Knowledge Networking

for Technology "Leapfrogging"

BY PROFESSOR NAZLI CHOUCRI

Globalization imposes new demands and new opportunities in access to knowledge and its applications. Knowledge networking can accelerate this access and the sharing of information about technology choices. Developing countries thus can "leapfrog" directly to "frontier" technologies which are more effective, cleaner, and less costly than the usual infrastructure. To seek these benefits, Professor Nazli Choucri of the Massachusetts Institute of Technology Department of Political Science offers a "no-risk" strategy for knowledge networking, technology advancement and capacity-building.

INTRODUCTION

Global paradox and technology advances

The global consensus that development must meet the needs of present generations without compromising options for future generations shapes all facets of globalization. By its endorsement of Agenda 21, the international community has expressed its unreserved support for both the goal and the process of sustainable development. Given the obvious challenges, there is a powerful paradox.

The paradox is this: on the one hand, the obstacles to sustainable development are formidable and seem near-unsurmountable; on the other hand, the key elements required to transform obstacles into opportunity are already in place. Resolving the paradox requires transforming latent opportunity into effective strategy. And that requires bold and effective management of technology—in terms of choices and investments, transfer and cooperation—and access to the scope and scale of relevant knowledge to dictate technology investment priorities. Box 1 lists 10 reasons why technology advance is crucial to development.

In order to progress beyond the foundations provided by Agenda 21 and current implementation efforts, it is necessary to create new technology options and development possibilities—in analytical, strategic, and operational terms —for all countries and at all levels of development. In this age of accelerating globalization, access to relevant knowl-

BOX 1—WHY TECHNOLOGY ADVANCE IS IMPORTANT FOR SUSTAINABLE DEVELOPMENT

Emphasizing positive aspirations.
In the context of development, technology and technology choice are among the very few factors that can be altered as a function of national policy. This gives developing countries some "hope" on potential possibilities for development.and lasting involvement of all citizens in the future of their nations.

Responding to leapfrogging.
Technology choice allows countries the possibility of "leapfrogging" without reproducing the outmoded physical and technological conditions in the industrial countries. Furthermore, given rapid rates of population growth, acceleration is necessary. Developing countries simply do not have the time to pursue the same historical development path as the industrial West.

Facilitating redevelopment and reconstruction.
In areas destroyed by warfare, choices of technology in reconstruction strategies enable countries to select strategies that would not have been possible before.

Increasing choices.
Effective management of technology factors gives countries the option of taking their destiny in their own hands. It also enables them to avoid building or rebuilding outmoded (and usually inefficient) infrastructure. Instead, they can put in place "frontier technology," which is likely to be more effective, cleaner, and less costly than the "usual" infrastructure.

Respecting socioeconomic diversity.
Changes in technology, by definition, are based on concepts and realities of diversity—diversity in economic, demographic and financial conditions, and in overall goals and objectives. Technology choices can and should be custom-made in response to different conditions in different developing countries.

Connecting environment and development.
Technology factors allow countries to avoid choosing between environment and development. Developing countries are in the fortunate position of having options that the industrial countries did not have when they were going through their own industrialization at an earlier period. With appropriate technology, strategies of development may proceed without necessarily destroying natural environments.

Enabling private sector involvement.
The private sector would welcome a robust initiative recognizing the importance of innovations, technological capabilities, and technology choices. We can also think of ways in which the private sector would be willing to participate actively in a global strategy to accelerate appropriate technological change.

Improving uses of financial resources.
There is no shortage of capital in the world, no shortage of financial resources. What is scarce is a set of effective strategies of confidence building to facilitate the deployment of financial resources.

Advancing knowledge networking.
Effective technology choices benefit everyone. Everyone loses because of, and bears the costs for, poor choices. Technology strategies and choices could be reinforced through effective knowledge networking strategies.

