the United States is 400,000. Under the conservative assumption that one-third of these come from Latin America and the Caribbean, the estimate for the region would be a figure in the neighborhood of 130,000. Taken into account that, as of 1999, the total number of scientists and engineers working in S&T research activities in the region was 146,294, the above estimate implies that, roughly 47 percent of the region's stock of S&T researchers is employed in the innovation systems of developed countries.

Fourth, a significant portion of the financial resources being spent on S&T comes from outside the region. This includes the innovation spending made with charge to foreign direct investment flows, loans from the Inter-American Development Bank and the World Bank, and funds from other international cooperation sources. In some countries and in particular years of the last two decades, the percentage of foreign funds within total R&D expenditures has been over 20 percent and in one case reached 53 percent.[45] In the period 1962-1995, the Inter-American Development Bank approved 31 S&T operations in the total amount of US$1.4 billion.[46]

3.2.7 National Innovation Systems in the Region are Heterogeneous

There is considerable heterogeneity in the region's national innovation systems. Sometimes the internal gaps within the region are even bigger than the gaps with the industrialized nations. Looking, for instance at the indicators of innovation output, one finds that, in 1998, the invention coefficient for the United States was about 13 times larger than the coefficient for Uruguay, the leading regional country in this measure (see Table 4). Uruguay's coefficient, in turn, was about 39 times larger than Peru's and Paraguay's. Looking at innovation effort indicators, it is found that, in 1997, expenditure on science and technology as a percentage of GDP was about twice as large as it was in Cuba and Brazil, the best Latin American performers. It is also found that the

[45] The case in question was El Salvador in 1992.
[46] See Inter-American Development Bank (2001).

indicator for Brazil was almost nine times larger than the indicator for El Salvador (see Table 10). Similar results are found in terms of the human resources devoted to knowledge creation and innovation: while the number of researchers per thousand people in the labor force is five times larger in the United States than in Argentina, the number for Argentina is 67 times that of El Salvador (see Table 11). Most human (and financial) resources for science and technology are concentrated in the biggest and relatively more developed countries. According to the Red Iberoamericana de Indicadores de Ciencia y Tecnología (2000), about 73 percent of researchers in the Region are concentrated in Brazil, Argentina, and Mexico.

The Inter-American Development Bank (2001) has proposed a three-category classification of the Region's countries from the standpoint of the degree of development of their national innovation systems.[47] In a first group of relatively advanced nations, it places Argentina, Brazil, Chile, Mexico, and Venezuela. In a second group, characterized by "significant national capacity and specialized institutions to promote S&T, we find Colombia, Costa Rica, Uruguay, and the English-speaking Caribbean. In the third group we find the remaining countries in the Region, which "fare very poorly, in some cases with a complete absence of policies, institutions, and investments in national S&T development" (p. 9).

3.3 Towards a Characterization of the Region's National Innovation Systems: The Formal Organizations

The next building block in this diagnosis of the Latin American and Caribbean innovation systems is a brief examination of the main formal organizations (other than firms) that play an explicit role in it, namely, industrial and technological research institutes, universities, and policymaking bodies. Although funding agencies are also an important system, discussion of their characteristics in the Latin American and Caribbean setting is beyond the scope of this section.

3.3.1 Research Institutes

Research institutes face a difficult challenge in all countries, as they must keep a balance between the long-run imperative of keeping abreast with the research frontier in their field and the institutional duty to satisfy short-run, concrete demands from their business-sector clientele.[48]

[47] The classification refers only to countries that are Bank members.
[48] The point is made by Goldman (1994), cited by Alcorta and Peres (1995).

According to an evaluation summarized in Machado (1993),[49] industrial technology institutions in the region[50] have not been able to keep such a balance. Most did not have knowledge of some key technological advances in their fields, nor were they actively seeking partners, domestic or foreign, that could help them in that respect. Many were not even aware of technological information already in the public domain and had no experience in reverse engineering and copying, activities that are in great demand by small- and medium-size firms. Research programs are frequently determined on the basis of the researchers' personal agendas and not as a result of a study of industry needs, and there is little consultation with the business sector. Of eight research institutes studied by Machado, none had ever conducted a customer satisfaction survey. There are few examples of successful technology transfer from institutes to industry.

In short, then, it is not only that the linkages between non-agricultural firms and industrial research institutes are weak. It is even worse than that. It is that the linkages are weak in part because, *due to internal deficiencies, research institutes quite frequently do not have much to offer to firms*.

3.3.2 Universities

In Latin America and the Caribbean, the quality of universities varies widely and the number of high-quality universities is limited (Meyer-Stamer, 1995). From the standpoint of relationships between universities and firms in the productive sectors, it seems fair to say that the average university in the region does not place these relations high on its agenda, and that many universities *really* do not have much to offer. It is also true, however, that, in this issue, as in many others, relationships are a two-way process. Demand for knowledge on the part of firms is weak both qualitatively and quantitatively (Sutz and Arocena, 2000). Very frequently, firms' strategies are not concerned with knowledge generation. This leads them to emphasize demand for routine consulting work in their relations with university faculty members. An entrenched tradition of relying on technology imports (which, to be sure, must be the best technical and economic option in many, but not all, cases) has led broad segments of the business class to discount in advance local universities as potential technological partners.

[49] Quoted by Alcorta and Peres (1995). Here I follow these authors' exposition of Machado's summary.
[50] I want to bring to the reader's attention that *agricultural* research institutes are outside the scope of this analysis.

To the universities' credit, it must be said that many studies of the relationships between them and the business world demonstrate that, usually, it is the universities that take the initiative in searching for partnerships with firms. By the same token, a number of universities have actively built organizational arrangements to foster university-industry relations (Sutz and Arocena, 2000). Nonetheless, it is still the case that university researchers have strong incentives to conduct their research according to the research agendas set by the leading segments of the respective scientific or technical discipline in developed countries. In most cases, it is unlikely that these agendas will be relevant to the pressing, day-to-day (or even strategic), problems faced by firms in the region.

