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Capacity Building for Sustainable Growth and Poverty Reduction

Alfred Watkins and Michael Ehst, Editors

THE WORLD BANK

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Capacity Building for Sustainable Growth and Poverty Reduction

Edited by
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Foreword

The World Bank has a long history of helping countries build science, technology, and innovation (STI) capacity. In the 1970s and 1980s, the World Bank worked on STI programs with emerging economies such as Hungary, Indonesia, Israel, the Republic of Korea, Mexico, and Spain. In the 1990s, the Bank had active STI capacity building programs in Brazil, Chile, China, India, and Mexico, among others. More recently, the list of countries with active STI capacity building programs has expanded dramatically. In addition to a continuing engagement with China and India, the Bank began developing STI capacity building programs in such diverse countries as Argentina, Botswana, Kazakhstan, Nigeria, Rwanda, Uganda, and Uruguay.

In July 2002, the World Bank presented a report to its Board of Executive Directors entitled, "Strategic Approaches to Science and Technology in Development," which reviewed the World Bank's experience in promoting science and technology (S&T) capacity and outlined an agenda for action. It noted the following:

> Science and technology have been central in the progress made to date in the fight against poverty and in stimulating economic growth. Today, however, the accelerating rate of progress in science and technology creates both tremendous opportunities and significant risks for developing

> countries. A lack of capacity among some developing countries to even access and utilize advances in S&T has prevented them from capturing the benefits of S&T that have become commonplace in the rest of the world. To date, the cost to developing countries of low S&T capacity has been confined mostly to lost opportunities, such as in the failure to capture the benefits of the Green Revolution in Sub-Saharan Africa. In the future, active threats to, inter alia, food safety, natural capital, and human health will join lost opportunities in comprising the full costs of inadequate S&T capacity [World Bank 2002, Executive Summary, v].

The report concluded, "The World Bank should be ready to play an appropriate role along with partner agencies in responding to the heightened demand for S&T-related services in this new environment of S&T prioritization" (World Bank 2002, v).

The Global Forum on Building Science, Technology, and Innovation Capacity for Sustainable Growth and Poverty Reduction, the February 2007 event underlying this report, is part of the Bank's efforts to respond to this heightened demand for S&T-related services.

But what exactly do we mean by STI capacity building and why is it relevant to the task of reducing poverty, generating wealth, and achieving the Millennium Development Goals (MDGs)? In his opening keynote remarks, Professor R. A. Mashelkar observed that STI usually stands for "science, technology, and innovation." Mashelkar suggested that it should also stand for "solve, transform, and impact." Seen from this vantage point, STI capacity building is not about supporting scientists in laboratories who are working on theoretical scientific problems such as the origins of the universe. Rather, it is about building STI capacity to complement the Bank's poverty reduction agenda.

As speaker after speaker at the Global Forum explained and illustrated with detailed case studies, STI capacity building is about building the technical, vocational, engineering, entrepreneurial, managerial, and scientific capacity to *solve* each country's pressing social and economic problems, *transform* their societies, and have a positive *impact* on the standards of living and quality of life of the poorest strata of society. In other words, it is about building the capacity to deliver clean water to rural villages, add value to natural resources so that subsistence farmers can generate cash incomes for their families, and help local industries compete in an increasingly competitive, open market.

Seen from this perspective, STI capacity building is an indispensable tool for promoting sustainable, inclusive globalization.

The cases from the Forum presented here capture the lessons from the STI capacity building experiences of both developing and industrial countries—governments working in partnership with the private sector, nongovernmental organizations, academia, and development partners. These cases highlight ways that STI capacity building programs have enabled countries to achieve the following:

- Provide essential services, such as access to clean drinking water in rural villages and availability of affordable, reliable energy sources
- Exploit opportunities to produce higher-productivity, value-added agriculture crops
- Transition from exporting unprocessed raw materials to exporting value-added products and from low-skilled assembly operations to higher-skilled manufacturing processes
- Create benefits from an increasingly open trading system and increased flows of foreign direct investment (FDI) by proactively generating spillovers to the local economy
- Maintain competitiveness in a rapidly changing global economy marked by rapid technological change

History suggests that these challenges are daunting, but they are not impossible to overcome. Many countries have managed to build the STI capacity they needed to thrive and prosper. So that other countries may profit from lessons learned, the Global Forum discussed what these countries achieved and how they achieved what they did.

The collective task is to help countries convert these lessons of experience into specific STI capacity building programs that can be implemented on the ground and that will have a significant, measurable impact on people's lives. A country's development must include a foundation of universal primary education and access to quality lower-secondary education. But meeting the MDGs, competing in a global economy, and providing high-wage jobs will entail STI capacity building as well. This capacity building will require targeting investments in education and training, improving research and development, supporting industrial innovation, promoting lifelong learning, and fostering policies for an enabling environment to create and apply knowledge, and private sector development.

The World Bank is poised to scale up its STI capacity building support based on the many excellent ideas discussed at the Global Forum.

Joy Phumaphi
Vice President
Human Development Network
The World Bank

Forum Presenters[1]

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1 Presenter titles are current as of the date of the Global Forum (February 2007).

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The presenters, panelists, and chairpersons at the Global Forum all volunteered their time and energy to bring the lessons of their STI capacity building experiences to the Forum participants. We thank all the speakers and participants for their time, dedication, and assistance. Videotapes synchronized with PowerPoint slides of each speaker's presentation are available online at www.worldbank.org/stiglobalforum.

Preparation of this report was a collaborative process. The following individuals took the lead in preparing the summaries of the individual Forum sessions:

- Session 1: Frans Doorman
- Session 2: Tatyana Soubbotina

- Session 3: Tatyana Soubbotina
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Abbreviations

ADB	African Development Bank
AERC	African Economic Research Consortium
AIST	African Institutes of Science and Technology
AIT	Asian Institute of Technology, Thailand
ASC	African Scientific Committee
ATV	Abuja Technology Village
BIOTEC	Genetic Engineering and Biotechnology National Center, Thailand
CARICOM	Caribbean Community
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIDA	Canadian International Development Agency
CITT	Centre of Innovation and Technology Transfer
CONICYT	National Science and Technology Council (Nicaragua)
CONICYT	National Commission for Scientific and Technological Research (Chile)
CORFO	Corporation de Fomento de la Producción (Chilean Economic Development Agency)
DCK	Dansk Chrysanthemum and Kultur

DFID	Department for International Development (United Kingdom)
EFQM	European Foundation for Quality Management
ERC	Engineering Research Center
ETRI	Electronic Technology Research Institute, Republic of Korea
FDI	foreign direct investment
FIP	Fisheries Research Fund, Chile
FONDEF	Scientific and Technological Development Fund, Chile
FONTEC	National Technological Development and Production Fund, Chile
FUMEC	U.S.-Mexico Foundation for Science
GDP	gross domestic product
GFAR	Global Forum on Agricultural Research
GRA	Global Research Alliance
GRI	Government Research Institute
HDD	hard disk drive
HDI	Human Development Index
IACWGE	Inter-Agency Committee on Women and Gender Equality
ICA	Investment Climate Assessment
ICT	information and communication technology
ICIPC	Colombian Plastic and Rubber Training and Research Institute
IDB	Inter-American Development Bank
IDCs	Innovative Developing Countries
IDRC	International Development Research Center (Canada)
IPR	intellectual property rights
IPSO	Israeli-Palestinian Scientific Organisation
ISAB	International Scientific Advisory Board
KILICAFE	Association of Kilimanjaro Specialty Coffee Growers
KIMM	Korea Institute of Machineries and Metals
KIST	Korea Institute of Science and Technology
KORSTIC	Korea S&T Information Center
KRICT	Korea Research Institute for Chemical Technology
KRISO	Korea Research Institute of Shipbuilding and Oceans
KRISS	Korea Research Institute of Standard Science
LAC	Latin America and the Caribbean
LDC	least developed country
MDGs	Millennium Development Goals

MIFIC	Ministry of Industry and Trade Promotion, Nicaragua
MNC	multinational corporation
MSI	Millennium Science Initiative
NCW	National Council for Women
NEEDS	National Economic Empowerment Development Strategy
NEPAD	New Partnership for Africa's Development
NERICA	New Rice for Africa
NGO	nongovernmental organization
NIS	National Innovation System
NSTC	National Science and Technology Council, Korea
Nuffic	Netherlands Organization for International Cooperation in Higher Education
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PAJ	Patent Abstracts of Japan
PBMR	Pebble-Bed Modular Reactor, South Africa
PDP	Product Development Partnership
PHEA	Partnership for Higher Education in Africa
PILOT	Pioneering Initiatives Linking Outgrowers to Trade
PPP	public–private partnership
PPPP	public–private partnership for the poor
PRI	publicly funded research institutes
ProChile	Export Promotion Office, Chile
PRSP	Poverty Reduction Strategy Paper
R&D	research and development
RESGEST	Regional Gender, Science, and Technology Secretariat for Southeast Asia
RISE	Regional Initiative in Science and Education
S&T	science and technology
SDPC	State Development and Planning Commission, China
SERI	Systems Engineering Research Institute, Korea
SETI	science, engineering, technology, and innovation
SIG	Science Initiative Group
SME	small and medium-sized enterprise
STI	science, technology, and innovation
STIPs	Science, Technology, and Innovation Policy (reviews)
TCS	Tata Consulting Services
TDX	Time Division Exchange, Korea

TNC	transnational corporation
TRI	Technology Research Institute
TRIPS	Trade Related Aspects of Intellectual Property
TWAS	Third World Academy of Sciences
UIL	university-industry linkage
UNCTAD	United Nations Conference on Trade and Development
UNDAF	United Nations Development Assistance Framework
UNDG	United Nations Development Group
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNICEF	United Nations Children's Fund
UPOV	International Union for the Protection of New Varieties of Plants
USAID	U.S. Agency for International Development
USPTO	United States Patent and Trademark Office
WESTU	Women Engineers, Scientists and Technicians in Uganda
WIPO	World Intellectual Property Organization
WSIS	World Summit on the Information Society
WTO	World Trade Organization

All dollars amounts are in U.S. dollars unless otherwise noted.

