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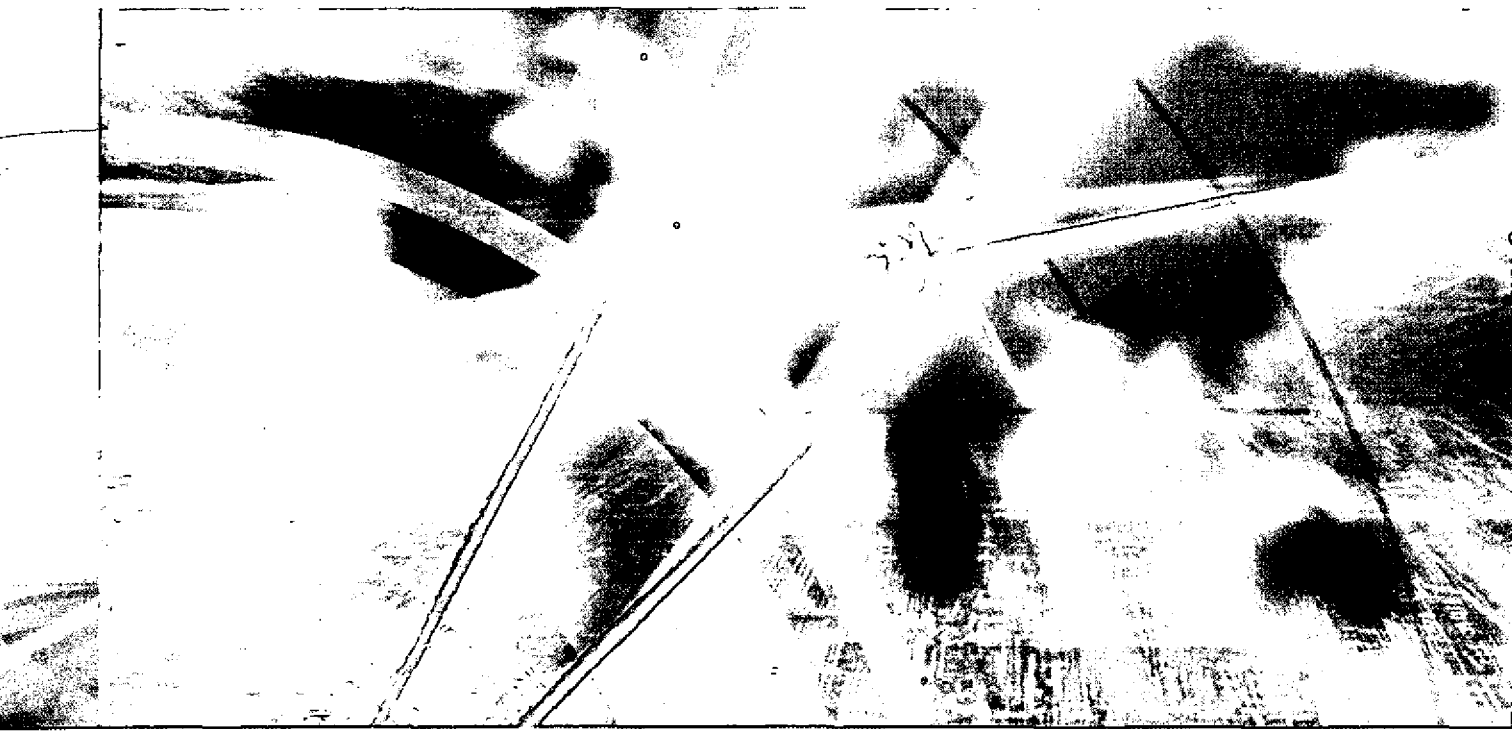

Dynamics of National Systems of Innovation

in Developing Countries and Transition Economies

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Dynamics of National Systems of Innovation in Developing Countries and Transition Economies

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Introduction to the UNIDO Industrial Promotion and Technology Branch Technology Paper Series

The UNIDO Industrial Promotion and Technology Branch (IPT) Technology Paper Series (TPS) provides a means for: stimulating policy thinking; improving policy orientation among policy makers; assisting in the management of science and technology policy craft in industrialisation; and disseminating current thinking on technology, and its industrial dynamics, in broad relation to the economic development within UNIDO's field of competence. Attention is paid to developing countries (DCs) and transition economies (TEs). The predominant orientation of TPS is Science and Technology (S&T) policy, policy management, co-ordination dynamics of knowledge-based and public-private partnerships in relation to technology in industrialisation.

The effective, and efficient, management of the policy and structural dimensions of technology, broadly encapsulating trends in innovation, R & D and science is increasingly viewed as crucial to economic development. The systemic aspects of national technology management in terms of incentives, institutional generation of knowledge and flows of technology (and investment) present policy challenges to DCs and TEs.

Strategic decisions at government level concerning the articulation of policy instruments, and co-ordination of supporting institutions with respect to economy-wide technological enterprise are vital to creating competitiveness, sustaining total factor productivity growth, and cohering the national system of innovation. Furthermore, the social capital – public sector as well as private sector – dimensions of the S&T intellectual infrastructure of DCs and TEs present opportunities for science and technology to be harnessed more productivity for socio-economic advance.