3.3.3 Policymaking Bodies

In most countries of the region the organizational component of the innovation system is formally structured along the following lines: 1) there is a central-government agency in charge of defining science and technology policy; 2) there is a set of executing agencies; 3) there are institutions in charge of basic and applied research (including the universities, both public and private); 4) there are institutions responsible for the definition of technical norms, standards, quality control, and certification; 5) there are institutions in charge of technical and vocational education, and short-term training of the active labor force; and 6) there are financial institutions and funding agencies.

The top tier of the organizational pyramid typically comprises a central-government agency empowered with policymaking authority and a technical advisory body. In three cases (Brazil, Costa Rica, and Venezuela) the policy agency is a full-blown Ministry, the Ministry of Science and Technology, and its head is a member of the cabinet. In other cases the highest authority is the Ministry of Planning or the President's Office assisted by a science and technology secretariat or a national research council. In several countries the advisory bodies have representation only from the ministries related to science and technology (such as education, industry, agriculture, and the planning agency). In other countries, besides these ministries, other sectors are represented (such as public and private universities, the scientific community, business-sector trade organizations, and regional science and technology bodies).

The organizational culture and style of the innovation policy agencies has been, in part, determined by their history. Because of this, a brief look at that history is warranted. Until the

mid-1960s, government initiatives in the area of innovation were almost entirely limited to provide support to scientific research in public research institutes and universities and therefore can be more appropriately characterized as science policy.[51] At that time technology development started to gain prominence as a policy problem, and technological self-determination became an important policy goal. While technology policy responsibilities and demands were grafted onto the existing science policy agencies, but their actual performance did not change much, as a considerable proportion of what came to be described as S&T policy amounted, in fact, to support for academic research. In the early 1970s, the growing awareness that there was a need to create effective demand for science and technology led policy makers to adopt a more selective and sector-specific approach. This brought about the organizational reform of the mid-1970s. The main action was the formal creation of "national S&T systems." The latter were created from above by simply formally putting together all organizations, institutes, agencies, societies, and individuals directly involved in scientific and technological activities under the direction of the S&T policy agencies. These were, in turn, charged with the functions of articulating, planning, and coordinating the whole "system."

The economic crises and stabilization program of the 1980s hit the S&T agencies hard, as fiscal adjustment efforts led to budgetary contraction. In some cases, the agencies were affected by the reduction in the size of public administration. In addition, some policies containing strong elements of interventionism (or perceived as such) were scaled down. In the meantime, public support for basic scientific research and for graduate training within and outside the region continued to absorb most of the public budget earmarked for S&T activities.

Throughout this process, the central organizational feature of the policy agencies was a fairly high degree of centralization in decision-making. Other shortcomings have been frequently highlighted. Writing about the Argentine case, for instance, Chudnovsky (1999), points out that "there is a lack of priorities, serious shortcomings in management, lack of coordination and of quality evaluation mechanisms, and serious imbalances in budgetary allocations" (p. 165). Other analysts have pointed to the lack of an appropriate juridical and institutional framework, which has kept public authorities, including the S&T agencies, in a situation of insulation and unaccountability. These authors have established, for some key countries, a connection between these institutional features and the experience of authoritarian

[51] In what follows I rely on Bastos and Cooper (1995).

political regimes. Insulation and unaccountability, instead of generating favorable conditions for state efficiency fuel policy rigidity and increase the likelihood of capture by private groups (Bastos, 1995).

An important caveat is in order. Most of what have been said so far relates mainly to the three largest countries in the Region (Argentina, Brazil, and Mexico), and, to a lesser extent, to Chile, Colombia, Costa Rica, Peru, Uruguay, and Venezuela. Moreover, in this matter, as in so many others, the English-speaking Caribbean is a category of its own. By contrast, as pointed out by the Inter-American Development Bank (2001), the institutional situation in the smaller and/or poorer countries is more dire. While there are a few good R&D institutions, often organized on a sub-regional basis, most of these countries have almost no institutional basis, except for a few universities. Regulatory frameworks, intellectual property rights institutions, and information and technical services are either weak or non-existent.

3.3.4 Legal Frameworks, Agencies and Policies Are in Transition

With the advent of the structural reform process in the region's economies in the late 1980s and early 1990s, the S&T agencies entered a period of transition that has not as yet concluded. So far, the two central features of the transition period have been: i) a change in S&T policies towards a greater emphasis on supporting business sector's efforts at technological modernization; and ii) the occurrence of major institutional and legal transformations of the formal organizational component of the innovation systems.

With the general re-orientation of development strategies in the region away from the import substitution model and towards a market-based model of development, the general direction of public policies have substantially changed. In particular, a new industrial-policy approach, and hence a new set of industrial policies, is emerging, a trend examined in Melo (2001). As argued there, the crucial issue in the new approach is the question of finding the ways and means of raising competitiveness. Access to, and competition in, external markets; productivity growth; efficiency; technological modernization, and similar topics have become the overriding concerns among both entrepreneurs and policy makers in the region. This new policy thrust has been felt in the area of innovation policies, and there too a new set of policies is emerging. It is increasingly understood that the central issue for innovation policy in the new circumstances is how to help the productive-enterprise sector to enhance its competitiveness

while responding to the long-run challenges posed by the knowledge-based economy in terms of basic scientific research.

The emerging policy trends in innovation policy start from the premise that government intervention is needed because of the existence of pervasive market failures in: i) the gathering and dissemination of information; ii) the initial introduction of new technologies, and iii) the financing of research and development.

As to the general content and orientation of the emerging policies, it is now widely accepted by policy makers in the Region that the unilateral specialization of S&T agencies in the funding of basic scientific research in the previous decades must give way to a new scheme of resource allocation where more attention in terms of both policy design efforts and financial resources must be assigned to support the productive firms' technological modernization. At the same time, the policy agencies do not seem about to swing to the other polar extreme of leaving the local scientific communities unprotected and scientific research financially weakened. The conditions seem to be ripe for reaching an appropriate balance between the two objectives.

There is also an increasing awareness that the need to make the distinction between science policy and technological-modernization policy must have consequences as far as the policy instruments and the appropriate institutional vehicles for each type of policy is concerned. This has led, *inter alia*, to institutional reforms such as the introduction of separate funding programs (or even agencies) for technological modernization, clearly differentiated from the traditional programs (or agencies) in charge of funding scientific research.