PART I

Introduction and Background

The World Bank convened a Global Forum in Washington, DC, on February 13–15, 2007, to discuss strategies, programs, and policies for building science, technology, and innovation (STI) capacity to promote sustainable growth and poverty reduction in developing countries.[1] The Global Forum was sponsored by the World Bank in cooperation with the Canadian International Development Agency (CIDA), the United Kingdom's Department for International Development (DFID), the Global Research Alliance (GRA), the Inter-American Development Bank (IDB), the Science Initiative Group (SIG), the United Nations Conference on Trade and Development (UNCTAD), and the United Nations Educational, Scientific, and Cultural Organization (UNESCO).

The principal theme of the Global Forum was that in today's increasingly competitive global economy, science, technology, and innovation capacity building can no longer be seen as a luxury, suitable primarily for wealthier, more economically dynamic countries. Rather, if developing countries hope to prosper in the global economy, and if world leaders expect globalization to foster sustainable development and sustainable poverty reduction, STI capacity building is an absolute necessity. In today's

1 Videotapes of each presentation, synchronized with the PowerPoint slides used during that presentation, are available on the Global Forum Web site at www.worldbank.org/stiglobalforum.

rapidly changing global economy, the critical economic development issue is no longer whether countries should build STI capacity but what type of capacity to build and how to build it, given each country's economic constraints and starting point.

With this in mind, the principal objectives of the Forum were to achieve the following:

- Understand the STI capacity building processes that are under way in different countries
- Share lessons of experience in building STI capacity, see which STI capacity building programs are working effectively and which are not generating the desired outcomes, and understand some of the reasons behind these disparate outcomes
- Build government capacity for STI policy making and enhance donor capacity to design successful STI capacity building projects
- Discuss how donor organizations could work together under the auspices of the Paris Declaration on Aid Effectiveness[2] and other similar international initiatives to improve their STI capacity building partnerships with developing countries

The Forum was organized around case studies of specific STI capacity building initiatives in developing countries. The speakers, by and large, were "thoughtful doers" who had actually designed, implemented, and managed STI capacity building programs. The Forum focused explicitly on issues of "how to build STI capacity"; rather than on questions of why building STI capacity is important or whether countries should build STI capacity. Each speaker was asked to explain what his or her case study accomplished, how it achieved its objectives, why it succeeded or failed, and what lessons of experience could be applied, with suitable modifications to accommodate country and cultural specifics, to future capacity building programs in other countries.

The Forum focused on the following specific issues and themes:

- *Reducing poverty and achieving the Millennium Development Goals (MDGs)*. What specific STI capacity building programs can help countries improve the quality of life—improved health care delivery, access to clean water, access to affordable energy, and so on—for people in the

2 The text of the Paris Declaration is available at http://www1.worldbank.org/harmonization/Paris/FINALPARISDECLARATION.pdf.

poorest strata of society? Why is it that existing proven technologies are frequently not adopted by people who presumably would benefit most from these technologies? What do the local communities know that engineers and scientists often overlook, and how can local opinions, perspectives, and views be incorporated into the STI capacity building process and into technology development and diffusion processes?

Three aspects are frequently overlooked in building the capacity of local communities to apply science and technology (S&T) to local problems. First, local communities must be active participants in the technology development process and not merely passive recipients of technology developed for them by outsiders. Second, entrepreneurship and marketing skills are critical but often overlooked capacities required for successful diffusion of appropriate technologies. Without them, technically superior solutions will not be widely adopted and, therefore, will be of little use. Finally, STI capacity building must fit into broader efforts to build the productive capacities of countries.[3] Productive capacity puts STI capacities into use. Without this demand, increasing the supply of appropriate technologies and technically proficient workers will have little lasting impact. Local involvement, entrepreneurship, and effective demand may seem like commonsense ingredients, but experience suggests they are frequently overlooked, to the detriment of effective STI capacity building efforts.

- *Adding value to natural resource exports*. Although it may seem paradoxical at first, many economists consider an abundant supply of natural resources to be a potential curse—slowing growth, hindering economic diversification, and limiting the effectiveness of government capacity building efforts. For many countries, especially those whose exports consist primarily of unprocessed raw materials, this has indeed been the case.

  Yet research demonstrates that natural resource endowments do not automatically inhibit economic development (Lederman and Maloney 2007). On the contrary, countries can grow and prosper by adding value to their natural resources before they are exported and by building the STI capacity to compete effectively in the more knowledge-intensive segments of the natural resource value chain. Finland, for example, is a major exporter of knowledge- and skill-intensive forestry

3 Productive capacities can be defined as "the productive resources, entrepreneurial capabilities and production linkages which together determine the capacity of a country to produce goods and services and enable it to grow and develop" (UNCTAD 2006, 61).

sector products (fine paper, pulp and paper-making equipment and process control systems, engineering services, and so on), but not of unprocessed or semiprocessed round wood or lumber. To escape the natural resource curse, countries have to build appropriate STI capacity so that local enterprises have the ability to produce and export more knowledge-intensive goods and services and workers have the skills to perform more complex tasks.

What are successful strategies that countries and companies can pursue to add value to natural resource exports? What STI capacities are needed to produce more knowledge-intensive, resource-based goods and services? How can exporters build linkages to customers and supply chains? How can public-private partnerships (PPPs) and technology research institutions work with domestic firms to find and adopt foreign technologies?

- *Upgrading technology and capturing the latecomer's advantage*. Today's developing countries, by definition, are latecomers. Other, more developed countries, managed to gain a head start and develop earlier. But this does not mean that developing countries are doomed to fall progressively further behind. Countries can narrow the gap and perhaps even catch up if they learn how to convert their latecomer status into an advantage. For example, latecomers do not have to invent most of the production or process technologies they will be using. Nor do they have to start with the oldest technology and follow the same historical progression that more advanced countries followed. They have the potential to leapfrog and move directly to more advanced technologies. This rapid technological progression entails building the domestic capacity to find existing technologies, adapt them for local use, and incorporate them into the production process.

  How do firms and countries catch up to technological leaders? How do they learn? Perhaps even more important, how do they learn to learn? And what can they learn from the historical lessons of experience of countries, sectors, and enterprises that have successfully learned to catch up?

  Over time, different countries have developed a variety of strategies for accomplishing these objectives. Some have relied on foreign direct investment (FDI) as a source of technological and market information. Spillovers from FDI do not happen spontaneously and automatically, however, and local enterprises frequently do not have the financial resources or technical capacity to exploit these opportunities. They need assistance in the form of PPPs. These partnerships can take the form of supplier development programs that are designed to help local enterprises become qualified suppliers to transnational corporations (TNCs). Or they can take the form of Government Research Institutes (GRIs) and Engineering Research Centers (ERCs), which perform generic technology search, adaptation, and development tasks for all the enterprises in a specific sector.

- *The role of research and development (R&D)*. The vast majority of technologies required to reduce poverty, add value to natural resources, and upgrade the technological proficiency of local industry have already been invented. They are typically in widespread use in many industrial countries. The problem is that these technologies are not widely used in many developing countries. This problem suggests that the major STI capacity building task entails building the developing country capacity to use existing technologies. For the most part, this requires developing engineering, technical, and vocational skills, rather than conducting frontier-level R&D.

  However, this does not mean that there is no role for R&D in developing countries or that these countries should not devote any resources to building their R&D capacity. It simply means that building R&D capacity, by itself, will not solve many of the most pressing development challenges facing these countries.

  What R&D capacity, then, should be built, especially at the early stages of development? How can this R&D capacity complement university science and engineering education and training initiatives? How can this R&D capacity be harnessed to solve the country's economic development challenges? What can be done to improve the quality of existing R&D capacity and to establish regional or international centers of excellence? Can building high-level R&D capacity help to reverse the brain drain and engage the skills and energy of the diaspora? Last but not least, how can countries with limited numbers of university professors and scientists join together in multicountry R&D capacity building initiatives?

- *Gender*. STI capacity building programs have important gender dimensions and implications. For example, it is important to ensure that boys and girls, men and women, have equal opportunities to study math and science, engineering, and other technical and vocational subjects. However, equal access to education and to scientific careers is only one facet of the gender dimension of STI capacity building. It is just as important to ensure that STI capacity building programs improve the lives of the least advantaged members of society. This will not happen automatically. It will require a conscious effort, along the lines specified by the United Nations' Gender Advisory Board and other organizations and declarations focused on the gender issues surrounding STI.

Key Messages from the Forum

A number of key messages emerged from the case studies presented at the Forum. These include the following:

- *STI capacity building is not a diversion from poverty reduction and the MDGs; it is an essential tool for achieving the MDGs and reducing poverty*. As the speakers in two sessions—Building Local Capacity for Developing and Diffusing Appropriate Technologies and Building STI Capacity to Add Value to Natural Resource Sectors—observed, countries cannot hope to achieve the MDGs if they do not have the scientific, engineering, and technical or vocational capacity to handle such mundane but necessary tasks as repairing farm machinery or testing drinking water. Talking about the MDGs without helping countries develop the technical, vocational, and scientific tools that they will need to achieve these goals is a futile exercise. Progress will be neither sustainable nor inclusive. *Building STI capacity is therefore as essential for low-income countries as it is for middle-income or wealthy countries*.