The Reviewers of TPS welcome papers and work in progress on technological development in DCs and TEs within UNIDO's field of competence. The expectation is that submissions focus on technology policy – craft, analysis, formulation, implementation – in relation to economic development manifest as higher levels of technology intensity in manufacturing industry. TPS will be published electronically on the UNIDO website as well as in hard copy form.

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Acronyms and Abbreviations

COLCIENCIAS/OCYT	Colombian Science and Technology Agency / Science and Technology Observatory
CYTED	Ibero-American Science and Technology Cooperation Program
DCTE	Developing Countries and Transition Economies
DFI	Direct Foreign Investment
ICSU	International Council for Science
IPR	Intellectual Property Rights
LDC	Least Developed Countries
MNC	Multinational Company
NRC	National Research Council of Canada
NSI	National System (s) of Innovation
PRI	Public Research Institutes
R&D	Research and Development
RICYT	Latin American Science and Technology Indicators Network
S&T	Science and Technology
SME	Small and Medium Size Enterprises
STI	Science, Technology and Innovation

Executive Summary

The generation of innovations which determines the performance of a country depends to a large extent on how different actors interact with each other as elements of a collective system of knowledge creation and use, named the ***national system of innovation (NSI)***. The NSI approach is used for analytical purposes in the study of research and innovation because of the economic importance of knowledge, the increase of systemic approaches to STI development, and the large number of institutions involved in knowledge generation. For policy makers the approach is of key importance as it allows to identify leverage points for enhancing innovativeness and competitiveness. "Activities" and "functions" can be identified in the system which provide it with a "functional boundary". Earlier studies of NSI were centered at the national level, but more recently, regional, sector, and sub national systems, have also been defined and described.

NIS differ enormously from country to country. In the case of developed countries many elements of this complex system are in place. In developing countries and transition economies (DCTE), only a handful have an operating NIS, while in others it is weak or extremely weak. Studies have analyzed causes for this situation, and identified as particularly important the absence of a culture for innovation as well as systemic weaknesses. Different proposals have been put forward to describe alternative systems, with the particular view of shifting the emphasis from innovation to learning and technology development, which fit better to the conditions prevailing in these countries. In spite of existing weaknesses, a NSI is present in DCTE and its approach is useful for policy and strategy definitions.

The present global transit towards a knowledge economy represents a daunting challenge to developing countries and transition economies. They must move faster in creating innovative capacities for improved productivity and competitiveness or their inclusion in the world economy will be absolutely marginal. To meet this challenge closer attention must be given to the processes of learning and innovation. In this way, NSI in these countries should be conceived as a creative space in social learning for the exchange of knowledge and information flows among actors. At the center of the system are the entrepreneurial and productive sectors, composed of value chains which function according to the needs of consumers and users, and maintain leadership in the generation, diffusion and application of knowledge. The NSI should also be deeply rooted in the human resource development system as a response to the challenge of building up a "learning economy". In this context, and considering that the concept and approach of NSI in DCTE should be better adapted to the conditions prevailing in them, a working definition of NSI is proposed as:

> "The network of institutions in the private and public sectors whose activities and interactions, generate, import, modify, adapt, and diffuse new and traditional knowledge, facilitate learning, and educate innovators and entrepreneurs, transferring the benefits of science and technology, according to the requirement of greater competitiveness in the economy and satisfying social, cultural and environmental demands"

To build up such system, able to face existing challenges imposed by globalization, the existence of global values chains, and regional agreements, the state must define policies and strategies for STI, considering that a strong policy approach is necessary to create favorable conditions on which to build bases for productive and competitive strengths. Under present global conditions, the development and use of knowledge as a key resource of the economic base cannot not simply be left to the operation of market forces.

Key words: innovation systems, innovation policy, science and technology, developing countries, transition economies, knowledge, learning

Dynamics of National Systems of Innovation in Developing Countries and Transition Economies

Introduction

A systems approach for the study and policy design in S&T has been used by developed and developing countries for quite some time. However, it is only after the work of Freeman (1987), Lundvall (1992) and Nelson and Rosenberg (1993), that the concept and approaches of national systems of innovation (NSI) were developed, and a vast and rich literature produced. An important description of the conceptual evolution of NSI can be found in Lundvall et al (2002).

This paper reviews this intellectual production to up-date concepts and approaches of NSI, as applied to developing countries and transition economies (DCTE), particularly the least developed, to contribute to their efforts for sustainable industrialization in light of the new realities brought about by globalization, the establishment of trade blocs, and the expansion of regional/[1] and global value chains.

Section 1 introduces definitions of NSI and Section 2 describes the approach, the actors and flows, and its boundaries. Reference is made to regional, sub national and sector systems and the efforts in the development of innovation indicators as applied to DCTE. Section 3 discusses the general characteristics of NSI in DCTE, examining systemic weaknesses. Alternative models proposed for these countries are mentioned, and the reasons for the adoption of the NSI approach in DCTE given. Section 4 describes the NSI in selected countries and Section 5 proposes a concept of NSI applied to DCTE, and briefly discusses, the role of governments, support institutions, and international organizations, in promoting and shaping its development.