Appendix 2 surveys the policies being now pursued to stimulate private-sector efforts at technological innovation. This policy re-orientation has been accompanied by, and, to an important extent, has also caused, major legal and institutional transformations of the formal organizational component in the innovation systems.[52] In this ongoing transitional period, the

[52] To illustrate the extent of the legal-institutional transformation in the 1990s, it is appropriate to allude to some of the legal milestones in this process. Taking the countries in alphabetical order, the main legal changes in the decade of the 1990s were as follows. In Argentina, the Law for the Promotion of Technological Innovation was approved in 1990; in addition, in 1996, the Technological and Scientific Cabinet and the National Agency for the Promotion of Science and Technology were created. In Brazil, the National Council for Science and Technology (CCT), an advisory body, was created in 1996. In Bolivia, in 1991, the government issued Supreme Decree 22908 to regulate science, technology and innovation activities, and in 2000 the Senate approved, in the first instance, the Law for the Promotion of Science, Technology, and Innovation. In 1990, the Colombian Congress approved the law that provided a legal foundation for the National System of Science and Technology; thereafter, in 1995, the National Innovation System was legally created. In Ecuador the new institutional framework was established in 1994 through Executive Decree 1603, which reorganized the National System of Science and Technology, and Decree 1605 that created the Science and Technology Foundation. In 1992, the National Council of Science and Technology was

governments in the region are increasingly accepting, as their guiding framework, the systemic conception of innovation as a social practice conducted by a wide variety of actors. Most S&T policy élites in the Region are employing the conceptual tools of the national innovation systems approach to think about strategic, institutional and policy issues. A number of countries have formally incorporated the systemic conception in their legal reforms of the 1990s. A more participatory approach, which assigns a greater role to the business sector and allows for more dialogue with it, is being implemented. There is a growing awareness that a rational separation of policymaking and programming, promotion, execution, and evaluation functions requires that different government organizations be in charge of the different functions.

New management practices are being introduced that strengthen the planning of activities, the coordination of organizations and efforts, and the evaluation of results. One of these practices is the drawing, participatory discussion, and formal approval of multi-year strategic plans.[53] The plans typically define the conceptual framework, objectives, strategies, policies, priorities, intermediate goals, guidelines, action programs, and quantitative targets for government and its agencies. They also evaluate the system's accomplishments in the previous years and diagnose the policy challenges that need to be addressed.

4 The Policy Issues

Not all the systemic issues raised about the region's national innovation systems in the diagnostic part of this paper are amenable to direct policy intervention. My claim is, then, that the best way for government and public policy to address systemic issues is to play a leading role in an active catch-up strategy, on the assumption that the implementation of such a strategy will allow the Latin American and Caribbean countries gradually to transform their national innovation systems into more mature and more enabling frameworks for domestic firms' creation of knowledge and its application to the production of higher-quality, lower-cost products.

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created. In Guatemala the Law for the Promotion of Science and Technology was approved in 1991. The Honduran Council of Science and Technology was created in 1992. The Nicaraguan Council of Science and Technology was created in 1995. The Law that regulates science and technology activities was passed in 1997 by the Panamanian legislature. In Paraguay, Law 1028 of 1997 established the National System of Science and Technology. In Uruguay the Institutional System of Science of Technology was reformed in 1999 within the context of a general reform of the Uruguayan state. Also in 1999 the Ministry of Science and Technology was created in Venezuela.

[53] For the content and style of these plans, see CONACYT (1995), CONICET (1999a), CONICET (1999b), and Ministério da Ciência e Tecnologia (1996).

The central premise is that Latin American and Caribbean countries have no other worthy option than an active strategy of catching up with the advanced countries' productivity levels and standards of living. There is not, of course, a single catch-up strategy that is valid for all countries. In the case of the region's economies it seems, in a first instance, that it is better to talk of families of catch-up strategies and that, in this vein, at least three broadly defined families could be outlined according to whether the country in question is one of the three largest economies, one of the intermediate-size economies, or one of the smaller and/or poorer countries. Ultimately the best strategy is country-specific. However, catching-up strategies share some basic features worth mentioning.

The essence of catch-up strategies is the generalized and intensive building of problem-solving capabilities throughout a national innovation system, with the end result that firms will be able to improve their productivity, *initially* by imitating and adapting to local conditions, product, process, and organizational technologies already developed elsewhere; and *subsequently* by steady quality improvement, cost reduction, and incremental change.[54] While in the initial phase the imitation of already established technologies prevails, in a second phase, and on the basis of more developed innovative capabilities, the emphasis shifts to higher value-added production, continuous improvement, and new-product generation.

An important caveat should be noted: a number of particular firms or sectors in the individual economies of the region may arguably already be considered internationally competitive and hence keeping up with the leaders. There may even be firms and sectors that already are on the leading edge, or close to the leading edge in their industries. To the extent that that is the case, the catch-up strategy makes no sense for these sectors and strategies of keeping up or even getting ahead are called forth. This makes public policy all the more complex and, right from the outset, introduces some nuances into the forthcoming discussion.

The role of government in such a strategy is multiple. First, it must assume a leadership role. Second, it has a rule-setting function in the exercise of which it must create a general

[54] This definition is largely inspired by Mytelka's (1998) definition of a catch-up strategy. However, I see a country's catch-up development stage as roughly going through a two-phase process where the first phase is predominantly an imitation phase, and the second phase relies increasingly less on imitation and increasingly more on own knowledge-and-experience accumulation which makes it possible to undertake quality-improvement and cost-reduction tasks on a national scale. In Mytelka's view the catch-up strategy is limited to the imitating-and-adapting phase. She would probably reply that if a country were able to emphasize quality-improvement and cost-reduction, that would (presumably) indicate that it is already engaged in a keep-up strategy. My contention is that

policy environment conducive to private investment in technological innovation. Third, it must perform a planning function. Fourth, it has a fundamental role to play in the human-resource development system. Fifth, it must be responsible for promotion functions. Sixth, it cannot escape undertaking productive functions within an otherwise predominantly private innovation system. And, seventh, it has to discharge a regulatory function. Let us briefly discuss each of these functions.[55]

