National Innovation Systems Overview and Country Cases

Stephen Feinson
Center for Science, Policy, and Outcomes

CSPO research assistants Victor Bennett and Grischa Metlay contributed to this report, particularly in the Brazilian and Korean sections.

National Innovation Systems – Overview and Country Cases

Part I – NIS Overview

The concept of National Innovation Systems (NIS) has been gaining intellectual and practical coherence over a number of decades, enjoying initial strong adoption by OECD and developed countries, and more recently becoming the focus of increased attention as a means to address some of the more profound issues for developing nations. As the divide(s) between the developed and developing world becomes increasingly stark, economists and policy makers view NIS as having great potential both as a source of understanding of the roots and primary causes of the gulf in economic development, as well as a powerful conceptual framework that can produce policies and institutions capable of bridging that gulf.

This section will describe the recent history of NIS and its use as an organizing framework for understanding and promoting innovation and economic development within developed countries. It will describe the main components typically associated with NIS, the mix of institutions, policies and practices that comprise the system, as well as the boundaries of these components. The focus will then turn to an assessment of the NIS concept in the context of developing nations, with attention to variation and differentiation within the developing world. Finally, a conceptual map will be presented as a means of further understanding NIS on a general level, as well as in preparation for application to specific developing country case studies in the next section.

History of the NIS Approach

Although there are a number of historical antecedents to the NIS concept, "its main background should be found in the needs of policy makers and students of innovation" (Lundvall, 2002, p. 215), representing an evolutionary process incorporating observation with economic theory. Following World War II, "a linear model of science and technology 'push' was often dominant in the new science councils that advised governments. It seemed so obvious that the Atom Bomb was the outcome of a chain reaction: basic physics => large-scale development in big labs => applications and innovations (whether military or civil)" (Freeman, 1995, p. 9). While this linear perspective loomed (and indeed in some areas of science policy still looms) large as an organizing principle for policy-makers, it proved unable to account for differential rates of technological innovation and economic development experienced by industrialized countries.

Despite similarly large investments in R&D by various industrialized and semi-industrialized countries starting in the 1950's and 60's "evidence accumulated that the rate of technical change and of economic growth depended more on efficient diffusion than on being first in the world with radical innovations and as much on social innovations as on technical innovations" (Freeman, 1995, p. 10). This evidence, gathered in numerous studies at the level of the firm and industry, was reinforced "by two contrasting experiences [in the 1980's]...on the one hand the extraordinary success of first Japan and then South Korea in technological and economic catch-up; and on the other hand the collapse of the Socialist economies of Eastern Europe" (Freeman, 1995, p. 11). Lundvall and colleagues speculate that NIS thinking gained ground in part due to the fact that "mainstream macroeconomic theory and policy have failed to deliver an understanding and control of the factors behind international competitiveness and economic development" (Lundvall, 2002, p. 214).

The increase in practices and policies that focused on innovation and its sources became a central theme for international and national economic bodies, most notably the OECD, which

introduced Country Reports on 'Innovation' and spent more and more ink emphasizing the importance of diffusion and innovation for economic growth (Freeman, 1995, p. 10). The OECD's NIS Project "stresses the need for domestic policies to adjust their objectives and instruments to the new paradigm for technological innovation, based upon more systematic and intensive exploitation of available knowledge bases and strategies of recombination and integration for the generation of novelty [and]...identifies many areas for potential international economic liberalization and cooperation that would serve to strengthen the respective national innovation systems" (OECD, 1994). This type of effort involves cataloguing and analyzing innovation as it appears within national systems, identifying best-practices, and advocating policies for member countries, and indeed the broader international communities. (See Box 1 below) Similar efforts have been undertaken by the European Commission and the United States National Science and Technology Council. (European Commission, *Building an Innovative Economy in Europe*, 2001; The National Science and Technology Council's *Summit on Innovation: Federal Policy for the New Millennium*)

Box 1. The NIS project

The OECD project on national innovation systems (NIS) has evolved along two tracks: *i*) general analysis involving all countries; and *ii*) more in-depth analysis of specific aspects within focus groups.

The **general analysis** comprised:

- A comparison of national innovation systems based on a standardised set of quantitative indicators and information on countries' institutional profiles.
- The production of country reports on national patterns of knowledge flows and related aspects of innovation processes.

Work within **focus groups** involved countries with advanced methodologies, data sets, or special research/policy interests co-operating in the following six areas:

- *Innovative firms* (lead countries: Canada, France). This focus group aimed at defining characteristics of firms that favour (or hamper) innovative activities, with a view to determining how government policy can directly or indirectly help increase the stock of innovative firms.

- *Innovative firm networks** (lead country: Denmark). This focus group analysed and compared the networking activities of innovative firms in participating countries through a co-ordinated firm-level survey based on a new methodology.

- *Clusters** (lead country: Netherlands). This focus group addressed two main questions: To what extent and in which respects do clusters differ in their innovation performance and mechanisms of knowledge transfer? What policy recommendations can be derived from a "cluster approach" to technology and innovation policy?

- *Mobility of human resources** (lead countries: Norway, Sweden). This focus group examined the role of the mobility of human resources in the circulation of knowledge within an NIS. Their work involved the production of comparable stock and mobility data for three countries (Finland, Norway and Sweden) which have access to labour-registry data, with special emphasis on the highly educated in natural sciences and engineering.

- *Organisational mapping** (lead country: Belgium). This focus group carried out a qualitative comparison of NIS institutional profiles and a quantitative comparison of networks of R&D collaboration at international level, based on existing databases.

- *Catching-up economies* (lead country: Korea). This focus group examined the specific features of national innovation systems in what are termed "catching-up economies", especially the need to build up an indigenous science and technology base.

Source: OECD, *Managing National Systems of Innovation*, 1999

What is a National Innovation System?

Definitions of National Innovation Systems

"... The network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987)
"... The elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge... and are either located within or rooted inside the borders of a nation state" (Lundvall, 1992)
"... The set of institutions whose interactions determine the innovative performance of national firms" (Nelson and Rosenberg, 1993)
"... The national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society" (Edquist and Lundvall, 1993)
"... A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology" (Niosi et al., 1993)
"... The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country" (Patel and Pavitt, 1994)
"... That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies" (Metcalfe, 1995)

Source: Niosi, 2002, p. 292

Theories on innovation have gradually expanded their focus and complexity, beginning with the individual firm or entrepreneur, broadening out to the environment and industry in which that firm operates, and finally encompassing the national system of regulations, institutions, human capital and government programs as well. (Niosi et al, 1993, p. 210) Since the NIS perspective attempts to explain an increasingly complicated bundle of actors, behaviors, and flows, it is useful to unpack the term itself. Specifically we should ask what do we mean by innovation, what are the boundaries and content of the system we are examining, and why is the national level the most useful one for our purposes?

The economist Bengt-Ake Lundvall has pointed out that innovation "is a ubiquitous phenomenon in the modern economy. In practically all parts of the economy, and at all times, we expect to find on-going processes of learning, searching and exploring, which result in new products, new techniques, new forms of organization and new markets" (Lundvall, 2000, p. 8). He stresses that innovation is both gradual and cumulative, and is a process rather than a stage. This process, however, is not linear "but involve[s] continuous interactivity between suppliers, clients, universities, productivity centers, standard setting bodies, banks and other critical social and economic actors" (Mytelka, 2001, p. 3).

Therefore innovation is not merely an individual act of learning by a firm or entrepreneur, but is situated within a larger system that both enables and draws on the innovative process. Beyond the most basic definition of a system as "anything that is not chaos,' Lundvall argues that innovation systems are both social and dynamic (Lundvall, 2000, p. 2). This refers to both the nature of the institutions that make up the system, as well as to the linkages and flows that connect them to one another. It is social in the sense that it relies on "an institutional context…constituted by laws, social rules, cultural norms, routines, habits, technical stan-

dards, etc." (Lundvall, 2000, p. 24) in short the full range of factors that govern societal interactions. It is dynamic due to the "financial flows between government and private organizations...human flows between universities, firms, and government laboratories, regulation flows emanating from government agencies towards innovation organizations, and knowledge flows (spillovers) among these institutions" (Niosi, 2002, p. 292).