Enabling capacity-building through knowledge networking.
Only with appropriate attention to knowledge networking can technological prospects and possibilities be enhanced and strategies for development be comprehensive in scope. Conversely, if knowledge networking is ignored, then technology capacity will be undermined.

edge—to science and technology—is a critical imperative, as is the choice of "best applications" of knowledge.

Globalization and knowledge networking

It is generally understood that knowledge is a critical driver for social change. Judicious uses of communication, information, electronic connectivity, and related mechanisms can enhance the applications of knowledge. Less appreciated is the importance of knowledge networking in various forms and modes—for accelerating access to relevant knowledge, and to information about technology choices. Before reasonable individuals (governments, firms, or institutions) in a decision-making capacity can be asked to do something, they must have access to basic data, robust information, and coherent knowledge about the issues at hand.

Globalization imposed new demands and new opportunities in access to knowledge and its applications. The demands are created by the very speed at which knowledge advances in industrial countries and the plethora of applications possible. Hence, choosing among alternatives is often a daunting task. The opportunities are engendered by new technologies that facilitate access to information, data, theories, evidence, and the overall knowledge base upon which they are predicated. But there are serious technology gaps.

Effective networking has three preconditions. First is reliable connectivity and communication, in terms of basic infrastructure in place. Second is robust content in terms of the availability of core data, information, and interpretations. Third is effective capacity, institutional as well as individual, to perform essential tasks.

Effective networking has three pre-conditions: reliable connectivity and communication; robust data and interpretations; and effective capacity, institutional as well as individual, to perform essential tasks.

To date, advances in electronic technologies have greatly reduced the costs of global communication. However, such communications have largely been one-way; effective connectivity requires two-way exchanges in which the recipient also becomes a sender. This ability to "conference" is especially crucial as business and industry in developing countries seek to respond to experiences in the industrial West and, more important, seek to share their own experiences among themselves and with industrial countries.

Technology "leapfrogging"

Technology "leapfrogging" enables developing countries to avoid replicating the historical and polluting trajectory of the industrial West, accelerate their own development, and seek to meet their own needs and requirements. This is not a

normative issue, nor is it philosophical. It is a strategic, pragmatic, and practical imperative, which focuses attention on actions to avoid "old-fashioned" technology. If there is to be effective technology cooperation or transfer, then it must surely be positioned at the frontier of technology, and not along the historical trajectory of known polluting products and processes.

Reducing barriers to selection of and access to relevant technological interventions, strategies, or products is a major priority for all countries of the world. It is especially pressing for the industrializing countries as well as the least developed. The reason is this: For the effectiveness of sustainability and survival strategies, it is imperative that the mistakes made in the West be avoided. The quest for technology "leapfrogging" becomes a necessity, not a choice. And reducing the technology "gaps" is a necessary prerequisite for "leapfrogging" initiatives.

For countries like India, China, and Brazil among others, where socio-economic conditions are varied, markets are diverse, consumers are diffuse in their orientation, and purchasing power may be on the verge of a "take-off," the importance of knowledge networking cannot be underestimated. Such capability is far from a luxury.

The challenge for each country is to proceed along its own trajectory of sustainability, expand its overall technological and institutional capabilities, and thus make the best and most effective uses of its natural and socio-economic endowments. For all countries, there are three crucial and interconnected priorities: (a) strengthen technology capacity by reducing technology gaps and raising institutional performance; (b) acquire knowledge about "best technologies" as well as knowledge-networking mechanisms and processes; and (c) maintain access to networks of knowledge as well as interactions with major knowledge and information providers.

THE TECHNOLOGY STAKES

Access to knowledge is the cornerstone of any development strategy. And barriers to knowledge exacerbate prevailing technology gaps, thus further impeding development prospects.