- *Building STI capacity for growth and poverty reduction is not about theoretical, abstract scientific research*. As R. A. Mashelkar observed in his keynote address, STI must stand for "solve, transform, and impact." Seen from this vantage point, STI capacity building must not be about supporting scientists working on abstract scientific problems such as the origin of the universe. If that were the case, STI capacity building would be a distraction from the Bank's poverty reduction agenda. Instead, STI capacity building must be about building the technical, vocational, engineering, entrepreneurial, managerial, and scientific capacity to *solve* each country's pressing social and economic problems, *transform* their societies, and have a positive *impact* on the standards of living and quality of life of the poorest strata of society. Seen from this perspective, building STI capacity entails supporting scientists working on applied research topics as well as training engineers, technicians, and craftsmen to construct infrastructure projects or to work in innovative private enterprises.

- *The capacity to absorb and diffuse existing knowledge is at least as important as the capacity to produce new knowledge*. As Calestous Juma observed in his keynote address, which closed the Global Forum, the challenge for developing countries is *not* to push themselves onto the frontiers of scientific knowledge, but rather to put readily available knowledge to use solving pressing social and economic problems. In other words, innovation is frequently independent of new frontier scientific discoveries. Innovation more frequently entails building the capacity to use technologies that are in widespread use elsewhere but that are new to the country, new to the firm, or used in new ways. To facilitate this type of innovation, countries must build the capacity to find, absorb, and use these technologies. Many of the speakers in the session on Leveraging FDI for Technological Learning and Supplier Development and Fernando Chaparro in the session on Building R&D Capacity in Developing Countries explained how individual countries build the capacity to find existing knowledge and transfer it to private enterprises.

- *Committed, capable national leadership with coherent STI capacity building policies is an absolute necessity*. STI capacity building is not a laissez-faire process. This is as true for China and the Republic of Korea as it is for Mozambique and Nigeria. The government has an important role to play in setting the agenda, mobilizing resources, and developing and implementing coherent STI capacity building programs. Because STI capacity building is a crosscutting issue, transcending sectoral and ministerial boundaries, committed national leadership will be required to overcome turf rivalries and induce ministers to think outside their silos. The ministers of science and technology speaking at the Forum reinforced this message based on their own experiences using STI—successfully and unsuccessfully—to advance national social and economic goals.

- *Basic literacy is essential, but it is not sufficient*. As Paul Wolfowitz, World Bank president, observed, and as the panelists in the session on Building R&D Capacity in Developing Countries reiterated, developing countries will not have the capacity to address their social and economic problems if they focus only on basic literacy to the exclusion of secondary and tertiary education. Strengthening higher education, along with technical and vocational education, is essential for creating a globally competitive economy. A country with primary education graduates will be able to compete only on the basis of unskilled, low-wage labor. By definition, this is not a path to sustainable development, poverty reduction, and steadily rising standards of living.

- *The centrality of women to poverty reduction means that STI capacity building should target gender disparities in strategies to achieve the MDGs*. As the speakers at the Gender Session observed, the driving issue is no longer gender equity, per se, but inclusion in the sense of mainstreaming gender considerations into all aspects of S&T capacity building for sustainable development. The case studies discussed at the gender-focused session of the Forum describe the obstacles to poverty alleviation presented by gender disparities and explain how S&T programs targeted toward marginalized groups, including women in many countries, can lead to significant poverty reduction. Ensuring that everyone in society (men as well as women) has access to quality S&T education and training and career opportunities is, therefore, essential and smart public policy.

- *STI capacity building is about much more than high tech*. High-tech industries—electronics, computers, and so on—are not always synonymous with high value added, high wages, and rapid growth. On the contrary, developing countries may get more development "bang for the buck" by helping low-tech but knowledge-intensive sectors, such as horticulture and food processing, become more competitive and innovative than by trying to compete in a few high-tech niche products and industries. All too often policy makers, however, tend to view high tech as the surest route to competitiveness and prosperity. They mistakenly devote considerable resources to building the STI capacity needed to support a small high-tech sector while ignoring the STI capacity building programs that are needed to support the potentially much larger non-high-tech part of the economy. However, these non-high-tech industries may be precisely the ones that generate the greatest social and economic returns to STI capacity building. Speakers in the sessions on Building STI Capacity to Add Value to Natural Resource Sectors and Leveraging FDI for Technological Learning and Supplier Development discussed ways that some countries were able to develop programs to increase the knowledge intensity and value added of these low-tech sectors.

- *Regional initiatives are an important component of STI capacity building*. As Phillip Griffiths, Wole Soboyejo, and Jeffrey Fine all pointed out, it may not be feasible or desirable to establish duplicate STI institutions in each and every country. This is especially true in regions that have large numbers of smaller countries with limited STI capacity. The trained manpower may simply not be available. Expensive facilities may lie idle for long periods of time. Instead of spending money on what could turn out to be underutilized, duplicate, poorly staffed facilities, countries may be able to reap substantial economies of scale or financial savings by banding together to support regional STI capacity building initiatives that complement national STI capacity building programs. These initiatives can include regional initiatives to support specialized R&D facilities, train scientists and teachers, or support specialized graduate science and engineering programs.

As Sonia Plaza noted, however, regional initiatives will require new funding modalities by the World Bank, regional development banks, and bilateral development partners. Most capacity building programs focus on bilateral funding arrangements between the funding organization, on the one hand, and government agencies, on the other. Adapting these existing business modalities to finance regional initiatives will require new ways of doing business. This will be a critical challenge for the future.

- *Centers of excellence do not have to be only brick-and-mortar institutions*. As Claudio Wernli reported, centers of excellence can be virtual institutions, encompassing networks of scientists from different institutions in the same country or even from different countries. The important point is that scientists join forces to work on a common set of problems. Physical facilities to support the work will undoubtedly be required. But this is not the same as expecting that every scientist and researcher affiliated with a center of excellence has to reside in the same place or work in the same laboratory. Nor does it mean that only those scientists affiliated with a specific institution can be considered part of a center of excellence.

- *A good business climate must be paired with STI capabilities to develop an innovative, globally competitive economy*. Basic policies need to be in place to ensure reasonable macroeconomic stability, to promote a good business climate, and to reduce the cost of doing business. It makes little sense to build STI capacity if the legal, regulatory, financial, and economic conditions deter farmers, entrepreneurs, and investors from investing and innovating. However, capacity building is not a passive process. Productive capacity does not develop automatically once a good business climate is in place and the cost of doing business is reduced to reasonable levels. It requires conscious, deliberate policies and programs as demonstrated by the successful programs discussed during the Global Forum.

Put differently, foreign investors can be a major source of technological, scientific, and market intelligence. But technological diffusion and spillovers do not happen spontaneously and automatically when countries open themselves to trade and FDI. On the contrary, a country needs to build the capacity so that universities, local research institutions, and local enterprises have the capacity to work with foreign investors, learn from them, and supply knowledge-intensive goods and services to them. Deliberate STI capacity-building programs, along the lines of the diverse programs described in the session, Leveraging FDI for Technological Learning and Supplier Development, will be required. Similarly, the capacity to absorb existing technologies and knowledge from outside the country does not happen automatically. Specific institutions and policies need to be in place to facilitate this process.

- *Fostering entrepreneurship is a critical component of STI capacity building*. The ability to absorb and utilize new technology and the capacity to innovate must reside in private enterprises. Entrepreneurs are the ones who organize the production processes, link farmers and workers to global markets, and train them to meet the exacting production and quality control standards required by demanding international customers. Seen from this perspective, entrepreneurship is an essential aspect of STI capacity building. Supporting entrepreneurship entails establishing and maintaining a good business climate. It also entails developing innovative PPPs to support technical and vocational training tailored to the needs of the private sector and, at times, delivered by the private sector. PPPs can also ensure that R&D institutes focus their efforts on the technological needs of private sector entrepreneurs and that specialized institutions help the private sector find, adapt, and adopt technology that will enhance competitiveness. The public sector can boost the private sector's technological absorptive capacity by supporting mission-oriented R&D programs, technology diffusion programs, and many of the tried-and-true technological development devices discussed at the Global Forum. But scientific knowledge by itself will not result in economic gains and social progress unless it is absorbed by a private sector that will convert knowledge into wealth.
- *STI capacity building should not be confined to S&T projects and programs or higher education projects and programs*. As Charles Weiss observed, STI capacity building must become an integral component of all investment activities. Twenty and thirty years ago, for example, World Bank infrastructure and industrial development projects had explicit

STI capacity building objectives. This focus on capacity building disappeared with the shift to policy-based lending. Capacity building needs to be revived and incorporated into agriculture and rural development, environment, private sector development, and infrastructure programs. Donors should not only finance the physical investments but capacity building programs as well. For example, when building infrastructure projects, outside contractors could be required to accept student interns and industrial attachments during all phases of the work—from engineering, to design, to construction, to operations and maintenance.

- *There is no single correct recipe for building STI capacity.* Different countries have developed various policies and programs for building STI capacity. But while the programs differ in technical details and specific tactics, successful programs tend to focus on a common set of core issues: promotion of entrepreneurship; adaptation and adoption of existing technology; both the supply and demand for S&T capacities; specific social and economic goals; and promotion of interactions among public institutions, academia, and the private sector. Success in building STI capacity requires a continuous process of institutional learning by the government agencies that create and administer STI policies and programs and the labs, universities, and firms that create and use knowledge.