1. National System of Innovation: Definitions

Innovation is at the base of economic, social and cultural development, and of natural resources and environmental protection and utilization. A country's performance is measured by a degree of "innovativeness" in its enterprises as well as in its government, financial, academic and other social

1 By region (or subregion) it will be understood in this paper the geographical space shared by two or more countries. The term local (or subnational) will be used to depict geographical spaces within a national territory.

institutions. Innovation is the result of a social process, influenced (and influencing) by the contextual conditions that favor development, and allows individual progress and that of the whole of society, thus it is not only technological. Technology based innovation, which this paper mainly refers to, is understood as a cumulative and non linear process, recognized as a key factor for productivity growth and competitiveness.

The generation of innovations results from a complex set of relationships that occur among actors that produce, adapt, distribute and apply various kinds of knowledge. A country's performance depends to a large extent on how these actors interact with each other as elements of a collective system of knowledge creation and use, named the ***national system of innovation (NSI)***. Box 1 shows some existing definitions.

Box 1. Definitions of a National System of Innovation

- " .. 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 set of institutions and economic structures affecting the rate and direction of technological change in the society (Edquist and Lundvall, 1993)
- "... 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 of 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 artefacts which define new technologies." (Metcalfe, 1995).
- ".. the innovative performance of an economy depends not only on how the individual institutions (e.g. firms, research institutes, universities) perform in isolation, but on how they interact with each other as elements of a collective system of knowledge creation and use, and on their interplay with social institutions (such as values, norms, legal frameworks)" (Smith, 1996).
- ".. the set of organizations, institutions, and linkages for the generation, diffusion, and application of scientific and technological knowledge operating in a specific country" (Galli and Teubal, 1997).

Source: Several authors.

2. National System of Innovation: Approach and Evolution

2.1. The approach

The NSI approach is used for analytical purposes in the study of research and innovation due to (OECD, 1997): a) the economic importance of knowledge, b) the increasing rise of systemic approaches to the study of STI development, and c) the growing number of institutions involved in knowledge generation. For policy makers the NSI approach is of key importance as it allows to identify leverage points for enhancing innovativeness and competitiveness. Further, the approach may be also used as the context for institutional evaluation.

2.2. Actors and flows

Empirical studies show differences in countries' performance and patterns of technological specialization. Countries tend to develop along certain technological paths or trajectories determined by past and present patterns of knowledge accumulation. Which path a country takes, is then determined largely by institutional actors, including the broad range of interactions and types of flows that

characterize the NSI (OECD, 1997). Schoser (1999) has developed a taxonomy that helps identifying institutions and flows that make up the NSI (Table 1).

Table 1. National System of Innovation Taxonomy

		Distance from Innovation Process	
		Narrow NSI	**Broad NSI**
Level of Formality	Formal	1)Innovation network in the narrow sense: -Companies, patents. -University and non university research institutes and publications. -Technology transfer agencies. -Technology policy and programs.	2) Formal institutions in the background of the innovation process: -Educational and financial system, labor market, unions, legislation, taxes, policies (f.e. environmental and competition).
	Informal	3) Informal cognitive and behavioral patterns in the innovation process: -Quality of relationships between customers and suppliers, interactive learning. -Degree of competitive or cooperative behavior among companies. -Companies willing 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.

Taken from Feinson (2002)

2.3. Regional, sub national and sector systems of innovation

Regional, sector (technology fields or product areas), and sub national systems, have also been defined and described more recently. Regional systems can make key contributions, through S&T cooperation and strategic alliances in technology development, to blocs that have moved away from a generally closed model to an open market model, thus exhibiting a more outward looking position and greater commitments to promote rather than to control regional or international trade, as already shown within the European Union.

In the understanding of innovation and economic growth, sectors provide an important level of analysis as it aims to provide a multidimensional, integrated, and dynamic view of production, thus overcoming the static view of more traditional analysis (Malerba, 2002). This is important with the view of enriching the concept of value chains, which are extensively used by many developing countries as an analytical base for industrial policy and strategic definitions. The sector system allows a better understanding of the structure and boundaries of chains, the intervening agents and their interactions.

Efforts have been conducted to define and analyze also sub national systems of innovation, based on the belief that this level can play a balancing political, cultural and economic role in a global economy. A sub national (and sector) approach is particularly important when dealing with learning, as the process occurs in practice in firms that are part of a specific geographic and institutional context. Examples of studies at this level have been extensive in Canada (Holbrook, 1997). In Brazil, Cassiolato and Lastres (1999), have analyzed the case of specific locations (and products) in Brazil, and the responses that local firms (and clusters) made to deal with structural changes, liberalization, privatization and deregulation. Findings suggest that a simple exposure to international competition is not sufficient to force actors to increase their innovative and collaborative efforts and deal with challenges based on a systems approach.

2.4. Boundaries of the national system of innovation

Edquist (2001) suggests that it is not enough to identify elements and flows in NSI, but that also "activities" and "functions" (the determinants of innovation) should be understood, thus providing a "functional boundary". Table 2 provides a list of "activities" and "functions" suggested by several authors.