This leads us to the final question of why, particularly in an age of much touted globalization, we should be concerned with understanding innovation at the national level as opposed to the regional or international (Lundvall, 2002, p. 214). There exist both empirical and practical reasons for focusing on the nation as the primary unit of analysis. Many of the gaps in development adhere to national boundaries, and strong correlations between poverty and geography have been observed (Sachs et al, 2001). Since the NIS perspective is primarily concerned with the flow of knowledge and its impact on economic growth, it makes sense to concentrate on the level that seems most centrally implicated in governing these flows. As one observer has argued, "Capital easily crosses national or regional boundaries. Knowledge flows less easily, because of the tacit character of much of it, which is embodied in human brains. Human capital means tacit knowledge, which is difficult to transfer without moving people. The less mobile factors of production and the most crucial for innovation are human capital, governmental regulations, public and semi-public institutions, and natural resources. For all these factors borders and location matter" (Niosi, 2002, p. 292).

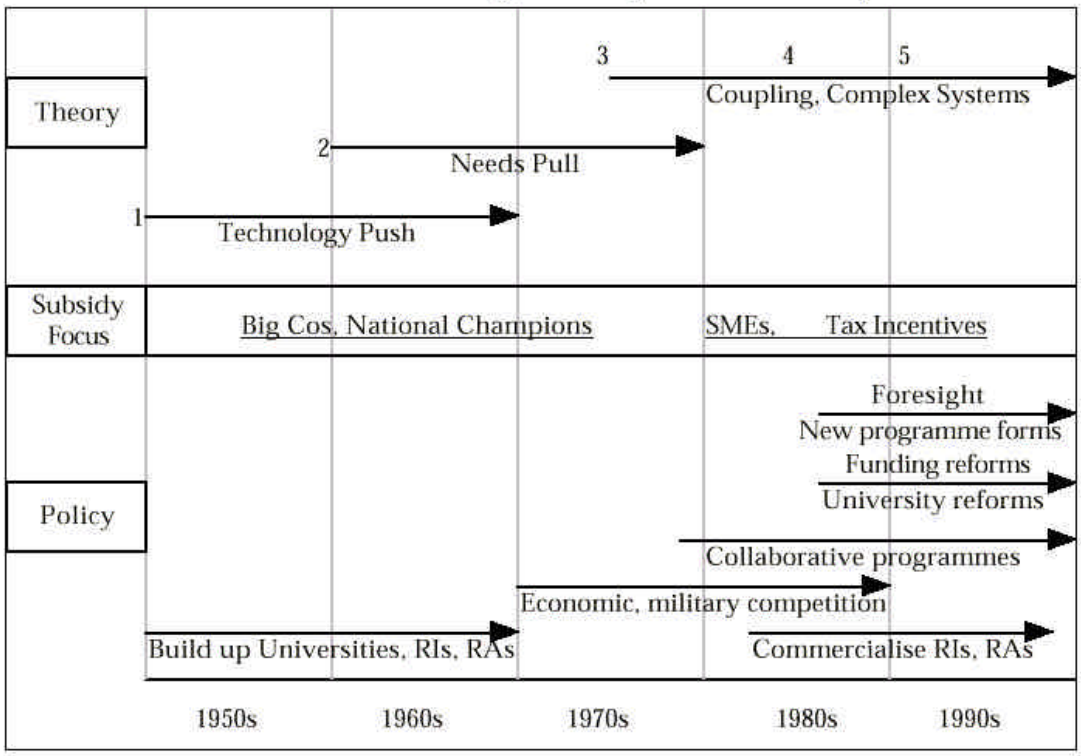
National Innovation Systems in Developing Economies

NIS policies and programs that seek to enhance a country's innovative and technological capacity, already quite popular in developed economies as noted above, have more recently come under sustained examination in the context of developing countries. The movement away from a linear approach towards attempts to conceptualize the complex interactions in an innovation system (See Figure 1), was the result of the realization that the answers did not lie in policies that relied solely on either 'technology push', "aimed at strengthening science and engineering education in the nascent universities," or on locally generated 'demand pull' for scientific and technological research (Mytelka, 2001, p. 1). Rather, as many development scholars have argued, successful economic and industrial development is intimately linked to a nation's capacity to acquire, absorb and disseminate modern technologies. Whereas in developed economies the innovation system serves the role of maintaining or improving an already established level of competitiveness and growth, developing countries are faced with the task of "catching-up."

Consistent with the national innovation system's holistic approach, a firm's comprehensive command of a particular technology necessitates not just its physical acquisition, but also a thorough understanding of how and why it works. Knowing the "how" and not the "why" prevents firms from fixing inevitable technical problems and from modifying the technology to fix local circumstances. Conversely, knowing the "why" and not the "how" makes operations on the shop floor nearly impossible and typically presents an impasse to efficient production (Dahlman and Nelson, 1995).

It is important to consider the role of the science sector in the context of creating or improving a developing nation's absorptive capacity. As one scholar has asserted, "science is not a simple consequence of initial industrial and technological development. It is not a 'natural consequence' of such a process. On the contrary, a certain level of scientific capability is a precondition of such development. As this development succeeds, it dynamically changes and upgrades the role of science and its interplay with technology" (Albuquerque, 1999, p.4). This cyclical relationship between science and technological innovation can be seen in two ways. First the scientific enterprise serve as a "focusing device," spotting avenues of technological development that are particularly appropriate to a less developed country. Second, a scientific

Figure 1 – Innovation in Theory and Policy



Source: Erik Arnold and Katalin Balázs, Methods in The Evaluation of Publicly Funded Basic Research, Technopolis Ltd, 1998

infrastructure can provide the knowledge base necessary for entering into key industries of growth (Albuquerque, 1999, p. 4).

The national innovation systems (NIS) approach offers improvements over alternative frameworks that conceptualize technological development in terms of inputs (e.g. science funding) and outputs (e.g. publications and patents). Whereas the inputs/outputs approach offers static glimpses of national innovation and assumes a linear model of technological development (i.e. science leads to improved technologies, which leads to industrial improvements), the NIS approach stresses dynamic networks of policies, institutions and people that mediate knowledge flows across national borders and within domestic industries. Additionally, the NIS approach offers a more realistic picture of development processes because it views innovation efforts as intimately linked to broader macroeconomic and educational policies. This systemic approach is also arguably better suited for policy-makers as it allows them to identify leverage points or weak links within the network. In general, NIS case studies suggest that public and academic efforts can "support, but may not substitute for the technological efforts of firms"(Nelson and Rosenberg 1993: 20), that the development of human capital via education and training is essential for fostering absorptive capacity, and that economic policies must be designed to compel international competitiveness. In arguing for an NIS approach specific to developing countries, it has been correctly asserted that "technology policy should be demystified. It does not need to be a business just for developed countries nor seen as a kind of unnecessary and wasteful luxury for poor countries" (Juma et al., 2001, p. 633).

Particularly in the context of developing economies, it should be stressed that the NIS approach is deeply at odds with neo-classical economic theories of growth. As Lundvall argued

regarding the NIS perspective:

> critical to derived dogmas about the general superiority of pure markets and of maximum flexibility in the conditions of wage earners. This reflects the assumption that innovation is rooted in processes of interactive learning and interactive learning does not thrive in pure markets. Especially in labor markets, industrial relations and inter-firm relationships, elements of 'rigidity' – of long-term non-market relationships involving authority, loyalty, and trust – are necessary to make learning possible. The pure market economy populated by short-term oriented, individualist rational men characterized by adaptive behavior would, if it could be reproduced in reality, get close to what Schumpter has defined as a state of Circular Flow. Little learning would take place, few innovations would be introduced and the economy would be stagnant. It would definitely be another world than modern capitalism. (Lundvall, 1997, p. 4)

He stresses that this divergence with neoclassical theories changes the analytical focus from allocation to innovation and from making choices to learning. (See table below) This "indicates a much broader and more interdisciplinary approach…it differs in being more explicit in terms of the institutional assumptions made and especially in avoiding any assumptions about factors being independent." (Lundvall, 1997, p. 13)

The complexity of innovation systems invariably precludes vast generalizations; indeed, there is broad agreement among scholars and practitioners on the fact that technological development is primarily a nation-specific and industry-specific phenomenon. Within the concept of 'developing nation' there is a significant amount of variation, which leads to country-specific issues for applying the NIS perspective. For example, some have examined apparent differences countries in Sub-Saharan Africa encounter in trying to attract Foreign Direct Investment (one form of technology and knowledge transfer that will be discussed in detail below). They observed that despite a boom in FDI to developing countries in the 1990's, African nations were unable to attract a proportional share of such investments, leading to the possibility that there is an "adverse regional affect" for countries in Africa (Asiedu, 2001, p. 107).