The task of catching up with the advanced countries is a gargantuan endeavor. The most reasonable way of conceiving it is as a national project whose completion requires that a vast amount of societal energies be mobilized. It is only natural that state institutions and the political leadership elected by the people to rule through those institutions play the role of guiding the overall effort. A prime example of a country where the government has played such a leadership role is the United States. It is amply documented that the government of today's innovative country *par excellence* has consistently led the national innovation effort.[56]

The remaining six functions are specifications of the leading role of government. The planning function calls attention to government's power and responsibility to lead the way in the definition (through participatory decision processes) of clear strategic objectives. An appropriate instrument for such a purpose is the formulation of multi-year plans where measurable mid-term objectives, the policy measures and policy actions to reach them, and the required budgetary expenditures be laid down. The planning function also includes the selection of strategic research areas where efforts must be concentrated to accelerate the catching-up endeavor.

The promotion function requires the use of financial instruments, fiscal instruments, and the coordinating role of government to stimulate innovation and technological upgrading by the business sectors.

The productive function stems from the fact that in all countries in the region a subset of the institutions generating innovation are in the public sector. This subset includes, of course, public universities and public research institutes, but also state enterprises in countries that

without quality improvement and cost reduction there will not be in the end more than a very partial and unsatisfactory catching-up.

[55] I have partially relied on the taxonomy of government functions in Celso (2000).

[56] This it has done mainly under the form of basic research that initiates and supports technological advances. It has actively encouraged university research on a large scale. It has channeled the innovation efforts of industrial firms via procurement and development contracts (Freeman, 2001). Among innovation systems of developed countries, the U.S. system is unique in the exceptionally large part of total R&D expenditures financed by the federal government and performed by the business sector.

decided not to privatize all of them. These are major actors in the innovation system, and the government's responsibility is to manage them in such a way as to maximize their contribution to the catching-up effort.

The regulation function is related to the government's responsibility for setting general rules for all the agents in the system (including itself). The most relevant rules are in four areas, namely, 1) legal rules having to do with industrial property and its use; 2) market competition rules; 3) rules related to technical standards, quality standards and accreditation, and metrology; and 4) rules in the areas of safety, health, and environmental protection.

Quite naturally, a host of political and policy issues emerge in connection with all the enumerated functions. In what follows, the discussion will focus on a subset of policy issues having to do mainly with 1) the promotion function of government and 2) the institutional prerequisites for efficiency in technology policy implementation.

4.1 Innovation Promotion Policies

The first condition for a successful innovation promotion policy is the existence of a general economic policy framework capable of creating a favorable business climate for private sector investment in innovative activities. The well-known general background conditions that stimulate investment in general are also necessary conditions to stimulate investment in R&D. Macroeconomic stability and the rule of law, including the existence of a reasonably efficient judicial system and respect for property rights, are integral parts of the requisite environment.

Public policies to promote innovation can be classified in two broad categories:[57] 1) policies aimed at modifying the market incentives faced by firms; and 2) policies aimed at providing public goods. The issues arising in connection with these two groups of policies will be discussed seriatim.

4.1.1 Policies Aimed at Modifying Market Incentives

Policies aimed at modifying market incentives can, in turn, be classified in two categories, namely, 1) fiscal policies; and 2) provision of credit, provision of venture capital, and other financial policies.

[57] For this simple taxonomy I take as a point of departure Mani (1999) who, in turn, builds on Guinet and Kamata (1996).

A. Fiscal Policies

Fiscal policies include tax incentives; direct funding of research projects; the carrying out of joint cooperative projects between the government and the private sector; and the use of public procurement of goods and services as a tool to induce or guide innovation.

Among the fiscal incentives, the most important and widely used instrument in the developed countries (and in a few developing countries as well) is tax incentives (Mani, 1999). With regard to best practices in designing and implementing R&D tax provisions, an OECD study[58] recommends, *inter alia*, that R&D tax policy; 1) must be designed as part of an overall strategy; 2) should include provisions for the deduction of all qualified R& D expenses *in the year in which they are incurred*; 3) should be flexible in order to accommodate firms at different stages of development; 4) should include special provisions relating to small and/ or new firms in order to encourage entrepreneurship and innovative start-ups. To these recommendations, another can be added: giving tax refunds to firms in those years when, because of absence of profits, they have no tax liabilities. This latter provision rewards innovative behavior independently from short-run profit performance and contributes to making innovation less dependent on the vagaries of the business cycle.

A second fiscal incentive is the direct public funding of research performed by the business sector. Empirical results by Guellec and van Pottelsberghe (2000) show that direct government funding of R&D performed by firms has a positive effect on R&D expenditure by firms: one dollar given to firms results, on average, in $1.70 dollars of research expenditure by the firms themselves.

According to Mani (1999), a comparison between tax incentives and direct government funding suggests that the latter is apt to be more efficient than the former when the aim is to enlarge the stock of basic knowledge available to the firms. But if the aim is to boost a country's rate of commercialization of new products, processes, or services, then a tax incentive has some advantages over direct funding. Success in commercialization hinges on a sound understanding of the market and tax incentives have the advantage of leaving the decisions of which projects to fund in the hands of the agents more likely to know the market, namely, the firms.

[58] See OECD (1996b).

B. Venture Capital Policies and Credit Policies

The obstacles faced by innovating firms in the financial area may be a major deterrent to innovation. Innovation is a genuinely uncertain activity, hence investments in innovation are high-risk investments. From the standpoint of the financing agent, both debt finance and equity finance of R&D investments entail risks additional to those present in investment projects based on established technologies. Furthermore, the issue is posed in different terms for start-up companies in technology intensive fields vis-à-vis mature firms. As pointed out by an OECD study,[59] starting technology-based firms (which, in today's knowledge-based economy are generally small firms) are likely to have seed and early-stage costs that are higher than for other small firms. Because of the perceived high risks, unproven innovations and difficulties in assessing the size of the potential market, technology-based firms often have greater problems finding external sources of finance. In addition, potential finance providers often underestimate potential returns and may not have the skills needed properly to evaluate the risks involved in investing in those firms' projects. These considerations imply that although debt finance for innovation is very important for both established firms and start-ups, the critical issue for the latter is the issue of access to sources of venture capital.