Overview of Issues, Options, and Priorities

There appears to be an emerging consensus that STI capacity building is an essential tool for sustainable development and poverty reduction. But what precisely is meant by STI capacity building? What capacities must be built? How have countries built these capacities? How should policy makers allocate scarce resources to different capacity building objectives and what specific capacities are the highest priorities for any given country at a given stage of development?

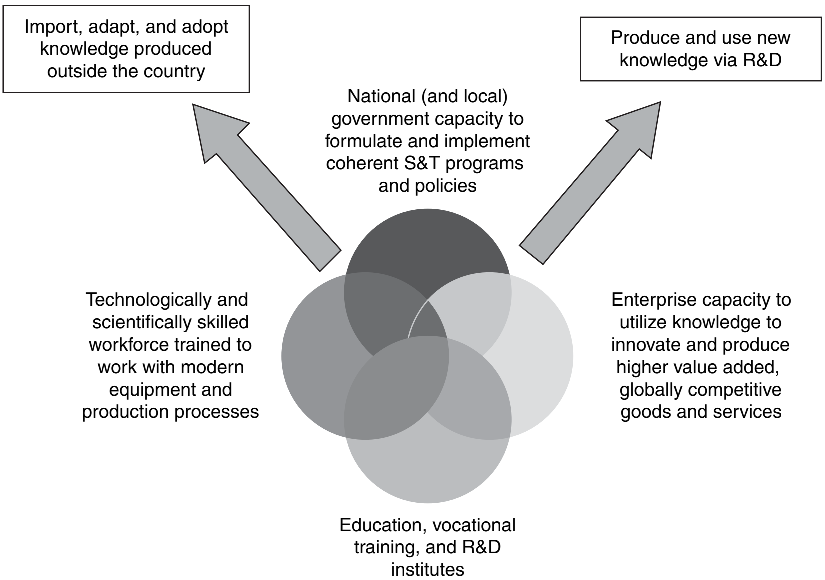
STI capacity building involves building two types of capacity (see figure I.1):

- To acquire and use existing knowledge
- To produce and use new knowledge

It also involves building capacity at four distinct levels:

- Government policy making
- Labor force skills and training

Figure I.1. Dimensions of STI Capacity



Source: Authors' creation.
Note: R&D = research and development; S&T = science and technology.

- Enterprise innovation
- Education and training institutions and research institutes

Dimensions of STI Capacity

A. Types of STI Capacity—The two types of capacity are as follows:

- *The capacity to acquire existing knowledge that was produced outside the country, adapt it for local use, diffuse it throughout the country, and adopt it locally*. Acquiring, adapting, diffusing, and adopting existing knowledge is a major conduit for building STI capacities in every country, irrespective of its level of development. Even if a country dramatically increases the size and quality of its research effort, it is unlikely that the local R&D system will generate more than a small fraction of the total knowledge needed by the country. Hence, most of the knowledge that any country will need if it is to grow and prosper will be produced by others. As a result, developing the capacity to identify, find, acquire, adapt, and adopt this existing knowledge must be an indispensable component of any country's STI capacity building strategy.[4]

Developing this skill involves much more than building the information and Internet infrastructure through investment in information and communication technology (ICT) and additional bandwidth. These infrastructure investments provide the physical facilities needed to tap into the existing pool of global knowledge. But developing the capacity to acquire, adapt, and adopt this knowledge is more difficult and complex than simply providing additional Internet connections and bandwidth, important though these might be. Understanding the challenges involved in helping local enterprises build the capacity to find new (for the enterprise) technologies and incorporate them into their production process were major themes of the Global Forum.

- *The capacity to produce and use new knowledge via R&D*. This may entail the capacity to conduct high-level basic research, alone or in partnership with leading global R&D institutes. Or it may entail building the capacity to find novel ways of solving local problems—for example, developing more fuel-efficient cook stoves, applying nanotechnology filtration systems to deliver potable water to a local village, or designing biogas energy systems. Not every country has the current capacity (or pressing need) to participate in the global R&D effort to find a cure for AIDS or to develop an antimalarial vaccine. But every country needs to develop the R&D capacity needed to find new, innovative ways to apply modern science to solving local problems.

B. Levels of STI Capacity Building—STI capacity building occurs at four levels.

- *The capacity of government to formulate coherent STI policies and link them to discrete development strategies*. These government policies include explicit STI policies—for example, grant programs to finance R&D, to link R&D more closely to the needs of industry, to foster

4 A recent RAND Corporation report identified 16 key technologies and then tried to assess whether various countries had the capacity to utilize these technologies. It found that many developing countries lacked the capacity to utilize many of the new emerging technologies (for details, see Silberglitt, Anton, Howell, and Wong, 2006).

technology upgrading in local industry, to stimulate enterprise demand for R&D, to support targeted STI capacity building programs in high-priority social and economic sectors, and so on. Governments must also consider implicit STI policies—that is, tax policies that encourage or discourage enterprise innovation; trade policies that protect uncompetitive domestic producers from competition thereby discouraging innovation; financing mechanisms that help to generate demand for local R&D activities; administrative barriers and other government rules, regulations, and restrictions that make it excessively difficult to start a new business; and so on. The importance of the implicit and explicit policy-making dimension cannot be overestimated. For example, many transition economies have a well-developed, even world-class, scientific infrastructure. But the absence of a suitable enabling environment often prevents them from converting this scientific capacity into knowledge-intensive, value-added goods and services. Other countries need to focus their policy-making attention on strengthening the knowledge production and acquisition skills of local enterprises or finding ways to help local enterprises train workers to perform more complex tasks and utilize more sophisticated machinery and inputs. The key point is that every country needs to identify those areas where its National Innovation System (NIS) is weakest and then design and implement coherent STI policies that can address these deficiencies.

- *The capacity of the workforce to engage in more knowledge-intensive production*. An educated, trained workforce is a sine qua non for STI capacity building. This entails more than simply producing more top-notch scientists. For many countries, a higher priority may be developing technical and vocational skills. One critical question is when education and training should take place in formal education institutions or when education and skills are best acquired via learning on the job? What is the appropriate balance between these different methods of delivering training? How can formal education institutions be induced to provide vocational and technical training that is more attuned to the needs of local industry? How have various countries used education and training to make the transition from a predominantly low-wage, unskilled labor force to a higher-wage, skilled labor force? This is a question of increasing both the supply of skilled workers (so that enterprises see the country as an appropriate location for skill-intensive activities) *and* the demand for skilled workers (so that investments in education and training do not result primarily in brain drain).

- *The capacity of enterprises to use new and existing knowledge to innovate and to design, produce, and market more knowledge-intensive, value-added goods and services*. Building the capacity to acquire and produce additional knowledge will be of little relevance unless agricultural, manufacturing, and service enterprises have the capacity to use this knowledge to produce higher-value goods and services. For example, in several countries world-class R&D facilities coexist alongside impoverished rural villages and uncompetitive local industries. Additional efforts to build R&D capacity and the supply of skilled workers will not help industry become more competitive unless complementary efforts are made to increase the private sector's demand for knowledge and the industry's capacity to innovate. All too often, public policy focuses on increasing the supply (or even the quality and relevance) of R&D and the supply of skilled workers, on the assumption that the demand already exists for more R&D and for more skilled workers. But is this always the case? If it is, why are so many skilled workers emigrating and why is brain drain such a serious problem for so many countries? Related to this are the questions of enterprise innovation. How much and what type of innovation is currently taking place in a country? What are the obstacles to greater innovation? Do firms face corruption and administrative barriers? Is the cost of doing business an obstacle to enterprise innovation? What about the lack of skilled workers who can produce more knowledge-intensive, value-added goods and services and conduct more complex tasks? Or is the greatest obstacle the scarcity of enterprises that have the organizational and managerial capabilities needed to produce more sophisticated goods and services? What types of enterprises are most innovative in developing economies—small or large, old or new?

- *Education, vocational training, and R&D institutes*. Education, vocational training, and R&D institutes are the main transmission mechanism between the global stock of knowledge, on the one hand, and enterprises and the workforce, on the other hand. It is a truism to suggest that a more skilled workforce is a prerequisite for producing more knowledge-intensive goods and services. However, a skilled workforce will only translate to more knowledge-intensive production if the supply of skills and knowledge produced by the education and training system broadly matches the demand for skilled workers in the economy. Among other things, this requires an education and vocational training system with the flexibility, autonomy, incentives, and technical capacity to respond to market signals and to work in partnership with potential private sector employers. All too often, these administrative and managerial prerequisites are missing. Spending more on education will not have the desired economic benefit unless the additional resources are accompanied by the necessary organizational and structural changes. R&D institutes are part of this transmission mechanism. When they operate optimally, R&D institutes serve a dual function: they produce new knowledge and they help to train the next generation of scientists. Unfortunately, R&D institutes frequently have weak links, at best, to the innovative needs of enterprises and do not play an active role in training young scientists. The Global Forum examined how some countries tackled these problems and turned these institutions into resources for economic growth, while strengthening their role as centers of excellence and transmission mechanisms for global knowledge.