Conceptualizing a National Innovation System in a Developing Economy

In any historical era, developed nations occupy the role of technological leaders while developing countries act as technological followers; the key to development success lies in closing the "technological gap" by importing existing technology and creating the internal capabilities to utilize and improve on those technologies. The acquisition and implementation of technological capabilities, however, involves heavy investments in technological and social infrastructures. Charles Edquist has presented a concept called Systems of Innovation for Development (SID), which stresses some key differences with the NIS approach taken in developed economies. He argues that there are four main areas where SID diverges from NIS:

- Product innovations are more important than process innovations because of effect on the product structure;
- Incremental innovations are more important and attainable than radical ones;
- Absorptions (diffusion) is more important than development of innovations that are new to the world;
- Innovations in low and medium technology sectors are more attainable than those in high technology systems.

Development scholars have placed a premium on developing nations' "absorptive capac-

Figure 2 – NIS vs Neo-Classical Economics

	Allocation	**Innovation**
Making Choices	1. Standard Neo-classical Perspective	2. The Neo-classical Perspective applied on Innovation
Learning	3. Austrian Approach to market as a process of learning.	4. National System of Innovation Perspective

ities," or their "ability to [acquire,] learn and implement the technologies and associated practices of already developed countries" (Dahlman and Nelson, 1995).

Although developing countries can either buy help with learning or by agreements not to sue from foreign firms, the promotion of national absorptive capacity through various components of the national innovation system is required for long-term industrial and economic development.

This focus on absorptive capacity shifts the emphasis for developing economies from innovation to learning, both passive and active. Passive learners "absorb the technological capabilities for production, using a kind of 'black-box' approach," while active learners master "technology and its improvements through a deliberate effort" (Juma et al., 2001) The choice of a passive or active learning strategy has a profound impact on a country's ability achieve the type of growth that will improve the living standards and well being of its citizens. As some have noted:

> Passive learners are doomed to depend on spurious competitiveness, such as low wages, natural resource depletion, and state subsidy or protection. They are, in the long run, doomed to remain underdeveloped. Active learning is a necessary, but not sufficient, condition for achieving development. A developed country relies on authentic competitiveness based on technology. However, as long as it is understood that technical change is not reduced just to innovation and simply technology transfer, it is realized that there is lots of room for domestic techno logical efforts in developing economies. (Juma et al., 2001, p. 633)

A Brazilian scholar, Eduardo Viotti, has argue that in the case of developing economies learning can be defined as "the process of technical change achieved by *diffusion* (in the perspective of technology absorption) and *incremental innovation.* In other words, *learning* is the absorption of already existing techniques, i.e., the absorption of *innovations* produced elsewhere, and the generation of improvements in the vicinity of acquired techniques" (Viotti, 2001, p. 6).

To conceptualize a national innovation system in a developing country context, therefore, we need to understand how learning takes place at three analytical levels: 1) the primary functions of the system; 2) the broad strategies that can be employed to effectively create and manage those functions; and 3) the actors, institutions and linkages within the system that collectively implement that strategy.

Activities and Functions within a National Innovation System

A fundamental problem confronting analysts of national innovation systems is the danger of expanding the concept to the point where it includes virtually all aspects of a country's social, economic, political, and cultural activities. As some have pointed out, since "the whole socio-economic system can, of course, not be considered to be included in the SI (system of

innovation)... The question is then which parts that should be included?" (Edquist, 2002). One way of approximating an answer to this question is to identify the "functional boundaries" of an NIS, beyond the "overall function of producing, diffusing and using innovations".

Johnson and Jacobsson (2000) outline five primary functions:

- Create 'new' knowledge;
- Guide the direction of the search process;
- Supply resources, i.e. capital and competence;
- Facilitate the creation of positive external economies (in the form of an exchange of information, knowledge, and visions); and
- Facilitate the formation of markets. (Johnson and Jacobsson, 2000, 3-4)

Other researchers have provided a somewhat expanded list including:

- to create human capital;
- to create and diffuse technological opportunities;
- to create and diffuse products;
- to incubate in order to provide facilities, equipment, and administrative support,
- to facilitate regulation for technologies, materials, and products that may enlarge the market and enhance market access;
- to legitimize technology and firms;
- to create markets and diffuse market knowledge;
- to enhance networking;
- to direct technology, market, and partner research;
- to facilitate financing; and
- to create a labor market that [can be utilized]. (Rickne, 2000, as cited in Edquist, 2001)

Either list of functions envisions "active absorption [of knowledge]...[which] generates opportunities of learning that usually go far beyond production capability [and] is one of the bases for the development of the technological capability" (Viotti, 2001, p. 9).

Xielin Liu and Steven White (2001) have developed a different way of defining the functional boundaries of an NIS, identifying five fundamental activities as the core of a framework that can be thought of as "nation-specific". These are:

1. research (basic, developmental, engineering),
2. implementation (manufacturing),
3. end-use (customers of the product or process outputs),
4. linkage (bringing together complementary knowledge), and
5. education. (Liu and White, 2001, 6-7)

Overarching Strategies to Enhance Knowledge Flows

Acquiring Foreign Technology

Developing countries can acquire technology in three ways: imitation of foreign capital goods; foreign direct investment; and foreign licensing. The government can influence these avenues of acquisition in a variety of ways including: FDI policies, foreign licensing regulations, intellectual property rights regimes, and the purchase of technologies for public enterprises. More fundamentally, the government has a responsibility to contribute to the formation of the human and social capital needed to evaluate, choose, implement, and modify foreign technologies.

As a great deal of technological information is embodied in capital goods, developing countries might acquire technologies by importing them from developed countries and imitating them domestically, thus enabling them to keep apace with international market trends. Naturally, trade and tariff laws, as well as intellectual property laws, go a long way in mediating this avenue of acquisition. Since this type of technology acquisition does not include the transfer of theoretical or practical knowledge, it is of limited use without an already existing base of human capital capable of filling in those gaps. Furthermore, imitation costs can be close to innovation costs (Mansfield et. al., 1981) and the loose intellectual property rights that would be needed to maintain such a system might be prohibitively damaging to foreign trade relations.

Foreign direct investment (FDI) refers to the establishment of singly or jointly owned subsidiaries in a foreign country, and it includes "hiring foreign labor, setting up a new plant, meeting foreign regulations, [and] developing new marketing plans" (Saggi, 2000). Foreign licensing, on the other hand, involves leasing to previously established firms the rights, and sometimes the equipment, to produce a particular capital good. In the case of FDI and sometimes licensing, the foreign firm provides assistance implementing the new technology, and this presents an important source of theoretical and practical knowledge. Host countries can limit the bargaining power and options available to multinational firms by creating policies that either hamper or facilitate licensing vis-à-vis FDI (Pack and Saggi, 1997). Developing countries also might regulate the amount of domestic ownership in multinational firms, which would be consistent with protectionist economic policies, and more local ownership might also increase the networks available for spillovers to other domestic firms.

Using and Diffusing Technologies

In order for nations to take full advantage of acquired technologies, governments need to enact policies that aid domestic firms in using and diffusing these technologies throughout the country. This goal is most readily achieved by establishing institutions and networks that dissipate the tacit and codified knowledge underlying novel technological systems. These networks do not develop automatically or immediately, but they are an essential part of a nation's "social absorptive capacity". With the help of government incentives, developing nations typically can create various formal and informal networks to improve: information, training, and extension; subcontracting; and standards, testing, and quality control.

In developing countries there is often a wide disparity between firms' performances within the same industry. In the early stages of development, "islands of modernization" can appear within an economy dominated by small firms engaged in cottage industries (Wiess, 1990). In many cases, however, there are performance disparities even between firms using the same technology, which exhibits the difference in ability to make effective use of the technology, and thus the importance of diffusing technological know-how.

The increasing reliance on scientifically advanced technologies has made the theoretical aspects of technological knowledge increasingly important. Until recently, trade schools and on-the-job training were suitable for producing individuals with the requisite knowledge for designing and developing technologies. In the modern development context, however, running modern technological systems requires higher levels of scientific training and the management skills to coordinate what is inevitably a multi-person or multi-firm affair (Nelson, 1990). Nations with low literacy rates and weak higher educational systems have a great deal of difficulty assimilating foreign technologies because they lack the essential human capital. Those with university-level education are needed to monitor and assess international technological developments, as well as implement any needed changes. Strong education is also necessary at the primary and secondary level to generally increase the literacy and numeracy of the population, and more specifically, so that entry-level employees can possess the understanding and skills necessary to make improvements on the shop floor.

Subcontracting is an effective way of conducting business while simultaneously creating the close contact that is required for effective tacit knowledge transfer. Exclusively contracting with more developed nations, however, precludes further diffusion of the technology locally, and thus a balance must be achieved. Korea, Singapore, and Taiwan, in particular, have realized that restrictive agreements will stymie local firms, and thus they have designed their economic policies to make local subcontractors more attractive in hopes that this will aid the spread of technology. To assure that local contractors produce products of similar quality, it is important to establish an organization that implements standards, testing, and quality control. Standardization systems require a substantial collaboration between the private and public sectors, but are usually administered by the public sector, as they are archetypical “public goods”.