In what follows, policies aimed at addressing the financial issues are discussed. Debt finance is discussed first and the issue of venture capital is discussed thereafter.

Credit incentives to innovation are used in a number of countries. The most frequent modality is loans for technological innovation and technology acquisition granted by public development banks or similar promotional agencies of the national governments. According to OECD (1997b), the loan programs are usually tailored to the risk characteristics of R&D investment pointed out above. Interest rates are preferential, the difference from the market rate being, obviously, a subsidy. The loans are granted for extended periods and, sometimes, release from debt obligations is an option in the case of borrower failure.[60]

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[59] See OECD (1997b).

[60] For the sake of illustration some of the existing credit programmes in OECD countries are mentioned in what follows. In Germany, for instance, the *Kreditanstalt für Wiederaufbau* (KfW), the federal promotional bank, provides loans through the Innovation Program. The *Deutsche Ausgleichsbank* (DtA) also provides credit for technological innovation. The loans are with a term of up to 20 years; with fixed interest rate extending over several years; low rates of interest, and grace periods of up to 10 years. The loans are targeted mainly at SMEs. Australia's AusIndustry, an agency of the Department of Industry, Science, and Resources, in charge of supporting industry, research and innovation, operates the R&D Start Program. This program assists firms in undertaking R&D and commercialization of inventions through a range of incentives. The basic incentive is a grant, but if the particular project qualifies as a high-quality project, it can receive a loan on top of the initial grant. The Program also grants

Following OECD (1997b), the policy instruments aimed at stimulating the supply of venture capital may be grouped into three main categories, namely, 1) the direct supply of capital to venture capital funds or small firms; 2) fiscal and financial incentives to investing in venture capital funds or start-up firms; 3) investor regulations determining the types of investors in venture capital.

Given the scarcity of domestic sources of venture capital in Latin America,[61] direct equity investment by the government is a policy issue of prime importance for the Region. There are several possible modalities of direct equity investments by the government. One type of program is where the government invests in private venture capital firms, which, in turn, provide equity to firms. This is the type of alternative that can be of limited applicability in the Region, except in the case of the biggest countries. Alternatively, the government can create its own venture capital fund or a hybrid fund with private sector participation. The lessons from the OECD countries' experience with government venture capital funds indicate that: 1) the preferential targets of these funds must be early-stage firms and technology-based firms; 2) public officials should not be directly involved in the investment process; rather, this responsibility should be delegated to top-quality venture capitalists from the private sector; 3) government venture capital funds must provide investee companies with more than money: they should receive advice regarding management, strategy, and finance; 4) venture capital programs should seek to maximize private sector participation, and as private sector involvement in a segment grows the government should phase out its programs.

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concessional loans for the early commercialization of technological innovations. In Korea, banks such as the Korea Development Bank, the Citizens National Bank, the Industrial Bank of Korea, and others, provide long-term, low-interest loans to private firms to finance the development of new product and process technologies as well as the commercialization of new technologies. The National Technology Agency of Finland provides soft loans for R&D projects that lead to internationally competitive product, processes or services. The Austrian Industrial Research Promotion Fund supports applied R&D in the business sector through loans and interest subsidies. The Japan Key Technology Center (JKTC), jointly ascribed to the Ministry of International Trade and Industry (MITI) and the Ministry of Posts and Telecommunications (MPT), provides loans to private firms for R&D. The loans finance up to 70 percent of an R&D project expenditures. An interesting feature of JKTC loans is that the interest charged after the grace period (which coincides with the period up to completion of the R&D project but with a maximum of five years) depends on the success of the project. However, *the relationship to the project success is not direct but inverse*. Completely successful projects pay 100 percent of the rate set at the time of the granting of the loan. In a descending scale, projects with lesser degrees of success pay 75 percent, 50 percent, 25 percent of the rate, or 0 percent, so that projects that are a total failure pay no interest. The rationale for this scheme is that it reduces the risk involved in technology development.

[61] On this, see, for instance, Jaffe (2000).

4.1.2 Policies Aimed at Providing Public Goods

The set of policies aimed at providing public goods that are relevant to the innovation practices of firms contains a number of elements. The most important are: 1) policies aimed at diffusion of technology; 2) policies to strengthen the human-resource development system; 3) the direct production of scientific and technological knowledge through government-funded R&D performed by the public universities and research institutes; 4) policies and initiatives where the government can play the irreplaceable role of convoking and organizing power as well as of coordinating element; and 5) policies having to do with the regulation and standards-setting function discussed above, to the extent that the products and services generated in the exercise of this function are important public goods which are necessary framework conditions for the carrying out of innovation in individual firms.

Due to space constraints the discussion here will limit itself to the policies for diffusion of technologies and to a single element of the set of policies where government can play the role of convoking and organizing power, namely, the promotion of innovation clusters.

A. Issues in Technology Diffusion

The rationale for emphasizing technology diffusion is straightforward: for countries whose main task is catching up, learning from the leaders through imitation and adaptation is the most effective and efficient form of internal innovation.

Technology diffusion is the social process whereby technology, including the tacit know-how needed to apply it, spreads from the original innovator to other users (OECD, 1997b). Diffusion is carried out through learning processes that require investment not only in equipment, but also in intangibles such as R&D and skilled staff capable of absorbing the knowledge involved in the technology in question. Summarizing the experience of the industrialized countries, the OECD Secretariat (1997) proposes a simplified typology of technology diffusion programs based on the two main axes of technology diffusion: 1) technology targets, and 2) technology services.

According to this report, the lessons that can be learned from the experience of technology diffusion in the OECD countries concerning best practices are as follows: 1) programs should be customer-focused and demand-driven; 2) technology diffusion systems should be comprehensive and cover different types of technologies, firms, and sectors, and

include the transfer of both off-the-shelf and existing technologies as well as more highly sophisticated technologies if there is a demand for them; 3) technology diffusion schemes should seek to provide a variety of different kinds of expertise and services (including training, networking, etc.); 4) programs should develop strong linkages with all technology-related service providers and promote networks among providers and users; 5) programs should go beyond technical problem-solving and address the managerial and organizational modifications required for firms to adapt to technical change: 6) programmes need to have sufficient resources, linkages, and leverage points to work with large numbers of firms over time.