Implications for STI Capacity Building Policies

In embarking on an STI capacity building program, policy makers need to decide which dimension of STI capacity should be highlighted at any given stage of development and what is most appropriate given each country's unique circumstances and starting point. They also need to maintain an appropriate balance between different types and levels of STI capacity building. For example, what is the appropriate balance among the following:

- Creating new knowledge versus acquiring existing knowledge?
- Increasing the supply of knowledge by increasing R&D and education versus increasing the demand for knowledge in the enterprise sector by improving the climate for innovation, entrepreneurship, and technology upgrading (including upgrading traditional technologies)?
- Financing hardware (building new laboratories, acquiring new scientific equipment) versus financing software (programs and policies that improve the incentives to innovate)?
- Pursuing horizontal policies (level the playing field; reduce administrative barriers and the cost of doing business; improve the quality, governance, and relevance of the education system; enhance intellectual property [IP] protection) that establish a good business climate versus pursuing vertical policies that strengthen the STI capacity in those sectors that the market has identified as probable winners?

- Developing new organizations and institutions versus enhancing the capabilities, performance, and linkages of existing STI organizations?

In considering their options, policy makers will need to consider the strengths and weaknesses of a country's current STI capacities as well as the short- and long-term cost and benefits of emphasizing different dimensions of capacity building. These tradeoffs can be assessed only in the context of a country's individual goals and objectives. Specifically, what problems is the country trying to solve by building STI capacity, and what is the best strategy for achieving these objectives?

In some cases, these issues involve difficult tradeoffs. For example, especially in the early stages of development when financial and human resources are scarce, policy makers will not be able to do everything at once. Under these circumstances, they will need to establish priorities and decide which specific dimension of STI capacity building will generate the greatest development bang for the buck. For example, if a country's industries are all operating far below the technology frontier, should policy focus on creating new knowledge and building R&D facilities or should it focus instead on building the enterprise sector's capacity to acquire and utilize existing knowledge?

In other cases, the issue is one of finding the appropriate balance between different dimensions of STI capacity building. For example, devoting too much attention to building R&D capacity or building the wrong type of R&D capacity may be just as detrimental as focusing too little on R&D. Similarly, improving STI "hardware" is likely to bring results only if it is done in combination with appropriate "software" progress. And to be most effective, horizontal policies probably need to be paired with appropriate vertical policies. Thus, for most countries, it is not a question of selecting one or the other, but maintaining an appropriate balance.

Global Forum Issues

To help policy makers assess these issues, priorities, and tradeoffs, the Forum was organized around the following constellation of ideas:[5]

- Reducing poverty and achieving the MDGs: the role of STI capacity building

5 These four dimensions of STI capacity building should not be seen as mutually exclusive or as either-or options. Countries and policy makers do not have to "choose" one STI capacity building objective to the exclusion of the others. Nor can countries be neatly pigeonholed into one category or another—for example, this country needs to

- Adding value to natural resource exports through STI capacity building
- Latecomer strategies for catching up—linkage, leverage, learning, and STI capacity building
- The role of R&D in the development process

Although all four sets of issues are related to the notion of "STI Capacity Building," they address different problems and entail the development of different skills and institutions. For example, for many countries without preexisting, well-developed R&D systems, national priorities for building STI capacity to reduce poverty and achieve the MDGs will most likely entail developing the technical and vocational skills needed to deliver quality health care and clean water to rural villages and low-income urban neighborhoods, improving public health systems, and using fairly simple, well-known cultivation techniques to minimize soil erosion. Priorities would also entail developing and diffusing simple, low-cost "appropriate" technologies—for example, more efficient wood-burning stoves, manual irrigation pumps and food processing equipment, and possibly the selective upgrading of traditional technologies.

Building the STI capacity to address these issues would focus primarily on strengthening applied vocational, technical, and engineering skills to solve local problems and entrepreneurship training to help small businesses produce, market, and distribute products based on these new technologies. It would also involve developing the capacity and know-how to license newly developed technologies to private enterprises that could sell and distribute them inside the country as well as in neighboring countries. Importantly, all of these essential tasks are distinct from building world-class R&D capacity.

Put differently, policy makers need to find the right balance between the creation of new knowledge via investments in R&D capacity and

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focus on the MDGs; that country should emphasize improvements in its R&D capacity. Innovative developing countries with world-class R&D capacity may face serious MDG problems. Poor countries may have isolated pockets of research excellence that may need to be nurtured. And middle-income countries facing increasing competitive pressures may need to balance the need to build (or rebuild) R&D capacity and also to focus on technology upgrading and generating more value added from its natural resource base. The point is that in a world of scarce financial resources and human capabilities, where it is impossible to do everything at once, policy makers will have to set priorities and determine sequences of STI capacity-building initiatives, which are based on each country's most pressing needs, objectives, and initial endowments. Properly assessing national STI needs, establishing priorities for addressing these needs, and understanding the different dimensions of STI capacity building will be critical to the success of any STI capacity-building program.

building the capacity to absorb, adapt, and adopt existing knowledge. In some cases, the knowledge required to solve many of the most pressing problems already exists and is widely used outside the country. Unfortunately, it is simply not in widespread use inside the country. In this case, the main STI capacity building issue is related to technology diffusion, which requires building up the skills to find, deploy, and utilize more sophisticated[6] technologies. For countries without substantial R&D capacity, therefore, the notion of STI capacity building should refer, at least initially, to developing the technical skills required to find, adapt, and utilize *existing* technology to produce more knowledge-intensive goods and services, even if these goods and services are such low-tech but knowledge-intensive items as roses, coffee, wine, fish farming, and rainwater harvesting systems.

A. Building STI Capacity to Reduce Poverty and Achieve the MDGs— With an annual per capita income of less than US$700, the typical resident of a low-income country lives below the $2 per day poverty line. Many are engaged in subsistence agriculture or casual, informal urban labor and few have access to electricity and clean drinking water. In many countries, wood is the main source of fuel. As a result, deforestation and soil erosion are serious concerns. In what is clearly a cruel irony, water from heavy rains cascades down hills and mountains, washing away farms and increasing soil erosion. Women and children then spend hours every day hauling drinking water back up to their villages. In another cruel irony, surplus food often rots because of a lack of storage capacity, whereas many of the people who produced the surplus crops do not have the security of a year-round stable food supply.

With this in mind, government officials are beginning to ask whether targeted efforts to build STI capacity could play a role in alleviating these problems, improving quality of life and well-being, and raising standards of living. The session Building Local Capacity for Developing and Diffusing Appropriate Technologies of the Global Forum highlighted areas in which STI capacity building programs can act as catalysts, disrupting the current low-level stagnant equilibrium and generating

6 "More sophisticated" is a relative term. It does not necessarily connote only high tech, biotech, or nanotechnology. It simply refers to technologies that are more sophisticated than those currently used inside the country, even if they are widely used outside the country and not considered especially sophisticated where they are commonly employed. Examples might include such knowledge as how to prune mango trees to reduce fungal infections.

self-reinforcing changes that start the village or country down the road to sustainable economic development.

Building STI capacity to reduce poverty and achieve the MDGs would entail boosting STI capacity on a number of related fronts, including the following:

- *Agriculture research and outreach*. The agricultural research and outreach system in many developing countries is fragmented and has limited capacity for meeting such priority needs as (i) boosting productivity of food crops; (ii) adding value to agricultural products through postharvest processing; and (iii) ensuring sustainable use of land resources for farming. As a result, the overall level of knowledge employed in the agriculture sector remains low, and agriculture is not yet living up to its potential as an engine of economic growth. Capacity gaps exist at multiple levels: public labs have poor linkages with farmers and the private sector; skilled researchers and technical staff are in short supply; and the private sector does little in-house research and training. Building the capacity of the agricultural research and training system—faculties of agriculture, technical schools, public research laboratories, and technology transfer centers—is an essential element of ensuring a sustainable food supply and boosting agricultural productivity (Juma 2007a).

- *Alternative energy*. Many of the world's poorest residents live in urban settlements and rural villages that are not connected to the central power grid. Building central generating plants and connecting remote villages to the central grid is neither feasible nor affordable in many countries. Therefore, to serve these people, countries will need to develop alternative, decentralized energy sources including wind, solar, thermal, small-scale hydro, and, where appropriate, bio fuel. While every home cannot be connected to these alternative energy supplies, at least initially, central locations such as schools and public health clinics can be electrified and can serve as central locations for computer centers, Internet cafes, and other public facilities.

- *Appropriate technologies*. Appropriate technologies are affordable and accessible technologies that can improve living conditions in villages and cities (biogas, rainwater harvesting, Ecosan latrines, pumps, and so on). They can also boost family and business incomes (maize millers, drip irrigation, small tractors). But the development and diffusion of these technologies have been slow and fragmented across urban and rural users in many developing countries. The technology diffusion agencies have limited capacity to identify appropriate technologies, modify them for use in the local context, and get them into the hands of entrepreneurs who can produce, market, and distribute them. A major capacity building task would consist of training technology and research institutes in transfer and commercialization activities.

- *Delivery of clean drinking water*. Waterborne diseases, caused by a shortage of potable water, are a major source of illness in many countries. Rainwater harvesting and other technologies in widespread use around the world can provide a relatively low-cost effective water supply for use in cooking and drinking water. The techniques and technologies for delivering clean drinking water to rural villages are widely known, but they are not sufficiently used in many countries. Part of the problem is the shortage of technical and vocational skills needed to build and maintain water distribution networks. A vocational training program to boost the supply of trained technicians along with a program to finance the construction of drinking water systems might help to address both the supply and demand side of the equation. Engineering and technical capacity is also needed for exploring and drilling underground water.

- *Public health*. Health education needs to be widely available to help educate the rural populace in such topics as nutrition, sanitation, hygiene, and, as mentioned earlier, the importance of clean drinking water. In addition, public health technicians and nurse practitioners need to be trained to maintain adequate public health records, administer vaccines and medicines, and provide routine health care services. Where possible, rural health clinics need to be connected via the Internet to regional health centers where more highly trained personnel are available to provide (via telemedicine) more sophisticated health care services. As this suggests, improvements in public health require social and institutional innovations as much as technological innovations.