Improving and Developing Technology

Technology is changing at an increasingly rapid pace but not all of that change is dramatic. Incremental improvements in processes, inputs, or equipment are required to adapt products and processes to the local environment as well as enhance productivity and lower costs. Many of these changes do not come from formal R&D in labs, but rather occur on the shop floor, or “blue-collar innovations”. The “cumulative productivity impact of small incremental changes that are usually undertaken on the shop floor can be much greater than the initial introduction of a major new technology” (Dahlman and Nelson, 95), which makes utility models or petty patents extremely important in the development context (Ranis, 1990).

Although too strong an emphasis on formal R&D might prevent firms from utilizing adequate pre-existing technologies, some commitment to R&D is essential once developing firms reach a certain stage of technological proficiency. If international competitiveness is the goal, then R&D labs are needed to conduct reverse engineering, tailor technologies to fit the needs of specific customers, and more generally keep apace with international industry trends. The applied knowledge generated in R&D facilities can spillover into other local industries or firms, but this is not necessarily the case. Restrictive FDI policies and weak intellectual property rights in India have produced a disincentive for multinational firms to conduct “cutting-edge” research there. In the Indian pharmaceutical industry, some R&D was necessary to comply with Indian safety regulations, but knowledge spillovers occurred exclusively between multinational firms (via cohesive trade associations), rather than between multinational and domestic firms (Feinberg and Majumda 2001).

The sheer quantity of R&D expenditure is less important than the purpose for which it is used. Military R&D, for example, contributes far fewer spillovers into the productive sector than R&D directed explicitly towards capital goods. One rough gauge of the commercial applicability of a country’s R&D program is the ratio between public and private R&D expenditures; Korea and Japan have a disproportionate percentage of R&D funded by the private sector, while

the situation is reversed in the cases of India and Brazil (Dahlman and Nelson, 1995). It is important to note, however, that this figure should not be accepted at face value. A significant amount of shop floor innovation is necessary to make a product successful, Dahlman and Nelson hint that it may be more than initial R&D, is often not included in R&D figures.

Adapting technologies to new clients or new production facilities may be as difficult, and possibly as productive, as the initial innovation. In industries where technological innovation is particularly rapid, industrial R&D is absolutely necessary, if only to monitor advancements in the field. Developing nations should concentrate their efforts on the industrial R&D expenditures that focus on "intermediation and support for the acquisition, assimilation, adaptation, and improvement of technology obtained primarily from abroad" (Dahlman and Nelson 1995). Expenditures of this type provide the most immediate benefits to developing economies without discouraging investment in product innovation.

Investing in Human Capital

For any of the above strategies, research has demonstrated that an economy's absorptive capacity "depends heavily upon the level of education and training" (Mytelka, 2001, p. 2). Nelson and Dahlman note "a key input is a technical human capital base able to assess and decide on technology matters, [which] requires a well-developed educational system that lays the necessary foundations at all levels." They argue that there are two levels, the university and primary/secondary, at which human capital investments must be aimed. The university level creates "qualified personnel who can monitor technological and other trends, assess their relevance to the prospects for the country and individual firms, and help to develop strategy for reacting to and taking advantage of trends" (Dahlman and Nelson 1995, p. 97). This means that there is a need "for strong scientific, engineering and socio-economic capabilities as a base for policy making, especially in sectors undergoing radical change" (Mytelka, 2001, p. 3). The primary/secondary level is a critical component necessary "to speed the diffusion and adoption of new technologies, to make local adaptations and improvements on the shop floor, and more generally to increase the awareness and ability to take advantage of technological opportunities" (Dahlman and Nelson 1995, p. 97).

Actors, Institutions and Linkages in a National Innovation System

Narrow vs. Broad NIS

Various attempts have been made to illustrate the actors and linkages that make a system of innovation function, as well as the flows of information and resources within the system itself and between the system and its environment. An analytical distinction has been made between a "narrow" NIS concept, which includes the institutions and policies directly involved in scientific and technological innovation, and a "broad" NIS perspective, which takes into account the social, cultural, and political environment of the country being examined.

The narrow version is an "integrated system of economic and institutional agents directly promoting the generation and use of innovation in a national economy" (Adeoti, 2002, p. 95) drawing on one or more of the strategies discussed above. While there is great variation between national economies and tremendous complexity within the system itself, it is possible to identify the characteristics of key innovation actors. According to OECD, NIS institutions, defined in the narrow context, can be divided into five main categories:

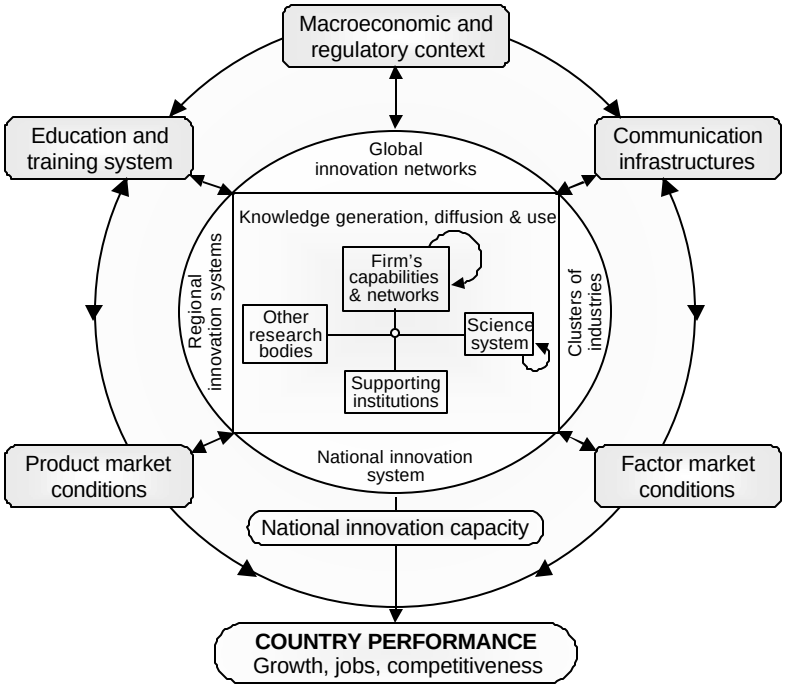
- *Governments* (local, regional, national and international, with different weights by country) that play the key role in setting broad policy directions;
- *Bridging institutions*, such as research councils and research associations, which act as intermediaries between governments and the performers of research;
- *Private enterprises* and the research institutes they finance;

- *Universities* and related institutions that provide key knowledge and skills;
- *Other public and private organizations* that play a role in the national innovation system (public laboratories, technology transfer organizations, joint research institutes, patent offices, training organizations and so on). (OECD 1999)

The broad definition of NIS includes, in addition to the components within the narrow NIS, all economic, political and other social institutions affecting learning, searching and exploring activities, e.g. a nation's financial system; its monetary policies; the internal organization of private firms; the pre-university educational system; labor markets; and regulatory policies and institutions. Conceptually, the narrow is embedded within the broad system, as depicted in an OECD diagram in Figure 3 below. While the individual institutions that make up both the broad and narrow innovation systems are important, "the intensity and variability of knowledge flows among constituents of a national system are critical determinants of its 'distribution power.' Along these lines, it has been suggested that policy-makers should shift their interest from steady structures and absolute measures of innovative activities...to the different types of interactions among actors within and beyond the boundaries of a national system." (Caloghirou et al., 2001, p. 14) Two specific examples of attempts to visualize national innovation systems are found in the Norwegian and Australian systems below (figures 4 and 5).