"Generations" of technology

To date, the international community has been involved in four "generations" of technology transfer. The first efforts were by well-intentioned individuals in the North seeking to solve the problems of the South (with uneven results at best). Second were the technologically competent individuals who introduced new concepts and technologies in the South, without direct inputs from users or stakeholders (with limited success). Third are more recent efforts informed by the limitations and failures of the past (buttressed by greater wisdom and experience). And finally are the current initiatives seeking to accelerate "leapfrogging" potentials.

Developing countries are by definition "latecomers." The options available to them are, also by definition, fundamentally different from those of industrial economies at earlier stages of their development. Therefore, developing countries may well have possibilities for "leapfrogging" in many traditional areas, such as pulp and paper mills, as well as in new areas, such as information and communication technologies. Leapfrogging in this sense would be enhanced technical effectiveness in a particular area, necessarily "reinventing" the earlier phases of technology systems that appeared in the historical experience of the West. Box 2 identifies five key technology gaps that impede putting innovations to work to achieve sustainability and socioeconomic development.

Given the technology gaps, what is needed is a mechanism for facilitating diffusion of knowledge about technology options and strategies, about "leapfrogging" potentials, and about experiences to date. The realities of globalization simply reinforce such gaps. And this is why reinforcing knowledge-networking capabilities remains among the most critical priorities for developing countries. In practice, the nature of these gaps varies considerably from country to country. Identifying the most pronounced gap in different countries is an important prerequisite for success in innovation, access to technology, and technology cooperation.

Knowledge networking—to diffuse knowledge about technology options and strategies, "leapfrogging" potentials, and experiences to date—is crucial if developing countries are to close technology gaps. Globalization simply reinforces such gaps.

While industrializing countries are in the unique position of avoiding the historical mistakes in the development trajectories of the industrial countries, they need better access to information about

BOX 2—FIVE TECHNOLOGY GAPS:

- BETWEEN innovation and commercialization in both the North and the South
- BETWEEN technology levels of the North and the South
- BETWEEN technology levels among countries of the South
- BETWEEN prevalence of known technologies and the diffusion of knowledge about technology
- BETWEEN applications of technology and diffusion of knowledge on experiences and impacts of applications.

existing technologies; enhanced cooperation of the North to avoid the use of detrimental or excessively hazardous technologies; and greater cooperation among themselves to help develop improved indigenous technologies.

What is at stake?

Appropriate deployment of technology is a necessary condition toward sustainability, at all levels of development. More advanced technologies can help to serve human needs better, more efficiently, and with less detriment to natural environments. Technology for sustainable development means applications of knowledge and skills (both organizational and mechanical) to generate:

- enhanced efficiency in economic activity
- cleaner manufacturing and energy production and consumption processes
- greater compatibility with social and cultural conditions
- increased flexibility in adaptation, innovation, and management of change
- strengthened capacity for making strategic choices
- reinforced mechanisms and institutions for capacity-building.

In contrast to economic growth, which implies an expansion of size and scale, sustainable development refers to the transformation of national assets (both natural and social) to meet the needs of present and future generations. Since strategies for sustainable development need to be "customized" to the specific conditions of individual countries, the expansion of capacity today must also be targeted to the needs of tomorrow. Technology choices must be compatible with current conditions, flexible, and adaptable in order to facilitate structural and social change toward sustainability.

The rate of technology growth worldwide continues to be on an upward spiral. Investments in technology— research and development, application, and commercialization—are also expanding, as are the returns on technological investments. But levels and rates are uneven among countries in fundamental, dramatic, and increasingly critical ways.

Prevailing controversies about the sources of "ideas" and their commercialization abound. Two basic, but not mutually exclusive, contentions—"science-push" vs. "market-push" explanations—point to the importance of education-related infrastructure, on the one hand, and demand-based, commercial capabilities, on the other. Both are based on foundations of knowledge and are "fueled" by knowledge-networking capacities.

The "no-risk" technology strategy

Given the above imperatives, we now put forth a "no-risk" strategy for technology advancement and capacity-building. A country cannot develop and adjust to changing circumstances without putting in place an effective institutional mechanism to facilitate techno-

logical change and the infrastructure and administrative capacities required to exploit knowledge-building opportunities. This strategy has two parts—"the Technology Triangle" and "the Global System for Sustainable Development."