- *Technical and vocational education*. Many developing countries suffer from a major shortage of skilled technicians and artisans needed to perform such diverse tasks as repairing automobiles, repairing and maintaining electrical appliances and such electronic equipment as printers and copiers, and designing and constructing such items as drinking water systems and energy systems. There is frequently a shortage of well-equipped technical and vocational schools. At the same time, graduates from the few schools that do exist are having difficulty finding jobs because they do not receive enough technical training. Developing new, more effective ways to deliver technical and vocational education and linking this education more closely to industry needs are critical STI capacity building challenges.

The Forum discussed a number of successful initiatives designed to show how STI capacity building programs have addressed some of the issues enumerated above. This was not an exhaustive discussion. But it did illustrate what can be done and how to do it. Key questions then become the extent to which the lessons of experience are relevant to other countries, and, if they are, what can be done to scale up these initiatives. Will multilateral, bilateral, donor, and government resources be sufficient to scale up these programs on a sustainable basis? If not, is the root problem one of inadequate resources or one of inappropriate solutions?

B. Adding Value to Natural Resource Exports through STI Capacity Building—If countries hope to become more prosperous, they must find ways to reduce the ranks of the rural and urban poor and not merely develop technologies that make life more tolerable for them. Reducing the ranks of the poor must entail creating more productive, higher-paying jobs outside subsistence agriculture and casual urban labor, developing new higher value-added exports,[7] attracting FDI, improving the quality of science and technical education at all levels,[8] and establishing supply chain linkages between local firms and foreign investors. STI capacity building is a critical tool for solving these problems.

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7 Higher value added should not be confused or equated with high tech. For example, electronics is generally regarded as a high-tech industry and horticulture as a low-tech industry. But horticulture production may, in fact, be more knowledge- and skill-intensive than assembling imported components into finished computers. The critical economic development issues are the value-added generated by a particular activity as well as the labor skills required to produce a particular product, not whether the finished product or industry is classified as high tech or low tech.

8 Improving the supply of skilled workers via education and training programs are absolute prerequisites for the success of any STI capacity building initiative. But increasing the supply of skilled workers may lead to brain drain if it is not accompanied by a corresponding increase in the demand for skilled workers by private enterprises. Building STI capacity to create wealth and diversify the economy is especially necessary to increase the demand for skilled workers. This is especially important for Africa, which is more prone to brain drain than most other regions.

From a theoretical economic perspective, the solution to these problems is clear and unambiguous. Labor should shift from low-productivity subsistence agriculture or casual labor to higher-productivity manufacturing and service sector jobs. Fortunately, much of the initial technical knowledge needed to create these new jobs already exists. Unfortunately, although this knowledge exists and is widely used outside many poor countries, it is not widely used by enterprises in poor countries. From this perspective, therefore, STI capacity building needs to focus on finding appropriate technologies, importing them, adapting them to local conditions, and helping firms (both managers and workers) use them to produce and market higher-value, more-knowledge-intensive goods and services.[9]

Developing countries need to establish applied engineering research institutes that focus their R&D efforts on developing such simple, low-cost technologies as more efficient wood-burning stoves, manual irrigation pumps, food processing and storage equipment, more efficient, low-cost construction materials and methods, and nonelectrical refrigeration or food-cooling equipment. However, it is not enough simply to produce prototypes of better equipment. Designs and blueprints have to be developed and transferred to small and medium enterprises (SMEs) that could produce, market, and distribute them to customers in local and regional markets. In this way, STI capacity building programs will support and reinforce parallel programs aimed at private sector development, economic diversification, entrepreneurship, and SME development.

Moreover, leveling the playing field, reducing administrative barriers, and decreasing the cost of doing business are essential but not sufficient conditions for higher productivity, increased competitiveness, rising standards of living, and economic diversification. Capacity building and barrier reduction are not the same. Barrier reduction is necessary, but not sufficient, for businesses to thrive and become more innovative. Enterprises will not be able to exploit the competitive opportunities generated by a good business climate if their workforce does not have the requisite skills to perform higher value-added tasks and if local

9 In a speech at a recent annual meeting of the Consultative Group on International Agricultural Research (CGIAR), World Bank Chief Economist Francois Bourguignon asked whether agricultural research should maintain its focus on improving crop yields—which, by depressing commodity prices, may have the perverse, unintended consequence of increasing rural poverty and stagnation—or begin to focus more on finding ways to add value to crops produced by rural villagers.

enterprises do not have the organizational and managerial capacity and technical competence to invest, innovate, enter into strategic supply chain arrangements with other firms, and operate closer to or at the global technology frontier. Seen from this perspective, therefore, STI capacity building is a necessary complement to barrier reduction.

Many countries suffer from a shortage of skilled technicians and craftsmen needed to perform such diverse tasks as repairing automobiles, repairing and maintaining electrical appliances and such electronic equipment as printers and copiers, and designing and constructing such facilities as rainwater harvesting systems and schools. At the moment, there is a shortage of well-equipped technical and vocational schools. Annual operating costs for these schools are also much higher than operating costs for traditional academic secondary schools. Thus, donors looking to maximize the number of students benefiting from donor-financed education programs often prefer to invest in lower-unit-cost secondary education, even when this preference does not coincide with the most urgent needs of the economy. At the same time, graduates from the few schools that do exist are having difficulty finding jobs because graduates do not receive enough technical training. Poor countries will have difficulty moving beyond subsistence agriculture without an adequate supply of personnel trained in these midlevel craft skills.

Investment climate improvements, while critically important, will not by themselves generate more competitive domestic enterprises if these firms lack the organizational capability to respond effectively to a better business climate. Building this capacity takes time and should be a major objective of any STI capacity building program.

FDI is frequently seen as an essential ingredient in any STI capacity building program. But FDI is not the automatic development panacea that some suggest. To the extent that a poor country is successful in attracting FDI, it may initially be due to the fact that it offers an abundant supply of natural resources and low-wage, unskilled labor. These are its current factor endowments and comparative advantage. But numerous empirical studies suggest that FDI does not automatically generate spillovers, clusters, or backward supply chain linkages to domestic suppliers (for a comprehensive review of these issues, see Hoekman and Javorcik 2006). Nor does the mere presence of FDI generate an automatic evolutionary path leading from low-skilled simple activities to higher-skilled activities. So while FDI can help to generate immediate employment and export revenues, host countries need to take a proactive STI capacity building approach if they wish to use FDI as a stepping stone to producing more sophisticated, knowledge-intensive goods and services.

This might include such items as skill development programs, technical and vocational education programs, technology upgrading policies, and supplier development programs. By improving the country's capacity to supply more sophisticated products and conduct more complex tasks, foreign (and domestic) investors might be induced to locate more knowledge-intensive activities in poor countries. This is largely how Singapore progressed in less than 40 years from a comparative advantage based on an abundant supply of low-wage, unskilled labor to a competitive advantage based on its capacity for frontier research, innovation, and high-tech, skill-intensive production.

Especially during an industry's early stage, when private enterprise capacity is weakest, some form of PPPs may be needed to identify suitable technologies, adapt them for local use, and encourage enterprises to adopt them for production (for case studies of how new export industries emerged in selected developing countries, see Chandra 2006). For example, fish farming and horticulture exports are generally thought of as low-tech activities. In fact, they require sophisticated inputs, skilled labor, laboratories to ensure that the fish comply with health and safety regulations, and technicians to work in industrial laboratories and quality control centers. In other words, public-private STI capacity building programs need to help countries develop the scientific and technical inputs needed to make these natural resource–based activities globally competitive (for a discussion of the STI capacity required to meet sanitary and phytosanitary standards, see Jaffee 2005; Jaffee and Henson 2004).

Finally, STI capacity is critical for maintaining the competitiveness of existing productive industries in the face of changing market demands, business climate, and environmental conditions. The effort to build up an industry to the point at which firms can compete for global market share does little for the sustained development of a country if the firms in that industry gradually lose their competitive advantage as new technologies are developed elsewhere that better meet the market need. Similarly, rapidly changing business and environmental conditions demand innovative responses from firms that wish to survive. Examples of this growth and collapse cycle abound, including the palm oil industry in Ghana falling victim to changing global demand, the Colombian coffee industry losing ground as the Vietnamese industry incorporated better production technologies, and the Peruvian fishing industry collapsing because of a water pollution–related epidemic. As these circumstances may overwhelm even a highly innovative firm's capacity to adapt, more national capacity to support innovation becomes necessary.

Rwanda is an example of a country that is beginning to develop high value-added export industries in such diverse fields as coffee, roses, and pyrethrum.[10] Private investors have plans to expand into additional value-added sectors including tea, silk, herbs and essential oils, and specialty vegetables. Investments in each of these existing and proposed ventures share several features in common, including the following:

- The businesses have carved out a niche at the high or premium end of the market. This is typically the most lucrative end of the market and the one that is most difficult to access.

- The entrepreneurs who developed these businesses all work (or plan to work) in partnership with subsistence farmers. Specifically, local farmers devote a portion of their time and land to growing a cash crop. The rest of their time is devoted to subsistence agriculture. The cash crop is expected to generate an annual income of approximately $300 to $500 per family. (A proposed horticulture program envisions a cash income of $3,500 per family within five years.) The subsistence farming activities will provide most of the family's basic food supply. Thus, the cash income can be used to finance such items as school fees, health care, or even an occasional luxury. The additional spending power of the local families has a noticeable impact on the commercial vitality of the local village.