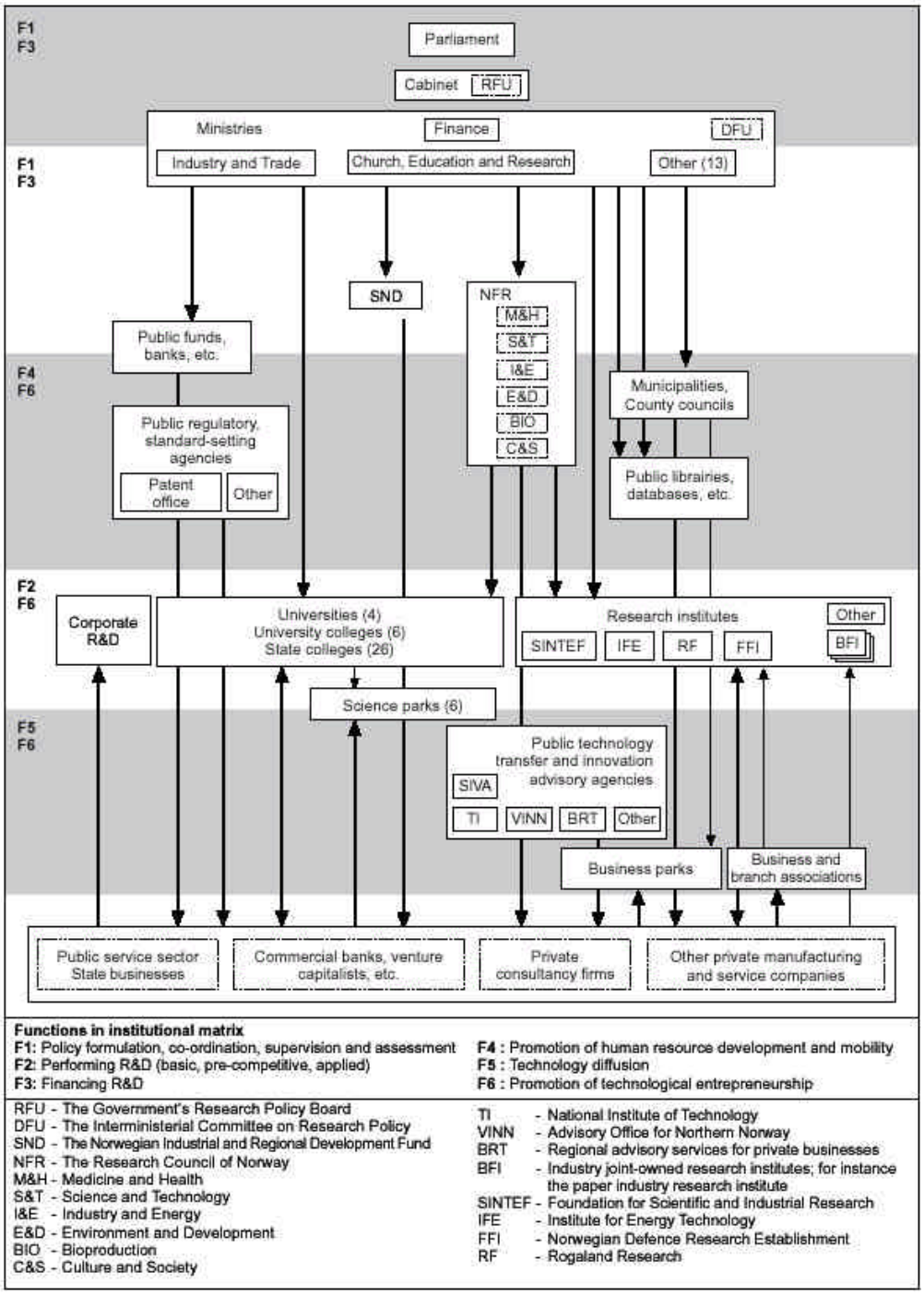
The NIS linkages, which reflect the absorptive capacity of the system, are determined by the ways in which knowledge and resources flow between the narrow and broad levels, and amongst the institutions and organizations via both formal and informal routes. Christof Schoser has developed a taxonomy (see figure 6 below) that helps to illuminate the importance of informal knowledge flows to the functioning of the entire system. Boxes 1 and 2 represent the formal institutions, both those within the narrow NIS directly involved in innovation and

Figure 3. Actors and linkages in the innovation system



Source: OECD, Managing National Innovation Systems, 1999

Figure 4 **The Norwegian system of innovation – organisational structure**



Functions in institutional matrix

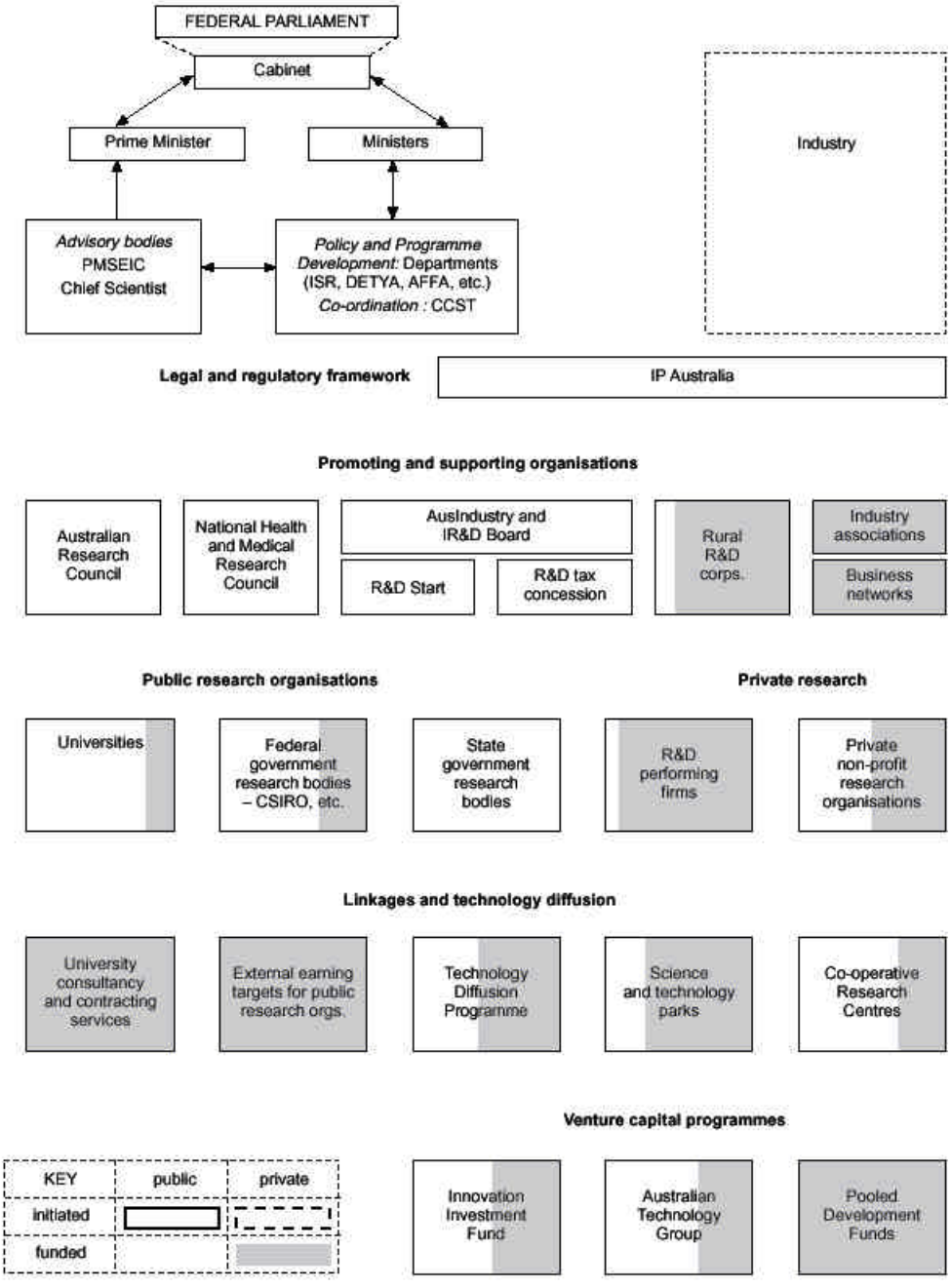
F1: Policy formulation, co-ordination, supervision and assessment
F2: Performing R&D (basic, pre-competitive, applied)
F3: Financing R&D
F4 : Promotion of human resource development and mobility
F5 : Technology diffusion
F6 : Promotion of technological entrepreneurship

RFU - The Government's Research Policy Board
DFU - The Interministerial Committee on Research Policy
SND - The Norwegian Industrial and Regional Development Fund
NFR - The Research Council of Norway
M&H - Medicine and Health
S&T - Science and Technology
I&E - Industry and Energy
E&D - Environment and Development
BIO - Bioproduction
C&S - Culture and Society

TI - National Institute of Technology
VINN - Advisory Office for Northern Norway
BRT - Regional advisory services for private businesses
BFI - Industry joint-owned research institutes; for instance the paper industry research institute
SINTEF - Foundation for Scientific and Industrial Research
IFE - Institute for Energy Technology
FFI - Norwegian Defence Research Establishment
RF - Rogaland Research

Source: STEP Group, 1997.

Figure 5 The Australian system of innovation – organisational structure



Source: Australian Department of Industry, Science and Resources, 1999.