Table 2. "Activities" and "functions" of a national system of innovation

Liu and White	Johnson and Jacobsson	Rickne	Mullin
-Research (basic, development, engineering). -Implementation (manufacturing) -End-use (customers of the product or process outputs). -Linkage (bringing together complementary knowledge). -Education.	-Create "new" knowledge. -Guide the direction of the search process. -Supply resources, i.e. capital, competence and others. -Facilitate the creation of positive external economies under the form of an exchange of information, knowledge and visions.	-Create human capital. -Create and diffuse technological opportunities. -Create and diffuse products. Incubate in order to provide -facilities, equipment and administrative support. -Facilitate regulation for technologies, materials and products that may enlarge market and enhance market access. -Legitimize technology and firms. -Create markets and diffuse market knowledge. -Enhance networking. -Direct technology, market and partner research.	Central government functions -Policy formulations and resource allocation at the national level. -Specialized advisory functions. -Regulatory policy – making. Shared functions -Financing of innovation related activities. -Performance of research, development and innovation. -Creation of linkages an knowledge flows. -Human resources development and capacity building. -Provision of technical services and infrastructure

Liu and White	Johnson and Jacobsson	Rickne	Mullin
		-Facilitate financing. -Create a labor market that the new technology based firms can utilize.	

Source: Edquist (2001) and Mullin (2003)

2.5. The performance of national systems of innovation: indicators

From the policy perspective, the use and choice of indicators are issues of importance, as they not only assist policy makers but also inform the public who ultimately support research and innovation through their taxes. Considering the variety of non traditional processes in DCTE, the Bogota Manual (RICYT, 2001), based on the Oslo Manual, has been prepared, displacing the focus on innovation towards the technological effort and its management.

3. National System of Innovation in DCTED

3.1. Present characteristics

The traditional definitions of NSI requires that many elements and flows of a complex system be in place. One of these are flows of information, knowledge and finance, Table 3 shows a limited number of them by groups of countries. Developing countries are divided into two groups: developing, those that have already developed their NSI to some extent and LDC composed of those which have not.

Table 3. NSI in Developed Countries and DCTE

Direction of flows	Flow of Finance			Flow of Information & Knowledge (including that embedded in goods and services)		
	Developed	Developing	LDC	Developed	Developing	LDC
National / Local Government >	Yes	yes	Yes	- - -	- - -	- - -
National Public Labs	yes	weak	no	- - -	- - -	- - -
Private Sector Producers >	- - -	- - -	- - -	yes	weak	mostly
National / Local Public Labs				yes	weak	no or
National Public Labs > University				yes	weak	very
Labs				yes	weak	weak
>Private Sector				yes	weak	
Labs						
>Private Sector						
Producer						
>Public Sector						
S&T Users						
>Rest-of-						
world/multinationa						
ls						
National / Local Government >	yes	yes	yes	- - -	- - -	- - -
University Labs	yes	weak	weak	- - -	- - -	- - -
Private Sector Producers	- - -	- - -	- - -	yes	weak	mostly
>University Labs				yes	weak	very
University Labs >National Public				yes	weak	weak
Labs				yes	weak	
>Private Sector Labs				yes	weak	
>Private Sector Producers						
>Public Sector S&T Users						
> Rest-of-						
world/multinationals						

Direction of flows	Flow of Finance			Flow of Information & Knowledge (including that embedded in goods and services)		
	Developed	Developing	LDC	Developed	Developing	LDC
National / Local Government >	yes	weak	No	- - -	- - -	- - -
Private Sector Labs	yes	yes	no	- - -	- - -	- - -
Financial Institutions > Private	yes	yes	weak	- - -	- - -	- - -
Sector Labs	yes	weak	rare	- - -	- - -	- - -
Financial Institutions > Private	yes	weak	rare	- - -	- - -	- - -
Sector Producers	- - -	- - -	- - -	yes	weak or	no or
Private Sector Producers > Private				yes	very weak	very
Sector Labs				yes		weak
Private Sector Producers >				yes		
University Labs				yes		
Private Sector Producers >Rest-				yes		
of-world / multinationals						
Private Sector Labs >National						
Public Labs						
>University Labs						
>Public Sector S&T Users						
>Private Sector Producers						
>Rest-of-						
world/multinationals						
Rest-of-world / multinationals	yes	weak	No	- - -	- - -	- - -
>Private Sector Labs	yes	very weak	rare	- - -	- - -	- - -
Rest-of-world / multinationals	yes	very weak	rare	- - -	- - -	- - -
>University Labs	- - -	- - -	- - -	yes	yes	yes
Rest-of-world / multinationals				yes	yes	yes
>National / Local Labs						
Rest-of-world / multinationals						
>Public Sector S&T Users						
> Private Sector						
Producers						

Based on Holbrook (1997).

Many studies have analyzed the causes for the situation depicted in Table 3; the lack of a culture for innovation is prominent. Studies also show that, in many countries, investment in innovation is at a low level, innovative firms are characterized by performing indoors R&D, industrial innovation is highly informal, but not necessarily of a low level of complexity, innovative firms have a comparatively important number of qualified technitians, and the lack of qualified personnel in small enterprises is not compensated by external services and advice. Systemic weaknesses have also been identified as shown in Table 4.