B. Issues in the Promotion of Innovation Clusters

A cluster is an agglomeration of firms in the same or in related lines of business.[62] In principle, a cluster can contain firms of all sizes in any combination, but some combinations are more frequent than others. The number of enterprises can be large or small. The promotion of clusters of enterprises is an effective whereby governments can create conditions for the private sector to enhance productivity, the rate of innovation, and the competitive performance of firms. This is because the local concentration of industries makes it possible for the participating firms to benefit from economies of scale, economies of agglomeration and supply side externalities that would not otherwise be available to the firms in isolation. Labor pooling, the availability of local input or equipment suppliers, and shared infrastructure are just a few instances of such advantages. More importantly, *clusters are optimal arrangements for the production and internal diffusion of tacit knowledge*, the kind of knowledge that gives a competitive edge to those who possess it.

There are many types of clusters and a number of different cluster typologies can be found in the literature. For the purpose of this chapter, the relevant thing is that all typologies recognize the existence of innovative or innovation clusters. According to the UNCTAD Secretariat's (1998) typology, innovative clusters center on knowledge-intensive activities and have the ability to undertake technology adaptations, design new products and processes, and bring them quickly to the markets. The flows of knowledge are particularly frequent and intense among firms belonging to innovation clusters. They work in (sometimes-invisible) networks of relationships in complex social settings where industrial activity is based on knowledge and

[62] This paragraph draws on Enright and Ffowcs-Williams (2000).

learning. The two paradigmatic innovation clusters are, of course, Silicon Valley in California and Boston's Route 128.[63] Other well-known innovation clusters are Japan's Tsukuba and the Research Triangle of Chapel Hill, Durham, and Raleigh in the state of North Carolina in the United States.

Innovation clusters are mainly found in industrialized countries. There are, however, a number of such clusters in the developing world. In the case of Latin America, and on the basis of Bortagaray's and Tiffin's (2000) findings, at least 31 clusters can be identified that meet the requirements of the UNCTAD Secretariat's definition.[64] It is noteworthy that some of these clusters are in high technology industries such as microelectronics (Campinas), telecommunications (Campinas, Curitiba), computer science and informatics (Campinas, Sao Leopoldo, Monterrey) software (Curitiba, Espírito Santo, Porto Real, Porto Alegre, Rio de Janeiro, San José); automation engineering (Espírito Santo); biotechnology (Belo Horizonte, Havana); electronics (Santa Rita de Sapucaí, Cuernavaca, Guadalajara); and aeronautics (Sao José dos Campos). The geographical distribution of these innovative clusters indicates that Brazil is the leading country with 22, followed by Mexico with 6, Argentina with 2, and Cuba, Costa Rica, and Uruguay with one each.

Policy experience with innovation clusters in Latin America and the Caribbean is limited but suggestive. According to Quandt (1999), the first attempt was Brazil's creation of thirteen "technological innovation nuclei" in selected universities and research centers in 1982. This was followed by the creation of the Program for the Implementation of Science Parks in 1984. Since 1993, many public and private entities have become involved in the promotion of incubators and science parks. In 1999, there were fifteen regions classified as emerging high technology

[63] According to Saxenian (1994, quoted by Bortagaray and Tiffin, 2000), Silicon Valley is now home to one-third of the 100 largest technology companies created since 1965. The market value of these firms increased by US$25 billion between 1986 and 1990. In 1990, Silicon Valley-based producers exported electronic products worth more than US$11 billion, almost one-third of the US total.

[64] Bortagaray's and Tiffin's (2000) typology makes the distinction between three types of innovative clusters. They are, in ascending order of innovation capabilities: i) innovative industrial clusters; ii) proto-innovation clusters; and iii) mature innovation clusters. The criteria for a cluster's being considered a mature innovation cluster are very demanding. It must be able to define the social structure of the community where it is located; create a dynamic, expanding group of firms based on cutting-edge scientific knowledge; draw in talent from around the world; generate venture capital; and drive the pace and direction of scientific and technological research. I would conjecture that, out of the many existing clusters in developed countries, only a handful would fit this description and most would be either in the industrial innovative category or in the class of proto-innovation clusters. In the case of Latin America, Bortagaray and Tiffin claim that none of the clusters they studied is a mature innovation cluster. Of the 31 they found in the broad category of innovative clusters, 17 are in the proto-innovation category and 14 are in the industrial innovative category.

centers, seven science parks and about 60 incubators housing nearly 500 firms. Mexico started to create business incubators in 1990. In 1999, there were fifteen operating incubators. Most of them are supported by the National Council for Science and Technology (CONACYT) and the Association of Incubators and Technological Parks. Some of the efforts are led by universities, others by R&D centers; two are led by the private sector. In Argentina, the *Polo Tecnológico Constituyentes*, organized around the main public S&T institutes, intends to develop processes of enterprise incubation but, according to Bortagaray and Tiffin (2000), the emphasis is more on supply-driven technology transfer out of the large government laboratories than on demand-driven cluster formation. In addition, a "virtual business incubator" to support technology-based firms is sponsored by the EMPRETEC Foundation.

The factors underlying successful innovation clusters in the developed world are a frontier research topic. In the case of Latin America and the Caribbean, much work is *a fortiori* still needed to shed light on the requirements for success. This means that policy and best-practice lessons are still far from settled. Promotion of innovation clusters is, indeed, a valid policy plank, but much caution is called for. Creation of true, viable innovation clusters is an extremely hard task, as the requirements in terms of quality of the universities and research institutes, human resource development, the general policy framework, the legal institutions, the financial system (especially, the provision of venture capital), and the business support institutions for having even an *average* (by international standards) innovation cluster are very demanding.