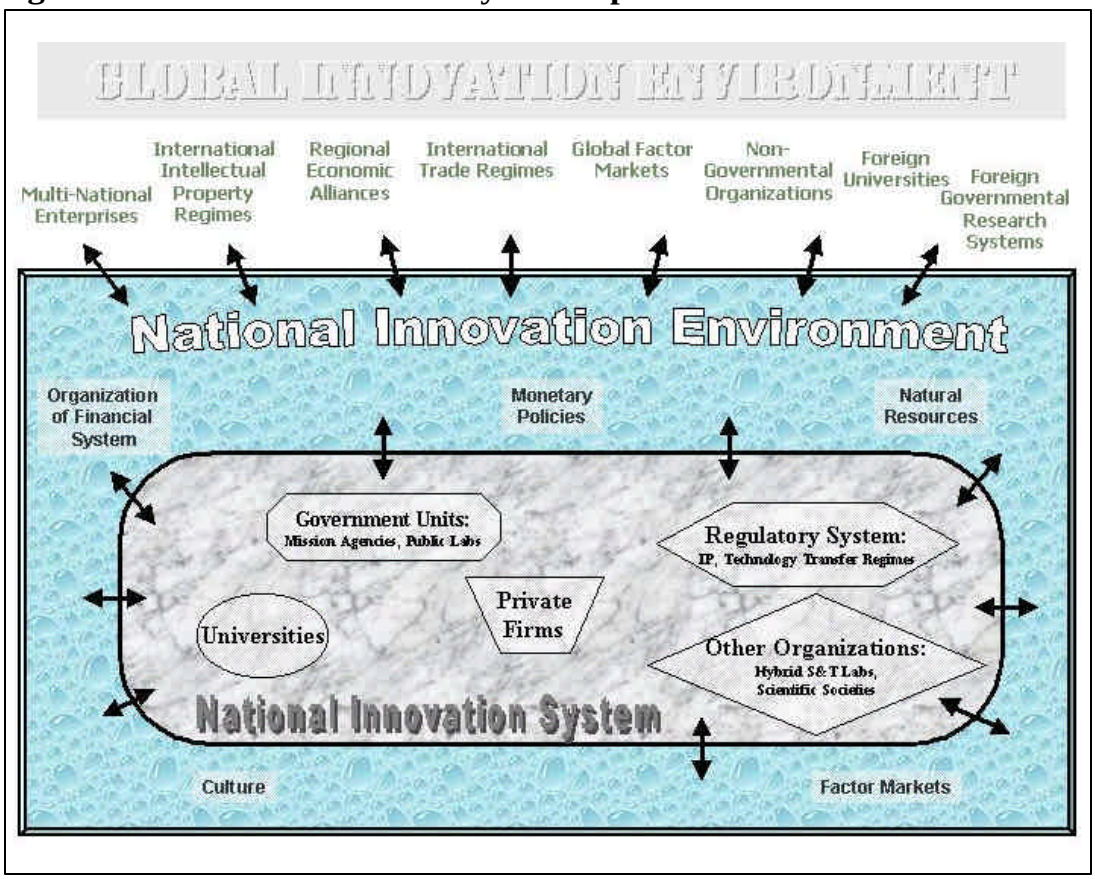
Figure 6 – NIS Taxonomy

DISTANCE FROM INNOVATION PROCESS

LEVEL OF FORMALITY	Narrow NIS	Broad NIS
Formal	(1) innovation network in a narrow sense - companies, patents - university and non-university research institutes, publications - technology transfer agencies, - technology policy and programs	(2) formal institutions in the back-ground of the innovation process educational and financial system, labor market, unions, legislation, taxes, policies like environmental and competition policy
Informal	(3) informal cognitive and behavioral patterns in the innovation process - quality of relationship between customers and suppliers, interactive learning - degree of competitive or cooperative behavior among companies, - companies' willingness to co-operate with scientific institutions, - closeness of relationship between companies and technology policy	(4) cultural and historical factors - values and attitudes (risk aversion, innovative spirit, mutual trust, time preference, attitude towards technology, consensus orientation) - historical development e.g. of the educational and financial system

Source: Adapted from Christof Schoser, 1999, p.5

Figure 7 – The National Innovation System Map



those in the broader NIS that impact scientific and technological innovation indirectly. Box 3 demonstrates some of the informal processes through which firms, research organizations and universities, and government research units interact. Box 4 depicts informal processes at the level of broad NIS, which includes cultural and historical factors that affect the innovation process.

With the distinction between formal and informal processes and links in mind, Figure 7 demonstrates a simplified map of the NIS concept, beginning with the narrow version of NIS, designated as the National Innovation System. The broad aspect of NIS is referred to as the National Innovation Environment, while a third level, the Global Innovation Environment, represents the international arena in which national systems of innovation function. This level includes intellectual property regimes, trade and labor systems, regional economic alliances, multi-national firms, and foreign sources of scientific and technological research such as NGO's, universities, and other governments' S&T systems.

For many, if not most developing countries, catching up technologically depends on the extent to which they are able to position their national innovation systems and environments to best take advantage of knowledge flows originating at the global level. As one researcher notes, "many of the developing countries will have to move from natural resource extraction economies to knowledge-based ventures that add value to these resources. All these changes require a shift in public policy at the national and global level. Domestic innovation will not be possible without access to international markets; access to international markets will not be possible without domestic technological innovation. Local factors and global dynamics are thus intertwined in new ways requiring fresh approaches to domestic and international policy" (Juma et al., 2001, p. 638) This perspective strongly implies that attention to single issues or sources of knowledge flows, such as patents or adoption of a mix of technology transfer strategies that is passive rather than active in nature, will not produce fundamental improvements in economic development.

Part II – Two NIS Case Studies – Brazil and South Korea

> …in the absence of appropriate external institutional conditions learning process may fail…The failure of learning processes in developing countries is in fact quite common. It is reflected in what is often called a "black-box" approach to production technology encountered quite often in developing country firms which receive technology via license agreements: firms may be unconcerned about how the technology works, provided only that they are able to produce with it. (Cooper, 1992, cited in Viotti, 2001)

Brazil – Passive Learning and NIS[1]

In the 1970's, Brazil's military governments implemented the First (1972-1974) and Second (1975-1979) National Development plans, which, suspicious of multinational firms, deepened import substitution policies, attempted to gain energy self-sufficiency, and stimulated substantial industrial growth through extensive domestic and foreign loans. Although foreign assistance proved necessary at times, the government encouraged majority ownership by domestic firms. This last period was characterized by debt-led growth; although Brazil's competitive position improved dramatically, this economic regime was unsustainable. In 1978 Brazil's foreign debt had grown to $40 billion and dramatic macroeconomic instabilities resulted from artificial exchange and high inflation rates. Throughout the

1980's Brazilian firms became increasingly less competitive in international markets.

Brazil's faltering performance in comparison with other developing countries, however, suggests substantial internal problems as well. These problems can be summarized as follows:
1) barriers to inward technology flux made it difficult for Brazil to acquire new technologies;
2) limited technological efforts on the part of domestic industries and an inability to convert public R&D efforts into productive improvements due to difficulties in using and diffusing information and skills; and
3) failure to cultivate domestic human capital. (Dahlman and Frischtak 1993)

R&D Policies –Capacities Divorced from Productive Activities

Concurrently, Brazil adopted explicit science and technology policies, the most important of which was the creation of the Secretaria de Tecnologia Industrial (STI) of the Ministry of Industry and Commerce (MIC) in 1972. The STI consolidated and expanded MIC's efforts by funding intra- and extramural R&D programs, disseminating technical information and instituting a system of intellectual property rights (Dahlman and Frischtak 1993). These efforts, however, were preponderantly statist and concentrated on national sovereignty by building local technological capabilities in military and strategic areas.

This has had a profound impact on the development of strong knowledge flows between actors conducting R&D and industries and firms who might benefit from that knowledge. Viotti notes that in the 1980's and beyond, Brazil is "in a stage in which R&D, and especially R, remains largely irrelevant to its industrialization…a large part of its yet relatively small technological effort is irrelevant to the needs of Brazilian industry, because it is largely divorced from productive activities" (Viotti, p. 10). He notes that FINEP, the institution created to finance industrial R&D, represents a very small actual amount of investment, having the spent the equivalent in 17 years of the amount that South Korea invests in a single year (Viotti, p. 10). Although many firms have undoubtedly benefited from FINEP's efforts, they have been hampered, however, for a variety of reasons: funds are primarily used to encourage import substitution; complicated bureaucratic procedure entail expensive delays; small firms have trouble qualifying for funds; and the operations are often too limited to appear attractive to large firms.