3.2. Alternative models

Different proposals have been put forward to describe alternative innovation systems in developing countries. Edquist (2001b), has suggested using the concept of "systems of innovation for development (SID)", focusing on absorption capacities, and indicating four main areas of divergence from a "traditional" NSI:

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

Lundvall et al (2002) have proposed that in order to apply a concept of NSI in developing countries in such a way that it does not result in negative effects on their development strategies, and rather stimulates policy learning, it is convenient to broaden and deepen the concept to make it more dynamic, in particular, to consider the promotion of learning capacity at all segments of the country's societies. Lall and Pietrobelli (2003) have proposed the concept of "national technology system", which considers the fact that most developing countries do not create new technologies but do import, absorb, adapt and improve on them, and that such efforts are vital to their growth and competitiveness, and have systemic elements similar to those of innovation systems in more developed countries.

Table 4. Systemic Weaknesses in Developing Countries and Transition Economies

Weakness	Description
1. Rigidities in organizations	Presence of obsolete or inappropriate institution is characteristic of such rigidities. Resistance to change stems from different reasons but a fundamental one is a knowledge and "innovation culture" gap in the leadership. Particularly weak are firms that do not value creativity and innovation, undervalue human capital
2. Ineffective financial system (for innovation)	Not only shortage of funds for R&D, but principally lack of financial mechanisms for technology development and innovation. The financing system itself must become innovative.
3. Sub-optimal knowledge networks	No interaction, or little or inappropriate types of interactions among critical actors, resulting in poor flows of knowledge and information.
4. Path – dependent system failure	Tendency of organizations to be path dependent. Organizational inefficiency resulting from history and connectedness to previous environments. Strong feeling that innovation brings uncertainty.
5. Organisational ineffectiveness	No very relevant research and training institutions as measured by their linkages to production and more particularly the dominant SME sector. Many coordinating and policy bodies themselves lack broad and specific competences, particularly in the smaller countries.
6. Institutional gaps	Institutional inadequacies manifest themselves as lack of rule of the game, poor enforcement of contractual laws, and inadequate intellectual property laws, and other norms that constitute disincentives to innovation and learning.

See Mytelka and Oyeyinka (2003)

3.3. Why a national systems of innovation approach in developing countries and transition economies

This paper argues that a NSI does exist and its approach is useful in DCTE, but its concept and approaches should be better adapted to the different conditions prevailing in them and the differences with more developed countries. The reasons for this are:

a) All countries have developed institutions, even if limited and many ineffective, dedicated to the production of knowledge, and many have public policies and strategies for building up technological capacities in firms.

b) In these countries, there are universities that in one way or another transfer knowledge, and enterprises that use local or imported technologies.

c) The present status of the world economy requires new conceptual, methodological and analytical frameworks to deal with its patterns. NSI represent an promising analytical tool for this purpose (Lastres and Cassiolato, 2003).

d) As the divide between developed and developing economies becomes larger, NSI can be viewed as having a great potential both as a source of understanding of the roots and primary causes of such gap, as well as a powerful conceptual framework that can produce policies and institutions capable of bridging such gap (Feinson, 2002).

e) The need of designing and implementing more sophisticated ways of promoting technological and industrial development.

f) Successful economic and industrial development are linked to a country's capacity to acquire, absorb and diffuse modern technologies, processes that make part of a NSI.

g) Technology policy must be demystified, it does not need to be a business just for the developed, nor seen as a kind of unnecessary and wasteful luxury for poor countries. A technology policy must be country specific and requires a systemic approach to its design.

h) The central building blocs of NSI allows taking into account the specificities of each region, country, locality or sector.

i) Sustainable industrial development requires technology development. Importers of technology need to undertake significant, costly and risky efforts to use it efficiently. This requires an efficient system able to offset some of the existing market and institutional weaknesses, specially the least developed countries whose economies are being opened to face global competition (Lall and Pietrobelli, 2003).

j) The approach allows to overcome the view of innovation as a process of radical change at the frontier of knowledge and recognizes that innovation extends well beyond R&D.

4. *National Systems of Innovation in Specific Countries*

DCTE greatly differ in their STI capacities and the importance given to them by public and private policies and strategies and therefore in their models of NSI. Many of these countries have yet to establish an operating NSI, but are making important efforts to do so.

A recent example is that of the Middle East, where the research base is expanding and some kind of specialization is taking place, for example in materials science in Egypt, chemistry in Iran and engineering in Saudi Arabia (ScienceWatch, 2003). Whether these trends be reproduced in the generation of innovations is still an open question. In the case of Sub Saharan countries, because of inadequate macroeconomic policies, the already small manufacturing sector is losing shares in world markets, as enterprises are less efficient than in other countries, the supply of modern skills is inadequate and the physical infrastructure is weak and often deteriorating (Masinda, 1998).

Lall and Pietrobelli (2003), have pointed out that strategy formulation is weak in Kenya due to the absence of an appropriate institutional mechanism. Where it exists, such is the case of Tanzania, Uganda and Ghana, it is too weak to affect other government areas, a situation that reflects the low priority attached to technology in most of Africa. To this situation it should be added the extreme weaknesses of management mechanisms (Aguirre and Kane, 2000). This situation that is quite representative of many the smaller developing countries of Asia (Aguirre and Southavilay, 2003) and Latin America, has not changed the traditional specialization of unprocessed primary goods, the slowest growing segment of world trade and also the one that offers least by the way of technological learning, skill creation and other externalities.