Consensus among the practitioners seems to move towards recommendations along the following lines. First, policy makers should let the private sector lead in innovation-cluster development initiatives. Government support should be given on the basis of a prior private-sector irreversible commitment of substantial resources. Policy makers should make sure that the critical mass of enterprises and skills can and shall be marshaled by private entrepreneurs before committing public resources to the support of a particular innovation cluster initiative. Second, government support should critically address issues of seed financing and venture capital. In addition, tax incentives and credit lines from the development banks for working and fixed capital for the firms belonging to the clusters are appropriate forms of government support. Third, the role of sub-national governments is decisive. In the Brazilian experience, for instance, several states have set enterprise incubators to promote clusters. It would seem that, from the

organizational standpoint, the best way to go is to promote innovation cluster formation through the establishment of consortia with the participation of national government S&T agencies, regional and local governments, universities and research institutes, and equipment and service providers. External support for clusters works best where cluster promotion policy is decentralized and builds on public-private partnerships. Fourth, the principle of decreasing government support as a particular cluster matures must be strictly observed.

4.2 Institutional Prerequisites for Efficiency in Technology Policy

Paraphrasing Lipsey (1999), one could say that *the ideas supporting the view that government intervention to promote technological innovation is necessary are both powerful and dangerous*. They are powerful because they shed light on a key ingredient of economic development and open new, promising avenues to public policy. They are dangerous, though, because in allowing for the possibility for selective intervention and/or context-specific policies they may end up, *if and when applied in the wrong institutional contexts*, opening the Pandora's box of rent-seeking behavior and related abuses. Technology policy is a complex matter. Good policy design and implementation require a considerable degree of institutional development, effective governance, and substantial administrative capabilities. Here, the spirit of Lipsey's advice on context-specific policies is wholly apposite even when applied to the broader issue of subsidies and similar interventions to promote technological innovation: "such policies should be avoided unless a country's political constitution, political practice, and administrative competence are all such as to reduce to acceptable levels the risk that the policies will be subverted for purposes other than those for which they were intended" (Lipsey, 1999, p.26).

For the state as the central political institution of a country to be able to assume a leadership in a long-run catch-up strategy, several institutional requirements must be met. They can be summarized, though, in the great desideratum that the state apparatus be both autonomous and embedded.[65] Embedded autonomy is a very demanding combination of state independence from particularistic social interests and responsiveness/commitment to both the general social interest and the long-run needs of economic development. A further specification of the concept requires that the political system and the institutional design of the state make possible: 1) a long-run institutionalized commitment of both the political leadership and the state institutions to

[65] The concept of embedded autonomy was proposed by Evans (1995).

a broadly defined but energetic enough catch-up strategy; 2) a capable, independent, and honest civil service; 3) an institutionalized partnership between the government and the key actors in technological innovation, i.e., the professional community of scientific researchers and technological innovators, the institutions of the human-resource development system, the private business sector, and the industrial working class.

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Appendix 1. Where Do Firms' Managers Believe the Obstacles Lie?

In the survey of Mexican chemical firms discussed by Blum (1995), firms were asked about the obstacles they faced in improving their innovation performance. They rated the high cost of innovative activities as an important obstacle and pointed to the lack of accessible credits and, more generally, to the lack of institutional support as related difficulties. Most of them also expressed that there were deficiencies in the provision of support services (both private and public) for technological development. A second obstacle, in their view, was the sloppiness of domestic producers of capital goods. In this connection, they claimed that their engineering and R&D units spent more time and effort in the modification and adaptation of machinery and parts purchased from other local firms, thus making up for suppliers' faults, than in generating new products and processes.

The survey of Ecuadorian firms reported in Andrade (1995) is helpful in identifying the main obstacles to innovation as perceived by the firms. The survey provides the answers given by both the firms belonging to the overall set of innovating firms and by those belonging to the subset of innovating firms that were also exporters. The ranking of obstacles is not the same for the complete set of innovators as it is for the subset of innovator-exporters. Whereas, for the former, the most cited obstacle is the lack of financing, for the latter, the first obstacle is the lack of legally established incentives to innovation. For exporters, lack of credit facilities is indeed, a problem, but it comes sixth in their ranking. The lack of incentives ranks as the second biggest obstacle in the larger set's perceptions. Other problems that rank high for both sets of firms are the lack of information about markets; the lack of technological information; the scarcity of qualified personnel; the lack of R&D institutions; and uncertainty about innovation opportunities. Lack of "general" information is not much of a constraint.

Appendix 2. Policies to Promote Technological Modernization in the Region

In the leading regional countries there is a definite preoccupation with, and an explicit policy towards, making science and technology more relevant to the imperative need of increasing competitiveness. As a result, almost every major industrial policy statement in the post-reform period has given a place of honor to technological modernization as one of the areas where government intervention is critical if the domestic private sector's ability to compete is to be enhanced.

The main areas of action for existing technology policies in the region are: a) promotion of research and development efforts by the private firms themselves; b) strengthening of cooperation between public sector research institutions and private firms; and c) creating or strengthening (as the case may be) the informational infrastructure necessary for the success of research and development activities by the firms.

There is considerable variation in the way countries go about defining mid-term objectives for their technology policies. Mexico's explicit policy, for instance, defines seven areas where government efforts must be concentrated: 1) fostering technological transfer as one of the key dimensions in the strengthening of production chains; 2) promotion of quality norms and systems in the micro-, small-, and medium-size-enterprise sectors; 3) strengthening basic technological capabilities in micro-, small-, and medium-size firms; 4) provision of basic information to the firms concerning issues such as voluntary normalization and the supply of technology advice and consulting services; 5) encouraging technology transfer from the more advanced countries; 6) protection of industrial intellectual property; and 7) stepping up efforts to create a culture of technological innovation in the business sector.

In contrast, Brazil's explicit policy (see Ministério da Ciência e Tecnologia, 1996) focuses on a set of specific, selected sectors grouped in two classes. To the first class belong those sectors where the country has already developed some technological capabilities but where there is still the need to deepen and further strengthen those capabilities. This class includes information technology and automation; aerospace technology (particularly satellites); nuclear technology; military technology, and agriculture. The second class consists of sectors where Brazil's development ranges from incipient to non-existent. The sectors singled out here for special attention are superconductivity, special materials, optical electronics, biotechnology,

applications of biotechnology to agriculture, energy conservation and alternative sources of energy. Promotion of technological research and innovation in the first group is seen as requiring the mobilization of a whole battery of policy instruments (to be presently examined) to encourage the firms themselves (albeit with the support of government and private, non-profit institutions) to undertake the tasks of technological innovation. Promotion of research and innovation in the second group is seen as revolving around the creation and future expansion of world-quality research centers devoted to basic and applied research. The rationale for tackling these research tasks lies in the idea that, while they do not respond to short-term market demands, they possess a high medium-to-long-term potential for both productive applications by the firms and appropriation of their benefits by society at large.