- In the case of pyrethrum and roses, the primary entrepreneurs are former members of the Rwandan diaspora who returned to start businesses in Rwanda. In the case of the coffee enterprise, the initial entrepreneur was a U.S. expatriate funded by the U.S. Agency for International Development (USAID). Subsequently, numerous Rwandan entrepreneurs have also entered the market for producing, processing, and exporting premium coffees. The silk industry is being developed primarily by a foreign investor.

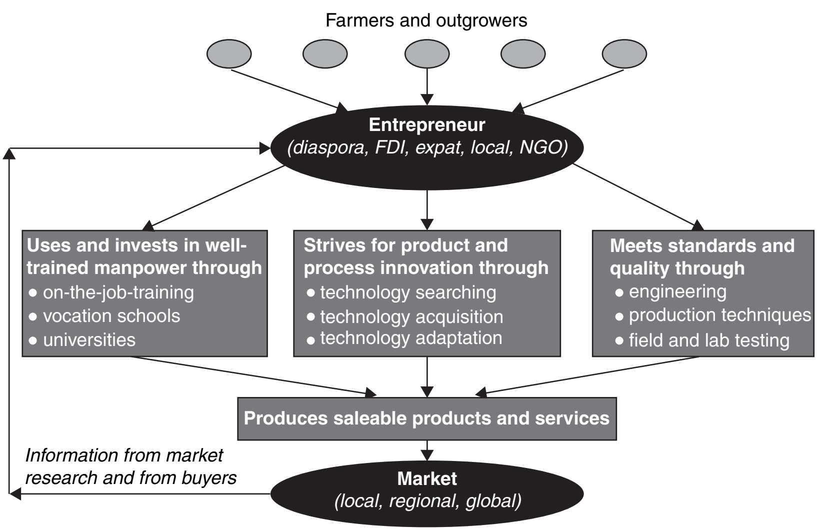
- In all cases, the entrepreneurs provided the undertaking with an invaluable package of rare (for Rwanda) skills, including the following: (i) an understanding of the importance of quality control; (ii) a technical

10 For a discussion of Rwanda's cut flower industry, see Beatrice Gakuba's presentation in the session Adding Value to Natural Resources in this volume or the video of her presentation available at www.worldbank.org/stiglobalforum.

understanding of how to achieve quality control; (iii) management, organizational, and entrepreneurial capacity; (iv) technology awareness and knowledge; and (v) access to markets or a clear strategy for establishing links to buyers. Individual subsistence farmers, who have been isolated from the global marketplace for generations, or even cooperatives made up of small-scale subsistence farmers, cannot be expected to possess these skills or this know-how. As a result, the entrepreneur is the critical ingredient and the key to the success of subsequent capacity building programs.

- In each case, the entrepreneurs start with a basic understanding of what the market required in terms of quantity, quality, and technical specifications (see figure I.2). They then reverse engineered the production process to determine the required inputs and the capacity building programs (training, supply chain linkages, logistics, and so on) required to meet the market demand. In other words, these successful capacity building programs are designed by market-savvy entrepreneurs in response to market demands and requirements. They were not developed and implemented in isolation from market requirements, and they are not the result of abstract capacity building programs.

Figure I.2. Enterprise-Based Model of STI Capacity Building: PPP Options



Source: Watkins and Verma 2008.
Note: FDI = foreign direct investment; NGO = nongovernmental organization; PPP = public–private partnership.

It is important to stress that these enterprises provide much more than markets for local farmers. They help the farmers organize into local producer coops. They train farmers in modern production techniques and quality control mechanisms. They also provide training in such "ancillary" activities as public health and sanitation and modern cultivation techniques for subsistence crops. Thus, in addition to boosting Rwanda's production of high value-added crops and boosting the cash income of participating farm families, the enterprises provide a major impetus to local economic development, education, and technology upgrading. In effect, entrepreneurs become agents of STI capacity building as well as employers of the STI capacity that they help to create.

As part of its STI capacity-building strategy, the government wants to identify market friendly, pro-business ways in which PPPs could help private sector entrepreneurs in these and other promising value-added export and import substitution sectors. Thus, it proposes to consult with entrepreneurs to identify areas in which government policy reforms or critical infrastructure investments could ease bottlenecks and reduce the cost of doing business in Rwanda. In addition, it wants to explore options for (i) placing R&D labs (a horticulture or botany laboratory) directly in private enterprises, which would help to ensure that the R&D conducted in these labs is directly related to the needs of private enterprises in that sector; and (ii) creating policies to encourage private entrepreneurs to organize or provide vocational and technical training directly related to the needs of that sector. This training would supplement the training provided by the existing vocational and technical training institutions.

C. Latecomer Strategies for Technology Upgrading and Catching Up: The Role of STI Capacity Building—How do countries and especially enterprises "catch up" to the technological leaders? How do they learn? More important, how do they learn to learn? And what can they learn from the historical lessons of experience of countries, sectors, and enterprises that have managed to catch up?

The session on Latecomer Strategies for Catching Up of the Global Forum provides some answers to these questions, based on lessons of experience from developing countries that have recently been successful at catching up to the leaders in various high-tech and low-tech sectors. It looked especially at how countries have employed innovative PPPs to support the technology catch-up process and foster local innovation.

The Global Forum also explored the role that FDI can, and cannot, play in this process. For example, empirical evidence suggests that FDI does not automatically generate spillovers that help local enterprises become more innovative and more technologically adept. Some countries have attracted FDI, but then found that it does not lead to much technological modernization over and above the direct employment benefits generated by the FDI itself. When lower-wage locations become available, the flow of new FDI slows dramatically and, just as troubling, foreign firms that operated in the host country are quick to move elsewhere. Growth slows dramatically and the country finds itself facing an economic crisis.

Other countries, by comparison, have been adept at using FDI as a learning or technology upgrading opportunity.[11] These countries may start with an abundance of low-wage, unskilled labor. But they quickly embark on a deliberate process of technology and skills upgrading, so that foreign investors who were attracted to the host country by the low-wage labor are gradually induced to locate more knowledge and skill-intensive activities in the host country. At the same time, these countries help local firms provide value-added goods and services to foreign investors and build other supply chain linkages between local firms and global firms operating in the country and region. The Global Forum discussed how these countries used FDI as a tool to promote technology upgrading.

Finally, the Global Forum explored the role of R&D in the technology upgrading process. Anecdotal and survey evidence suggests that enterprises innovate primarily by importing new, more modern capital equipment. There seems to be little domestic enterprise demand for local R&D capacity. This is not necessarily surprising. Since most domestic enterprises operate far below the technological frontier, they do not need to finance or conduct R&D to improve their productivity and competitiveness. However, it does suggest that grant programs to increase the domestic private sector's demand for R&D may be less effective than their proponents would wish.

This remainder of this section will briefly discuss two important strands of research related to the catching-up process: (i) the process of technology diffusion, linkage, leverage, and learning that successful latecomers have used to find new, high value-added niches in the global division of labor; and (ii) the array of skills and capabilities that individual enterprises must develop during the catching-up process.

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11 An excellent set of case studies illustrating how countries did and did not use FDI as a stepping stone to technology upgrading and international competitiveness is available in Lall and Urata (2003); also see Rasiah (2004).

Technology Diffusion, Linkage, Leverage, and Learning—Catching up means finding a niche in the global division of labor and using that initial niche to move from lower value-added, less-knowledge-intensive activities to higher value-added, more-knowledge-intensive activities. Getting an initial foothold and devising a strategy for moving up are not simple or straightforward tasks. According to Mathews (2002, 2007), the most critical aspect of the catching-up process is the absorption, adoption, and adaptation of products, processes, and technologies that are already in use elsewhere. This is the so-called process of technology diffusion and it is easier said than done, which is why it is so rarely done well and successfully. As Mathews observes, diffusion is not a passive process. It is not something that simply happens to an enterprise or an economy. It requires an active, conscious policy of linkage, leverage, and learning.

According to Mathews, "The strategic goal of the latecomer is clear: it is to catch up with the advanced firms, and to move as quickly as possible from imitation to innovation." A latecomer firm is "condemned to be follower by history, and it has to make the best of its resource-poor initial situation. It starts not from the powerful position of an IBM but from the resource-meager position of an isolated firm seeking some connection with the technological and business mainstream" (Mathews 2002, 471).

Latecomer firms and latecomer countries have a distinct advantage—if they are skillful enough to recognize it and develop tools and strategies for exploiting it. That advantage is the ability to tap into advanced technologies rather than devoting time, resources, and effort to develop new technologies or industries from scratch.[12] Mathews identifies three essential tools for the catch-up effort:

- *Linkage.* Latecomer firms must link themselves to dynamic firms that already have a successful foothold in the global economy. Linkage provides the latecomer firm with a window to the global marketplace and to global technology trends.
- *Leverage.* Latecomer firms must devise strategies and develop the capacity to exploit the knowledge and opportunities generated by linkages to more successful firms.

12 Juma, for example, observes, Africa potentially has access to more scientific and technical knowledge than the more advanced countries had in their early stages of industrialization (Juma 2007b). The task for Africa, therefore, will be to develop the scientific, engineering, technical, vocational, and entrepreneurial skills required to make use of this knowledge.