Larger developing countries have operating NSI and are going through an important process of specialization. India, for example, has significantly specialized in the software services industry, which accounts today for 2% of the GDP and 15% of exports, although the links and spin-offs to the NSI have been limited, it has done little to enhance productivity in other sectors of the economy. Thailand on the other hand is in the process of transforming its development policies, giving attention to the build-up of long term competitiveness in the real sector. Food processing is one of such sectors, and an agro-innovation system is being conceptualised. Although at a very different stage of development, Vietnam is also following a similar path (Chairatana and Sinh, 2003).

Table 5 shows the key strengths and weaknesses of the Thai innovation system, whose characteristics are reproduced along a number of larger DCTE.

Table 5. Strengths and Weaknesses of the Thai Innovation System

Strengths	Weaknesses
-Awareness -Entrepreneurialism -Foreign Direct Investment base (automotive, electrical, food, tourism, apparel) -Partial institutional restructuring (f.e. metrology) -Technical institutes – technology middleware -Semi-autonomy of S&T authority -Genuine commitment of key reformers -Potential support from: education reform, skill development fund and National S&T Committee	-Bureaucracy – Public institutions at the center -Basic framework/rationale of public investment -Economic fragmentation: inability of firms to penetrate large supply chains, many SME and few large corporations -Crisis legacy -No dialogue with private sector: weaknesses of business associations as learning organizations and public funding not yet performance based. -Weak incentives -Slow progress toward university autonomy -Scale of reform casts doubt on implementation.

Source: Amin (2001)

Wong (1999) has discussed the rapid industrial development of Korea, Taiwan and Singapore with distinctly different models of NSI, introducing an important analytical framework for characterizing the generic evolutionary paths for rapid technological catch-up by late-industrializing countries, as shown in Table 6.

Albuquerque (2003) has compared the behaviour of NSI in four large developing countries (Brazil, Mexico, India and South Africa), concluding that the four share in common an important presence of foreign and state owned firms in their technological production and show trends of sub national concentration and that differences exists in the scientific specialization. They also share in common an international position below the "threshold level" of mutually reinforcing S&T interactions, and below

the "critical mass" level for an adequate S&T production and that "islands of efficiency are present. Whether these will be able to push the rest of the country and spill-over to other less dynamic sectors of the economy is an open question.

In the recent past, several Latin American and Eastern European countries have applied technology foresight techniques for establishing STI priorities and deepen their industrial specialization. The use of this technique is considered of great importance for improving the performance of NSI in these countries (Aguirre, 2003). Other studies show that larger countries are in fact creating new areas of specialization or strengthening existing ones. An example of the innovation capacities that have been constructed is provided by Brazil and Malaysia (Ariffin and Figueiredo, 2003) in the electronics industry. In this case, it is interesting to note that the study has found pockets of innovative firms that innovate to become competitive by reducing costs, increasing productivity, reducing lead times and producing better products, regardless of whether they are in an import – substitution country or in an export oriented country.

Table 6. Different Technological Learning Process for Five Generic Technological Capability Development Routes

Generic Technological Capability Development Routes	Key Technological Learning Processes	Innovation Network Implications	Possible Facilitating State Policies
Reverse value chain (Taiwan's SME – PRI Innovation Network Model)	-Learning by doing -Learning by transacting -R&D	-Close interactions with customers. -Coordination among firms to standardize product-process interface and modular design	-Promote MNC –local contract manufacturing. -Coordinate and fund R&D consortia of local firms to diffuse design and product know how
Reverse product life cycle (PLC) (Korea's Large Firm Internalization Model) (Singapore's strategy	-Learning by doing -Reverse engineering -Imitative R&D	-Internalization of product and process capabilities. -Access to third-party consultants.	-Promote growth of large firms with "deep pocket" to undertake reverse PLC. -(Temporary)

Generic Technological Capability Development Routes	Key Technological Learning Processes	Innovation Network Implications	Possible Facilitating State Policies
emerges in the 1990's)		-"Reverse brain drain"	protection of domestic market. -Bargain for technology transfer in exchange for market -Encourage "reverse brain drain"
Process specialist (Singapore's DFI – Leveraging Model) followed by reverse value chain on smaller scale	-Learning by doing -Learning by transacting -R&D	-Close interaction with customers, suppliers and technology vendors	-Promote process technology acquisition and R&D. -Promote PRI and University – -Industry collaboration in process R&D.
Product pioneering (Taiwan's SME – PRI innovation Network Model since the late 1980's) (Singapore's strategy emerges in the 1990's)	-R&D -Market research	-Close interaction with universities / research institutes. -Close to lead-user market. -"Reverse brain drain"	-Promote venture capital industry development. -Fund PRI and University R&D. -Commerce & start-up incentives. -Encourage reverse brain drain
Applications pioneering (Singapore's strategy strong among service firms)	-Technology scanning -Integration with domain knowledge	-Close interaction with technology vendors.	-Promote diffusion & adoption of advanced technologies. -Fund diffusion infrastructure development

Source: Wong (1999)