Despite the setting of clear priorities designed to improve Brazil's science and technology infrastructure, R&D expenditures as a percentage of GNP remained flat throughout the 1980's while it increased dramatically in the more successful East Asian NICs. Moreover, between 70 and 90% of the R&D expenditures came from universities and public research institutes, and private firms employed less than 1% of Brazilian researchers. Like the Brazilian industrial sector, its research programs suffered from over diversification, and because of weak links between research institutes and industrial firms (less than 10% of product and process innovations came from public R&D efforts). In some cases, government policies prevented the use of less expensive, existing foreign technologies until the completion of public research projects despite delays in launching functional applications (Dahlman and Frischtak, 1993).

At one level, Brazil's domestic R&D efforts have provided a poor alternative to foreign innovation. Soon after the new civilian government came to power in 1985, Brazil created the Ministry of Science and Technology to spearhead national science and technology efforts. Brazil's penchant for comprehensive centralized planning has led to the creation of large government bureaucracies plagued with inefficient administration. Both FINEP and the National Council for Scientific and Technological Development have increased their administrative staff substantially over the years, but only one half of their employees have university degrees, creating layers of administrators that slow down the funding process and make it difficult for fundees to obtain information about current projects. The general elitism of these science and technology institutions has focused scarce resources on high end military and government proj-

ects to the detriment of less sophisticated, but more abundant, sectors of Brazilian industry. Institutions designed to mediate quality control, standardization and technological information between researchers and the productive sector (e.g. The National Institute for Metrology and The Brazilian Institute for Scientific and Technological Information) have also suffered from rigid bureaucracies, which have further impeded domestic flows of technical information.

IP Regimes – Bureaucratic Disincentives

Although Brazil's open intellectual property rights regime and technology transfer policies are designed to maximize the availability of technical information, poor planning, incomplete implementation, and failures within the R&D institutional structure have limited the diffusion and subsequent wide-spread use of up to date technologies. Policies designed to promote import substitution and minimize the outflow of foreign currency impeded Brazil's ability to acquire new, imported technologies. In the late 1950's and early 1960's, Brazil passed legislation requiring the Central Bank to control royalty payments on licensed foreign technology; the National Institute of Intellectual Property (INPI) took over these responsibilities in 1970. These payments cannot exceed 5% of net sales and are taxed at 25%. Payments are prohibited between subsidiaries and multinational corporations, and in joint ventures with greater than 50% local ownership. Licensing agreements last up to five years, at which point the licensee owns the technology. Although these regulations were designed to improve the bargaining position of domestic firms, they have likely been detrimental to development efforts because they subject domestic firms to cumbersome bureaucratic processes, and because they provide disincentives for transferring the best technologies to Brazil.

FDI – Focused on Foreign Currency Rather Than Technology

Consistent with Brazil's objective of attracting investment in domestic firms, FDI has been quite extensive and many firms are owned completely by multinational corporations. FDI policy, however, is designed to maximize the inflow of foreign currency, not to facilitate technological development. With profit remittances limited at 12% of total investments and not corrected for inflation, multinational corporations (especially those touting high technologies) have few incentives to place subsidiaries in Brazil as opposed to other developing countries. Although Brazil's weak intellectual property rights regime does not offer significant patent protection (notably in the chemicals/pharmaceuticals and metals industries), or trade secret protection, it is less of deterrence than the transfer and economic policies discussed above (see Frischtak 1989).

Beyond restricting technology transfer from foreign sources, Brazil's broader import substitution economy has hampered domestic development efforts. Beginning in the 1950's and continuing through the 1970's, trade barriers, entry regulations, and tax breaks induced producers to invest in domestic firms, creating rapid industrial expansion. By the 1980's, this resulted in an overdiversified industrial sector marked by low degrees of specialization. Those firms holding dominant market positions did so by taking advantage of low labor costs and exploiting natural resources. Shielded from domestic and international competition, firms had little incentive to specialize and did not conduct the R&D necessary to take advantage of economies of scale, or to introduce improved products. As a result, Brazilian firms fell well behind international best practices without any negative short-term ramifications.

Human Capital – Under Investment

Finally, Brazil's educational system has been insufficient for developing the human capital necessary for training a highly skilled labor force. In 1980 less that 73% of Brazil's labor force had not completed primary school and only 35% of potential secondary school students

were enrolled. Between 1960 and 1985, the number of students enrolled in undergraduate programs tripled, but this was accompanied by a decrease in the number of full-time faculty, which adversely affected the quality of college education. The quality of Brazil's graduate programs varies widely throughout the country, but only one quarter of graduate programs are satisfactory. This is exacerbated by the fact that a small proportion of students specialize in science, math and engineering as compared with other developing countries, and by the fact that new information coming out of graduate programs are not taught at the undergraduate level.

Despite fundamental problems in the Brazilian national innovation system, Brazilian firms have been able to achieve innovation on international scales in several sectors, most notably aeronautics, automobile engines and agriculture. Success in these cases is primarily attributable to exposure to abnormal levels of international competition or coordination through subcontracting. If Brazil wishes to extend it innovative capabilities beyond these areas, it will need to target and prepare specific sectors for increased competition and fix broader structural problems with it economic and educational policies.

Korea – Active Learning and NIS

Korea's success exhibits the benefit of viewing technological development as a complex system in creation and maintenance of dynamic and responsive technology policy. By incorporating the interactions of various facets of the national innovation system, the Korean government was able to establish and then evolve policies that allowed the nation a transition from a subsistence farming economy to acquiring technology, using and diffusing that technology throughout the nation, and finally to using this new capability to innovate. These changing roles have confronted the Korean government and technology industries with new and ever changing obstacles and economists question whether they will succeed at continuing to develop their technological capability. As late as 1961 Korea was still an economy relying on subsistence farming and more than 10% of their GNP came from American aid. In order to redevelop the industrial capacity from before the Korean War, the nation had to redevelop its capability and begin to acquire and then assimilate technology from abroad.

Knowledge Inflow – Restricted FDI

Korea's first goal was to promote the flow of technology into the country. Notably, Korea did not follow the traditional route of promoting foreign direct investment (FDI) and foreign licensing, but rather concentrated on turnkey factories. The steel, paper, chemical, and cement industries were all founded on imported turnkey plants, and then expanded by locals. A conscious decision was made to keep restrictions on FDI high because mature technologies, the only ones that would be licensed to Korea, could be obtained through other methods, most notably reverse engineering, and because this would allow Korea to maintain independence from developed nations and their technologies. Rather than license, Korea preferred to import capital goods. The importation of capital goods from advanced countries may have been the most productive method of technology transfer (Kim, 1993,361). Korea most likely relied on this channel more than any other NIC at the time (Westphal et al., 1985).

R&D Policy – Use and Diffusion

This assimilation represents the second goal of Korean tech policy, to promote the usage of technology and the diffusion of imported technology throughout local industry. In order to do this, the Korean government had to create a policy environment that was amenable to private R&D. R&D helps build capacity within firms so they can acquire technology from other firms in their industry both locally and abroad and helps them keep abreast of developments

abroad. To promote R&D, the government adopted a series of incentives including tax breaks and exemption from military services for key personnel. These incentives combined with the success of publicly funded R&D centers motivated firms to establish centers of their own. Between 1970 and 1987 the number of private R&D centers jumped from 1 to 604 (Kim, 1993, 371) and spending on R&D in the manufacturing sector increased from US$22 million to US$1.4 billion. Strong social absorptive capacity, substantial investment in R&D, and a stable economic and political environment helped to move Korea to the stage where it was able to begin innovating.

Outward Orientation and Innovation

In order to compensate for their small domestic market, the Korean government adopted a strong policy of outward orientation. Exports were seen as crucial to each firm's success, and the government adopted a number of incentive policies to help keep their firms competitive. These include tariff-free access to imported intermediate inputs, automatic access to bank loans for working capital for all export activities, and unrestricted access to foreign capital goods. These incentives helped encourage firms to expand vertically in order to help "sustain international competitiveness" (Kim, 1993, 363). Kim notes that outward orientation was essential to developing Korea's innovative capability in several ways including strong international competition forcing substantial investment in technological efforts and technical assistance from OEM buyers whose specifications helped them 'learn by doing'.

Unfortunately, this export orientation also came with the cost of leaving smaller Korean firms to compete with well-established international firms. In order to help incubate small and entrepreneurial firms, the Korean government designated several "strategic" industries that would be protected from foreign competition, tax incentives, and preferential financing. A key factor in Korea's success in many industries was the timing of the removal of protection. Early removal would have caused the firms to falter in competition with strong international competition, while late removal would have prevented the competition that motivates firms to innovate and remain competitive. Though policy decisions helped many Korean industries successfully weather the nation's shift to innovator, many challenges remain for policymakers.