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THE TECHNOLOGY TRIANGLE

Institutional Imperatives

To date it has been demonstrated repeatedly that, when the government teams up with academia and industry on a spectrum of technologies, the probabilities of success expand dramatically. Universities and scientific institutions create research that is "pre-competitive." Its results become of commercial value only when they are employed by industry. As noted earlier, government can facilitate the process of technology creation and commercialization through the use of appropriate incentives and by eliminating obstacles. The Technology Triangle refers to strategic linkages, cooperation, and mutually reinforcing policies among these three sets of institutions in society:

- universities and scientific institutions (that create knowledge and skills)
- business and industry (that employ and commercialize knowledge)
- government (that provides constraints and opportunities, regulations, and legislation, for expansion of knowledge and skills).

Institutional and organizational arrangements differ, as do the incentive structures and the sources of financial resources. However, if properly managed, and with the support and participation of non-governmental institutions, the institutional foundations for technological development can be expanded.

Actions in the Technology Triangle

Each of the individual elements—government, business, and the scientific and academic communities—performs necessary functions.

In support of a country's knowledge-building strategies as well as its science and technology system, government plays a special role as a source of financial support (for the education system, for basic science, and for some applications). Some of its agencies are also major "customers" for the output of science. Most notable is the defense industry, where financial allocations are made on strategic and political grounds, often considered "above the law" and not subject to the usual forms of budgetary

scrutiny. In industrial as well as developing countries the defense agencies have been major sources of financial support for science-based research. They are also the source of a wide network of supporting institutional linkages (known as "contracting" and "procurement") which provide essential services to support that system.

By contrast, business and industry are driven by profit, not security considerations. Their participation in strategic collaboration for technology advance is also essential to a robust Technology Triangle. The firms are the employers of the product of the education system and of the output of research-and-development institutions. They are the agents in the underlying "contracting" and "procurement" system noted above.

The institutions of science and technology (education, research, etc.) are fundamentally dependent both on government and on business and industry for their overall viability. They will be as good as they are pressed to be. They are pressed by government for performance in return for financial support; and they are pressed by business and industry for the quality of their trained products and for the quality of the (consulting) services they can provide.

Necessity, not luxury

Considerable evidence suggests that economic growth, international competitiveness, innovative capabilities, and technological change are all contingent on a viable and effective Technology Triangle. For this reason, a good Technology Triangle is more a necessity than a luxury; it is an imperative of national development. It becomes an effective institutional mechanism for sustaining the technological capabilities of a society only if all three parties perform with a degree of reliability and meet each other's needs, demands, and requirements to some predictable extent.

When such conditions prevail, then the Technology Triangle part of the proposed technology strategy is in place. But its robustness depends on continued access to knowledge and, therefore, on knowledge-networking capabilities and effective uses of advances in information technology. The Global System for Sustainable Development has been developed specifically for such purposes.

GLOBAL SYSTEM FOR SUSTAINABLE DEVELOPMENT

Knowledge networking for decision making

The Global System for Sustainable Development (GSSD) is an electronic knowledge-networking and management system for strategic decision-making.

It is designed to overcome obstacles created by the explosion of information, difficulties in tracking advances in science and technology, and the prevalence of technology "gaps." To this end, GSSD provides an integrated approach to sustainability issues, improves access to advances in science and technology,