5. Towards a Concept of National Innovation System in Developing Countries and Transition Economies

5.1. The challenges

In spite of large efforts and enormous investments made by governments, bilateral public and private donors, and international organizations, the majority of DCTE remain excluded from the benefits of globalization. The present transit towards a knowledge economy represents a new and daunting challenge to DCTE. Should they not move faster in creating innovative capacities for improved productivity and competitiveness their inclusion in the world economy will be absolutely marginal. To meet this challenge closer attention must be given to the processes of learning and innovation in a systemic way. More particularly, in the short term, the three basic challenges that must be faced are:

a) How to deal with strategic specialization, which implies a capacity of strategic and prospective analysis, to identify sectors or sub sectors where competitive advantages can be developed. This challenge is closely related with the definition of sustainable industrial policies.
b) How to pass from selective financial mechanisms to support technology and innovation projects in firms, to a massive financing scheme that permits the access to credit through the commercial financing system to a much larger number of firms.
c) How to design industrial organizations for rapid technological catch-up, noting that much of the innovation that is required is organizational and institutional.

5.2. Main characteristics

The NSI in the DCTE should be conceived as a creative space in social learning for the exchange of knowledge and information flows among national, sub national and sector agents. At the center of the system are the entrepreneurial and productive sectors, composed of value chains which function according to the needs of consumers, and maintain leadership in the generation, diffusion and application of knowledge and technology. The NSI is also rooted on human resource development to respond to the challenge of building up a "learning economy".

Key to innovation in these countries is learning and competence building. The rapid rate of technical change (and other economic conditions) quickly undermines established competences and requires continuous establishment of new ones. Firms that become learning organizations are more productive,

and create more stable jobs, Changes require organizational restructuring, and its promotion is a crucial element of innovation policy. Education and training institutions need to focus on students that learn to learn (Lundvall et al, 2002)

In this framework a definition of NSI for DCTE can be proposed as follows:

> "The network of institutions in the private and public sectors whose activities and interactions, generate, import, modify, adapt and diffuse new and traditional knowledge, facilitate learning, and educate innovators and entrepreneurs, transferring the benefits of science and technology, according to the requirements of greater competitiveness in the economy and satisfying social, cultural and environmental demands"

The introduction of the concept of traditional knowledge allows for the idea of minor and incremental innovations that make part of any development model with a certain degree of autonomy. Under it, STI policies are designed in such a way that the concepts of technology gap and obsolescence are referred mainly to the needs of each society and to its capacity and social objectives that are determined democratically, and not only to the technologies and research lines dominant in more advanced countries or in the international market. The introduction of the idea of traditional technologies in the definition of the NSI responds also to the need of introducing a mentality change that predominates in governments, firms and even academia of many developing countries, that perceive themselves as mere technology receptors and not as creators or even adaptors.

5.3. Policy and strategic trends and recommendations

5.3.1. Role of government, policy and strategic trends and recommendations

Today no modern state, interventionist or liberal, abstains itself from adopting a policy that facilitates knowledge and financial flows to support and create productive and competitive capacities in the economy. The main idea underlining a strong policy approach is that even though the creation or acquisition of technological and innovation capacities are primarily a matter of competence of firms in a free market economy, the responsibility to create favorable conditions to build bases for their strengthening is a key function of the state. The development and use of knowledge as a key resource of the economic base is not simply left to the operation of market forces.

Recent and present global economic and social tendencies in which knowledge /[2] occupies a key place, present a difficult new challenge to policy making and the definition of development agendas. The scientific and technological revolution have profoundly transformed not only the productive systems but also the social structure in developed countries, a phenomena that strongly influences DCTE, and translates itself into a great uncertainty on which are the best policies to adopt for the development of STI in them (Albornoz, 2001).

Policy oriented research in STI issues has taken place for decades in DCTE, and to these, studies on NSI have been added more recently. In spite of these extensive efforts, and with few exceptions (Gomez and Jaramillo, 1997), most of the countries have not been successful in formulating and implementing coherent policies, thus limiting the extraordinary contribution that STI can make to their development.

Under such context, and in front of the existing challenges and systemic weaknesses, the first public policy objective for the development of STI should be to adopt a systemic approach such as the national system of innovation (see f.e. IADB, 2001). Some of the key present trends in policy and strategies, and others that still need to be further developed, can be summarized in the way of recommendations:

a) Higher education is key to the development of NSI in DCTE. Policies in addressed to its strengthening and growth must to facilitate their transit to a model that recognizes the different ways knowledge is generated today, so they can harmonize the imperatives of academic excellence with the different demands of service to society and the economy; the local with the global conditions; the short and long term needs; education with the labor market; and science and technology with society. This process should allow the creation of propitious renewal and permanent updating of plans and study programs and research. Universities have the key function of contributing to the development of a culture for innovation.