Investments in Human Capital

This success could only have been possible because of the nation's strong absorptive capacity from a high level of general education. By the 1980's education represented 22% of the national budget, and public spending accounted for only one third of total spending on education. This investment actually provided great returns as Korea's literacy rate grew from 22% in 1953 to close to 100% by the eighties. Korea's investment in education allowed engineers and scientists to have a level of understanding of the local plants and imported technology great enough to not only maintain them, but to improve and reproduce them.

The Korean higher education system underwent a period of decay when funds were funneled to other areas of society. Kim notes that student/teacher ratios actually retrogressed between 1966 and 1985. Though considerable efforts have been made to improve the Korean higher education system, this effort has been focused more on "teaching oriented" and less directed towards research. This has led to a dearth of highly trained scientists and engineers that would form the foundation of a strong absorptive capacity. Efforts have been made to correct this, and a research focused university founded by the Ministry of Science and Technology (MOST) is making strides to fill this gap.

Future Challenges

Korea's rapid shift to becoming an innovator from agricultural subsistence in less than

50 years represents a very drastic change in economic environment. Industrialization has served to raise wages, but rising wages locally raise the threat of other developing nations will overtake them in labor-intensive industries. Wages either must fall, or moves must be made to further commit Korean industry to high-tech capital-intensive industries in order for the development rate to be sustained. This challenge is difficult for a number of reasons.
Korea may also face obstacles in importing technology. Other industrialized nations competing in the same markets may become increasingly "reluctant" to transfer technology to Korea (Kim, 1988). This is particularly worrisome because so much of the Korean high-tech prowess is highly centralized in the *chaebols*. The structure of large multinational conglomerates that gave Korea stability during their initial stages of growth may now hinder growth in that they are not as nimble and rely heavily on imported foreign inputs.

Over the last 50 years, Korea has successfully adapted to the rapidly changing economic environment that comes with growth. This adaptation has been largely successful because the government had acted to improve the entire national innovation system and thus develop all of the interlocking elements necessary for development. To maintain this growth, Korean policy makers must continue to develop the capability of the nation.

References

Adeoti, J. (2002). Building technological capability in the less developed countries: the role of national systems of innovation. Science and Public Policy, April 2002.

Albuquerque, E. (1999). Scientific Infrastructure and the catching up process, http://www.dii.uchile.cl/~lacea99/papers/102.pdf

Arnold, E. and Balázs, K. (1998) Methods in The Evaluation of Publicly Funded Basic Research, Technopolis Ltd.

Asiedu, E. (2001). On the determinants of foreign direct investment to developing countries: Is Africa different? World Development, Vol 30, No.1.

Caloghirou Y., N. Constantelou and N.S. Vonortas (2001): Innovation-related knowledge flows in European industry: Extent, mechanisms, implications — Final Report. Final Report to the Commission, DG XII, TSER Programme, Contract No: CT 98-1118, National Technical University of Athens, Laboratory of Industrial & Energy Economics.

Niosi, J., Saviotti, P., Bellon, B., and Crow, M. (1993) National systems of innovation: In search of a workable concept. Technology in Society, Vol. 15.

Dahlman, C. and Frischtak, C. (1993), "National systems supporting technical advance in industry: the Brazilian experience", in Nelson, R. (ed) National Innovation Systems - a Comparative Analysis, Oxford University Press, New York, Oxford.

Dahlman, C. and Nelson R. R. (1995). Social Absorption Capability, National Innovation Systems and Economic Development in Social Capability and Long Term Economic Growth. B. Koo and D. Perkins: 82-122.

Edquist, C. (2001). Systems of innovation for development. Background paper for Chapter 1: "Competitiveness, Innovation and Learning: Analytical Framework" for the UNIDO World Industrial Development Report (WIDR), 2001.

Edquist, Charles; Leif Hommen; Björn Johnson; Tarmo Lemola; Franco Malerba; Thomas Reiss and Keith Smith. 'The Systems of Innovation Approach and its General Policy Implications' and 'Specific Policy Implications of ISE and its Sub-projects', in Edquist, Charles and Maureen McKelvey (eds.). Systems of Innovation: Growth, Competitiveness and Employment, An Elgar Reference Collection, Edward Elgar Publishing, Cheltenham, UK, 2000

Feinberg, S. and Majumdar, S., "Technology spillovers from foreign direct investment in the Indian pharmaceutical industry", Journal of International Business Studies, 32, 3, Third Quarter 2001, pp.421-437

Freeman, C. (1995) `The "National System of Innovation" in Historical Perspective', Cambridge Journal of Economics, 19(1).

Freeman, C. (2002). Continental, national and sub-national innovation systems—complementarity and economic growth, Research Policy, 31.

Frischtak, C.R. (1989). Protection of intellectual property rights and industrial technology development in Brazil. Industry and Energy Department working paper. Industry series paper, no. 13.

Gibbons, M.C., H. Limoges, S. Nowotny, P.S. Schwartzman and M. Trow (1994): The New Production of Knowledge, London, Sage.

Johnson and Jacobsson (2000)

Juma C. Fang, K., Honca, D., Huete-Perez, J., Konde, V., and Lee, S. (2001) Global governance of technology: meeting the needs of developing countries, International Journal of Technology Management, Vol. 22, Nos. 7/8.

Bradshaw, Y., Kim, Y.J., and London, B., (1993). Transnational economic linkages, the state, and dependent development in South Korea, 1966-1988: A time-series analysis, Social Forces, Vol. 72.2.

Kim, K. (1988). Korea in the 1990s: Making the transition to a developed economy, World Development, Vol. 16.1.

Liu, X. and White, S. (2001). Comparing innovation systems: a framework and application to China's transnational context, Research Policy, 30.

Lundvall, BA. (1997) National Systems and National Styles of Innovation, paper presented at the Fourth International ASEAT Conference, "Differences in 'styles' of technological innovation," Manchester, UK, Sept. 1997.

Lundvall, (2002). Towards a learning society, Conceição, P., Heitor, M., and Lundvall, BA., eds., Innovation, Competence Building And Social Cohesion In Europe: Towards a Learning Society, Edward Elgar Publishing, Cheltenham, UK, 2000.

Lundvall, BA. (2000), Introduction, in Edquist, Charles and Maureen McKelvey (eds.). Systems of Innovation: Growth, Competitiveness and Employment, An Elgar Reference Collection, Edward Elgar Publishing, Cheltenham, UK, 2000.

Mansfield, E., Schwartz, M. and Wagner, S. (1981) "Imitation costs and patents: An empirical study," Economic Journal, 91:907-918.

Mytelka, L. (2001). Promoting scientific and technological knowledge for sustainable development, paper for the Third UN Conference on Least Developed Countries, Round Table: "Education for All and Sustainable Development in LDCs," May 2001.

Nelson, RR. (1990). US technological leadership: where did it come from and where did it go? Research Policy, Vol. 19.2.

Nelson, R. and Rosenberg, N. (1993). Technical innovation and national systems. In: Nelson, R. (ed). National innovation systems: a comparative analysis. New York, Oxford: Oxford University.

Niosi, J. (2002). National systems of innovations are "x-efficient" (and x-effective): Why some are slow learners, Research Policy, 31.

OECD (1994). Accessing and Expanding the Science and Technology Knowledge Base, http://www.oecd.org/pdf/M000014000/M00014640.pdf.

OECD (1999). Managing National Systems of Innovation.

Pack, H. and Saggi, K. (1997). "Inflows of Foreign Technology and Indigenous Technological Development," Review of Development Economics, 1.

Ranis, G. (1990). Asian and Latin American experience: lessons for Africa, Journal of International Development, vol. 2, No.2, April.

Sachs, J., Mellinger, A., and Gallup, J., (2001). The Geography of Poverty and Wealth, Scientific American, March.

Saggi, K. (2000). Trade, foreign direct investment and international technology transfer: a survey, World Bank, Washington DC.

Schoser, C. (1999). The institutions defining national systems of innovation: A new taxonomy to analyse the impact of globalization, paper presented at the Annual Conference of the European Association of Evolutionary Political Economy, Prague, November 1999.

Westphal, L., L. Kim, and C. Dahlman. 1985. Reflections on the Republic of Korea's acquisition of technological capability. In International Ttechnology Transfer, edited by N. Rosenberg and C. Frischtak. New York: Praeger.

Viotti, E. (2001). National learning systems: A new approach on technical change in late industrializing economies and evidences from the cases of Brazil and South Korea. Science, Technology and Innovation Discussion Paper No. 12, Center for International Development, Harvard University.