BOX 3—GSSD KEY FEATURES AND DELIVERABLES

- **A coherent and adaptive approach for managing the rapidly growing knowledge base associated with dilemmas of sustainability.** By "knowledge" is meant here both formal scientific evidence based on formal modes of inquiry, as well as informal culture-based insights that enable environmental challenges to be understood and interpreted within rich contexts.
- **An integrated knowledge-based platform for strategic decision-making.** By stressing connectivity across issues, as well as access to specific knowledge and information, GSSD serves as a support system for strategic analysis and decision-making.
- **A knowledge networking system predicated on principles of synergism, distributed networking, and decentralized management.** These features enable GSSD to support decentralized management of knowledge, and to counter trends toward centralizing knowledge (both theory and practice) in advanced industrial countries of the North. GSSD reinforces "flows" of knowledge to the South and eliminates barriers to access. Such barriers deprive the South of effectively utilizing indigenous knowledge for conservation and sustainability purposes.
- **An operational strategy for decentralization through establishment of GSSD mirror sites in select locations worldwide.** "Mirror-site" means an exact clone of the core system used in the global data base, as well as more localized information systems relevant to the site in question. Such sites may best be used in conjunction with language facilities other than English.

tracks the implementation of Agenda 21 and global accords, provides the basis for expanding knowledge for new accords, and enables "two-way" communication and conferencing.

In technical parlance, (GSSD) is an effort to provide a coherent knowledge base bearing on the multiple dimensions of sustainability—in all contexts and levels of development. It is also an effort to engage the research and policy communities in different parts of the world in "sorting out" the complex elements of sustainability and providing some intellectual order, analytical coherence, and directives for decision-making. GSSD is "intelligent" in the sense that it is responsive and adaptive to user needs.

GSSD users are two kinds: those searching for knowledge or wanting access to it, as "normal" users do all over the world; and those seeking to provide or input information, such as industry, governments, research institutions, etc. Box 3

BOX 4—VALUE-ADDED OF GSSD

Information consolidation.
Available information about new technologies can be consolidated and diffused by promoting (at very low cost) the strengthening of existing global technology networks of communication and computation. These include networks operated by international institutions, such as UNIDO, UNEP, and UNDP. They can be linked with private sector networks, such as those of the International Chamber of Commerce (ICC) or the World Business Council for Sustainable Development (WBCSD), and with technology networks of major universities and centers of research generating new technology, such as MIT, University of Tokyo, Technical University of Berlin, and others.

Decentralization of knowledge.
The opportunity thus exists to expand networking and information dissemination (including basic quality control) and reduce the tendencies toward centralization of information. Given advances in information technology summarized above, the cost of such networking would be minimal at best. Goodwill could be demonstrated by the private sector if "in kind" contributions could be made, such as use of their existing computation networks, thereby reducing costs further.

Expansion of networking systems.
Information networks can be used to expand potential opportunities for North-South and South-South technology cooperation. With greater access to information about "best technologies" and about locations of suppliers and users, new partners will find it easier to identify each other and initiate contacts around projects of mutual benefit. The "matching" process itself is of major importance.

Technology "census".
GSSD permits assembly of technology already in the public domain, for better access and fuller assessment. Not subject to patent restriction, technology in the public domain is also a global asset that calls for fuller utilization, as are opportunities inherent in technologies whose diffusion is limited due to information or networking constraints.

Realistic ("full costs") calculus.
At a minimum, the true costs of technology should be estimated and made known as part of the effort to improve choices. These full costs should be explicit in negotiations between buyers and sellers and in all related transactions. On the other hand, the system should create barriers to the transfer of technologies that impede sustainability. Impeding trade in environmentally damaging technologies has the added effect of creating incentives for the development of improved alternatives.

Creating innovative-technology markets.
Opportunities for new types of ventures can be generated through improving information networks, reducing undue barriers to technology access and trade, and promoting entrepreneurial partnerships (North-South and South-South) for private and public investments.

"Leveling the playing field."
Developing countries are likely to have a greater influence on shaping rules and regulations for new markets in technology than for existing markets. Since the greatest market opportunities for novel technologies are undoubtedly going to be in developing countries, anticipating now the shape and contours of markets in new technologies may help frame opportunities for the developing world.