The Policy Instruments

The array of policy instruments used by policy makers in the leading countries of the Region include: 1) grants to support scientific and technological development through the funding of research projects; 2) credit programs aimed at strengthening technological capabilities of industries and firms; 3) fiscal incentives to technological innovation; 4) programs geared to the needs of specific, targeted industries; 5) and horizontal programs aimed at addressing needs that emerge in some special areas of firms' technological performance.

The grants in question are typically non-reimbursable grants given to qualifying projects selected by means of competitive procedures. A distinction is made between, on one hand, scientific research projects carried out by research institutes and university researchers and, on the other, projects aimed at technological development at the industry and firm levels. For a project to be supported is generally required that it be in accordance with the priorities defined by the governmental agency in charge of science and technology policy.

One frequent objective found in the technology policy statements is that of fostering partnerships between firms and academic institutions to pursue research and innovation aimed at solving technological problems faced by the former. In the Brazilian case, there are two institutional mechanisms through which these partnerships are promoted. One is the so-called "Technological Platforms" which are fora where the relevant stakeholders get together to identify the technological obstacles faced by a particular productive sector (or a specific region in the country) and to define the actions to remove them. The expected outcome of these

meetings is the formation of partnerships between research institutes, universities and representatives of the particular productive sector (or region) to formulate cooperative research projects. These projects are eligible for funding from the government agencies. As is customary in the international practice of giving grants, the usual procedure is to demand that private firms participating in cooperative projects and applying for funds contribute counterpart funds to the project at hand.

The government agencies usually operate through trust funds, fiduciary funds, or specialized financial agencies to provide loans to firms, consortia of firms, or consortia of firms and research institutions, to carry out an articulated set of research and technological development activities that are expected to result in the invention of new products, significant improvement of the existing products, improvements in the production processes, strengthening of the infrastructure for innovation, quality-product improvements, or productivity improvements. To these basic core of innovation activities, some of the financial agencies add, as activities eligible for credit, others such as purchase of technological and scientific services; acquisition of scientific and technical documentation and information; consulting services; adaptation of imported products, processes or technologies to the local conditions; purchase (in the domestic or foreign markets) of product, process and /or service technologies; strengthening of technical teams devoted to technology development or technology adaptation; and creation, implementation, and expansion of technological research centres.

Inspired by the experience of the US. Small Business Administration's Small Business Innovation Research Program, the funding agencies typically provide non-reimbursable loans to technological innovation projects from micro- and small-size enterprises. Brazil and Mexico, for example have a number of special credit programs to encourage technological innovation by firms. In the case of Brazil, a first set of credit lines is a part of the Ministry of Science and Technology's Program to Support Scientific and Technological Development, funded by the World Bank, which includes two particularly interesting sub-programs, namely: a) the Program to Support Technological Sector Entities (TSEs), and b) the Program for Technology Management and Competitiveness. The TSEs are non-profit organizations that perform one or more of the following services to the firms of a particular productive sector: 1) product research and development; 2) provision of technical services; 3) metrology, normalization, and certification services; 4) quality management; 5) training; and 6) organization of technological

information banks. As for the Program for Technology Management and Competitiveness, it supports pilot projects in the field of technology management, executed by partnerships of firms and non-profit technical-support entities provided, that the projects have among their components: 1) the diagnosis of the current technological situation of the particular industry; 2) the training of senior management in the new concepts and instruments of technology management; and 3) the internal implementation at the firm level of the structure and mechanisms of technology management that will enable them to apply the concepts learned at the training stage.

In addition to these programs, FINEP, the Brazilian federal innovation financial agency, has: a) an "integral-support" credit line that finances all the aspects of a business plan for technological innovation from the stage of project formulation all the way through the construction of civil works; the purchase and installation of machinery, equipment and technical instruments; the licensing and/or purchase of technology; to the training, technical assistance, and initial working capital required; b) a pre-investment credit line to finance expenses associated to the payment of engineering consulting services; and c) a credit line to support technology, environmental, and quality-product management.

In a number of countries in the region which goes well beyond the leading countries, fiscal incentives to technology innovation are utilized as a policy instrument and typically include: 1) reduction in the corporate income tax; 2) reduction in VA taxes; 3) accelerated depreciation of capital goods and equipment acquired in the context of an innovation project; and 4) the granting of fiscal credits on expenses and additional investments in R&D. In addition to this basic set, some individual countries grant some special incentives. Colombia allows a deduction of 125 percent of the costs of innovation projects carried out by firms and grants exemption from VA taxes on imports of equipment and instruments for innovation projects by research centres, technological development entities and the universities. Brazil grants exemption from the Tax on Industrialized Products to firms producing information technology products provided that the firm spends more than five percent of its gross sales in R&D. It also allows the deduction as operational expenses of payments of royalties and other technical assistance payments made by advanced-technology firms.

Several countries in the Region have special programs for the promotion of technological innovation in specific sectors that are deemed to be strategic. Perhaps the best illustration is the

set of incentives given by the Brazilian government to firms in the information technology sector. This set includes, besides the above-mentioned exemption from the Tax on Industrialized Products, a policy of government purchases of information technology goods based not merely on price considerations but on the price-quality ratio of products offered in competitive bids by information technology firms. In addition, there is a program to support software production that includes loans to companies involved in software development and buyers' credit for their commercial customers.

Technology policies in the leading countries also include an array of programs and institutional efforts in the fields of product quality; product design; participation in, and/or organization of, technical fairs and other events where technological innovations are disseminated; organization of pools of technological consultants; promotion and defense of industrial property; and the formal organization and completion of technology-foresight exercises with implications for policy formulation and design.