2 An important discussion of what is meant by knowledge is presented by Fransman (2003), who favors a concept of knowledge as a belief thus "emphasizing the relativeness and openness of knowledge, and makes it easier to understand knowledge as a process rather than a state of affairs, knowledge constantly being transformed as an inherent part of the evolutionary process itself, constantly becoming other than what is was". Such concept fits well in line with those concepts of innovation and learning which are behind the NSI approach.

b) It is necessary to Identify the main factors which determine the demand for innovation, and the domestic capability to meet such demands. This is needed for several reasons, it can suggest both the current direction of innovation and technological efforts and the likely direction in which these efforts ought to be promoted, through public policy. Additionally it may be possible to identify the binding "compulsive requirements" in an economy according to the type of industry and /or technology used. This information will suggest the priority areas for action, as well as form the basis for more comprehensive and useful policy formulation.

c) The science sector must be seen as that capable of developing absorptive capacities. The scientific enterprise can serve as a "focusing device", spotting avenues of appropriate technological development and the scientific infrastructure can provide the knowledge base for entering into key industrial activities.

d) A focus on technology capacity building is necessary. Limited resources force the identification of priorities according to the specificity of NSI and stress more on how to build collective technological capacity which will be better placed to transfer knowledge to enterprises.

e) A policy and regulatory environment that promotes competition, under a framework which encourages local initiatives, must be sought. At the same time the efficiency and effectiveness of funding institutions must be carefully evaluated, in order to guarantee autonomy, reduced bureaucracies, transparency, peer-review based competition, small transactions costs, establishing stronger monitoring and evaluation systems, and increasing flexibility to change the nature and direction of support for research and innovation according to the circumstances. .

f) Research must be made more policy relevant. Efforts along this line are becoming more evident at world level and need to be internalized by DCTE (ICSU, 2003).

g) Many firms are not aware of possibilities of innovation using available technology. Thus the creation of a infrastructure for technology support must be created to provide information

services to provide such services. The continued creation of technology parks / incubators continues to be of key importance to enhance technology diffusion.

h) The use of techniques such as TF can help break path dependency. The understanding of issues in technology diffusion at world level can provide a mean to improve on this systemic weakness. Particularly important is to identify natural competitive advantages, which can be exploited, and thus contributing to a better productive specialization.

i) The effective management of research and innovation is at the core of any successful strategy. In order to seize the opportunities of globalization while at the same time face its challenges as well as local ones, such as poverty, and achieve leap – frogging and technological catch-up, DCTE public and academic institutions and enterprises must be capable of effectively managing not incremental and strategic innovations.

j) The basic technological objective for industry is to ensure the enhanced use of suitable technologies to enable enterprises to compete in global markets and increase exports of manufactured products, besides providing increased employment and income. This requires the exercise of initial technology choice from among alternatives and thereafter acceleration of the pace of indigenous technological innovation.

k) Private firms investing in STI require an effective protection not only of their investment but also of the results of their research and innovation. Thus institutional strengthening of institutions dealing with property rights and information, is still a high priority. IPR's must also be a matter of attention by universities and other research institutions.

5.3.2. Role of support institutions and international organizations

Support institutions and international organizations and donors have a number of critical roles to play in supporting the build up of NSI in DCTE. They are important participants in setting the global agenda, and thus can lobby if not influence, governments of DCTE, to pay attention to STI issues. They have the resources required to identify the frontiers of S&T change and can transfer and share their knowledge and insights, and also have the capacity to change some procedures regarding protection of property rights and other instruments that today affect the more open diffusion of

knowledge. For this to occur on a continuous basis channels must be set and the capacity for absorbing knowledge in these countries strengthened (see f.e. Mytelka and Oyeyinka, 2003).

Scientists conduct their research at scientific institutions. Unless these exist, not only in number but also in quality, science will never develop and produce an impact. Scientific institutions of excellence must be at the forefront of the search for a scenario of transition to sustainability. Such institutions must be built or preserved in the developing countries, and to insure their effectiveness their "delivery capacity" must be assessed. For this to be an efficient and impact producing process, centers of excellence in various relevant knowledge bases must be created. Support institutions, donors and international agencies can provide resources for this build – up and also stimulate TF and other strategic oriented activities.

The future orientation of technical cooperation should promote resource networking: a strategy that emphasizes the interaction of actors and the interplay of institutions inside the NSI. To this it should be added the need to extend cooperation activities directly to private firms and institutions. International cooperation must also happen at the market place.

Appropriate policies must encourage the transfer of technology from multinational corporations, as there can be a beneficial spill-over for the recipient economy. International organizations can provide insights in the capacities of such corporations and facilitate transfers. At the same time, they can encourage and facilitate the commercialization of research results. The relationship with such corporations and other types of strategic alliances that can be established at the regional and international levels must allow DCTE to participate fully in the operation of world value chains. Governments with support of international organizations can define strategies to guide this process.

In general, policy-makers require concrete empirical and comparative analysis for the design of specific STI. Regional, national, sub national or sector systems of innovation must be systematically compared with each other in a very detailed manner. The NSI approach is an analytical framework suited for such analysis because it places innovation at the center of focus and because it is able to capture differences between systems. At the same time such efforts can help DCTE to strengthen their own conceptual approaches to innovation and sustainable industrialization, and improve on their specialization, as countries cannot rely only in the exports of raw materials, but at the same time cannot produce all goods and services.

Donor policies are important and in many cases they must pass through permanent review and follow with agreed set of norms and practices. This includes coordination and an identification on the direction of bilateral and multilateral arrangements. In the past, such aid has at times created collections of institutions unrelated to one another, or investments on one type of research activity at the expense of others. The result is an unbalanced system with many unconnected parts. "It is a system capable of absorbing large sums of money with little noticeable impact on the lives of poor people in these countries"

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