BOX 5—GAINS FROM KNOWLEDGE NETWORKING

- identifying "best practices"
- eliminating technology barriers
- facilitating "leapfrogging" in information technology
- protecting quality controls
- retaining access to knowledge frontiers
- obtaining knowledge of practical experience

lists some key features and specific "deliverables" from GSSD to its CyberPartners.

Current developments of GSSD include (a) user-friendly interfaces, (b) linguistic diversity (beginning with Spanish—under implementation), (c) mirror-siting (or "cloning" GSSD and its capabilities and locating these in non-Western contexts), and (d) routinization of quality controls for data-base and knowledge systems. Box 4 presents the value-added of GSSD for its users.

Building on innovations

Innovations in "two-way" information technology and communication capability create the basis for the next phase in technology diffusion. With the direct participation of users, the development and transfer of technology effectively becomes an incidence of, and exercise in, technology cooperation. Such advances provide opportunities for developing countries to influence, even shape, the international community's ideas and actions on sustainable development.

This type of new computer-based information technology, supported by global communication networks, allows users all over the world to make their views known, in real time, about an issue at hand. More important, it allows users to transmit information about their own experiences to others. This capability eliminates the need for lengthy "evaluations" of technologies, investments, or experiences by outsiders; immediate feedback can now be obtained from the affected community—the stakeholders in question. Parenthetically, knowledge networking has been identified by the US National Science Foundation as one of its core pillars for future scientific and policy development, thus reinforcing the importance given to networking technologies by leading industrial countries. Box 5 shows some gains from knowledge networking.

CONTRIBUTIONS TO SUSTAINABLE DEVELOPMENT

Globalization of diffusion

The diffusion of information technology innovations and applications is no longer restricted to industrial countries.

The key principle, therefore, is that developing countries can, and should, be enabled to "leapfrog" the knowledge-related technologies by having access to "state-of-the-art" information systems and adapting them to their own inputs and requirements.

Access to, and innovations in, information technology—including expanding the uses of computer capabilities—must be supported by major strides in literacy rates and overall levels of education. Already we have seen how many of the rapidly industrializing countries are competing successfully with industrial countries in software development and data management techniques. Generally in developing countries it is the more advanced computer technology that is being introduced, rather than the old technology.

Competitive market conditions among suppliers (as well as software manufacturers) ensure sales of the newest technology at the lowest prices. For the less developed countries, access to the use of, rather than innovations in, information technology is expanding rapidly. For the least developed countries, advances in information technology are of use principally in relation to government decision-making and business and industry, rather than for broader dissemination.

Naturally, developing countries have a high interest in sustainable development, its dimensions and processes. Their role and experiences in sustainable development have special relevance to advances in the area of information systems. Indeed, there is commercial value in their contributions and inputs regarding sustainable development concepts, actions, and projects. "Two-way" communication capability expands potentials for participation of stakeholders in all countries, at all levels of development, related to any issue over which access to information is relevant. Both the access and contribution of developing countries to innovations in information technology will accelerate their own rates of technology change.

Diffusion of "best practices"

With improved communication, the diffusion of information on "best practices" in energy technology, pollution control, or "clean manufacturing" would be improved. Access to "best practices" enhances prospects for implementation where they are most needed. With improved communication, developed countries could obtain a better understanding of the nature and urgency of the problems in developing countries. With improved communication greater knowledge can be obtained by both developed and developing countries about possibilities of commercial ventures.

And, by enhancing access to knowledge about action, experience, and expectations between supplier and receiver of technology, there will be greater transparency in the exchange, and the overall quality of the exchange will be upgraded. So, too, improved

two-way communication could facilitate patentable, indigenous knowledge emerging from innovations in developing countries and from their unique conditions. That may facilitate the development and diffusion of patentable knowledge in the South. "Two-way" and "real-time" information technology and communication capability expands potentials for participation of stakeholders in all countries, at all levels of development, related to any issue over which access to information is relevant. ■