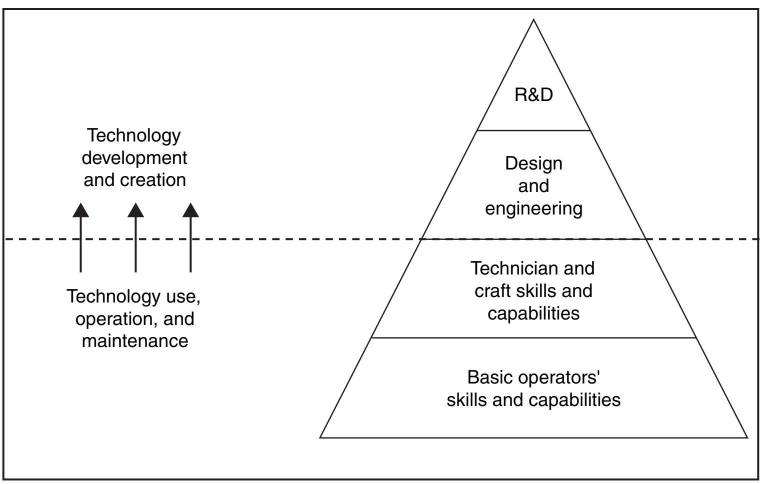
- *Learning.* Latecomer firms must develop the capacity to absorb and adapt the knowledge generated via linkage and leverage and convert it into new, more profitable economic opportunities.

This entire process, according to Mathews, must be "buttressed, supported and disciplined by an institutional framework. . . . Public agencies and various forms of inter-organizational superstructures create the conditions in which the process of learning and leverage can be applied, over and over again, each time at higher levels of technological and organizational capability" (2002, 479).

Enterprise Capability—Latecomer firms need to develop certain skills and capabilities if they wish to convert their latecomer status into a strategic advantage. At least two distinct types of skills are required: (i) practical technology absorption, adoption, and adaptation skills; and (ii) strategic technology acquisition skills.

Absorption, Adaptation, and Adoption Skills—R&D is only the tip of the technology development and innovation process (figure I.3), which, in addition to R&D, includes such non-R&D activities as the following: (i) skills for acquiring, using, and operating technologies at rising levels

Figure I.3. Hierarchy of the Structure of Industrial Technology



Source: Arnold, Bell, Bessant, and Brimble 2000.
Note: R&D = research and development.

of complexity, productivity, and quality; and (ii) design, engineering, and associated managerial capabilities to acquire technologies, develop a continuous stream of improvements, and generate innovations. Different skills are most relevant at different stages of technological development. For example, R&D is most relevant for firms that are closing in on the technological frontier or already at the frontier. Technology acquisition and utilization skills, on the other hand, are most relevant for firms that are at the technology acquisition, assimilation, or deepening stages (this analysis draws extensively from the discussion in Bell 2003).

Thus, as figure I.3 suggests, innovation and capacity building policy should not be limited to promoting R&D. A much broader focus is needed, with a stress on technology *creation*, including both R&D and design and engineering skills, technology *acquisition* skills, and technology *use* skills. These are all vital dimensions of technology development. Indeed, the non-R&D dimensions of technology development may be especially important for the vast majority of enterprises in developing countries that are not engaged in R&D, are far from the technological frontier, and do not require cutting-edge R&D to improve their competitive standing. For these firms, assistance in honing skills related to technology acquisition and use may be much more relevant than additional public R&D funding.

Technology Acquisition Skills—Acquiring knowledge is not simply a question of going out and purchasing it from outside vendors. Firms need to have the capacity to search for different technologies, to evaluate different technological options, to modify off-the-shelf technologies for use by a particular enterprise, and, last but by no means to least, to integrate new technologies into their production processes. These are not simple or easy tasks. They require a great deal of organizational, managerial, and technological sophistication. Simply put, enterprises need to acquire the skills that they need to acquire and use technology.

Recent studies suggest that business enterprises constitute both the "demand-side" and the "supply-side" of industrial technology. In other words, the business sector produces most of the technology that is required by the business sector. The technology does not come from fundamental or even applied research generated by R&D laboratories. Rather, it is generated by design and engineering activities spawned by interaction with customers, suppliers, and competitors. This helps to explain why clusters, competition, and linkages with other firms are so important to the technology development process.

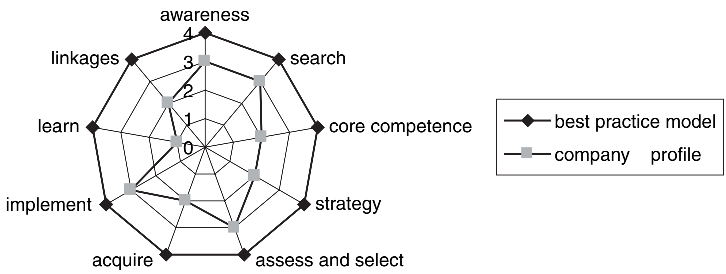
Evaluating Enterprise Innovation Capability—A study describing how firms innovate and use knowledge evaluates and ranks enterprises on the basis of nine key dimensions of technological capability (see figure I.4) (World Bank 2002). These variables encompass such factors as a firm's ability to develop a coherent technology strategy to support the business, acquire and absorb technologies, form and exploit linkages with networks of suppliers and collaborators, and develop several other critical core competencies.

Firms are then placed in one of four categories based on (i) the degree to which a firm is aware of the overall need to change and (ii) the degree to which management is aware of what to change and how to go about changing it (see figure I.5) (this discussion is from Arnold, Bell, Bessant, and Brimble 2000; and World Bank 2002, Part A).

At the lowest level are firms that have no capacity for technological change. At the highest level are firms such as Intel, Boeing, Siemens, and Microsoft that have the capacity to absorb technologies from around the world, innovate, and produce leading-edge, high-tech products.

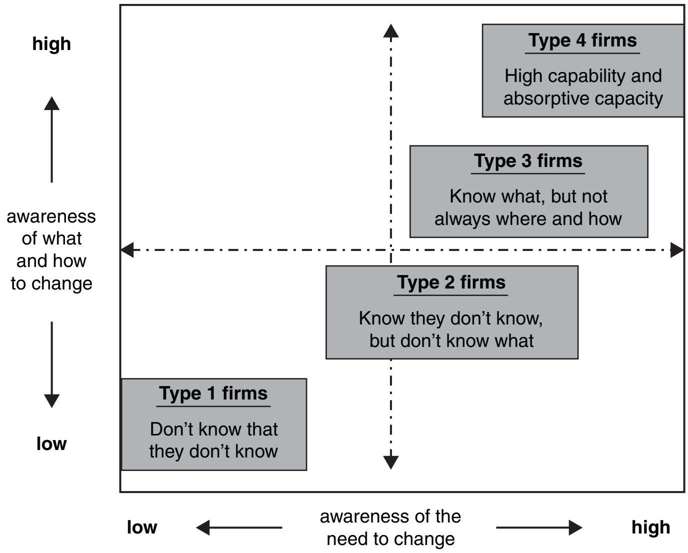
D. The Role of R&D in the Development Process—When should countries focus on building their R&D capacity and what sort of R&D capacity should they strive to build—one that is focused on applied research or one that tends to emphasize basic research? How can the growing R&D capacity in rapidly industrializing countries be harnessed to solve development problems in these and other developing countries? How can R&D organizations in industrial countries support this process? The session Building R&D Capacity in Developing Countries of the Global Forum addressed these issues.

Figure I.4. Nine Dimensions of Technological Capability



Source: Arnold, Bell, Bessant, and Brimble 2000.

Figure I.5. Groups of Firms According to Technological Capability



Source: Arnold, Bell, Bessant, and Brimble 2000.

It is important to stress at the outset that R&D capacity should not be equated *only* with the sort of frontier R&D done by scientists and engineers at the Massachusetts Institute of Technology (MIT) or in Silicon Valley. Nor should it be equated only with nanotechnology, biotech, and other assorted high-tech activities.[13] R&D capacity building in developing countries might include frontier R&D and the production of new knowledge for those countries that currently have the capacity to engage in these cutting-edge research activities. For other developing countries, the existing or newly created R&D capacity might be better deployed solving the problems of developing biogas generators and more efficient water pumps, providing clean drinking water, or developing more value-added products from locally grown crops and local natural resources.

13 Although not necessarily able nationally (or regionally) to undertake a full R&D/innovation process to address health (and agricultural) problems, local research institutes often contribute to the process, based on local knowledge and access to patient cohorts, biological diversity, and indigenous knowledge related to therapeutic properties of plants. Development of skills to protect, market, and license inventions will enable contributions to global product development processes (either through partnership with nonconventional development partners such as Product Development Partnerships [PDPs] or more conventional partners in the private sector). Such skills can also generate recognition of, and value for, locally developed research to spur greater industrial interest and investment.

Why should developing countries build R&D capacity? What is the purpose? One objective is to enable research institutes in developing countries to participate in global R&D projects aimed at developing country issues, such as new vaccines for tropical diseases or new drought-resistant crop varieties. Another objective is to develop the indigenous capacity to solve local problems. And still another objective is to build the capacity of developing country research institutes to collaborate on a more equal footing with research institutes and industrial laboratories in all parts of the world, irrespective of whether they are investigating problems of special relevance to developing countries. India, China, Brazil, and South Africa are frequently cited as examples of developing countries that have developed world-class R&D capacity. The Republic of Korea and Singapore are cited as examples of earlier success stories. The New Partnership for Africa's Development (NEPAD) S&T Action Plan provides a compelling rationale for emphasizing this aspect of S&T capacity building in Africa, but the arguments can easily be generalized to apply to other parts of the world as well.[14]

Progress along this dimension of S&T capacity building is commonly measured by such indicators as the share of gross domestic product (GDP) devoted to R&D, the number of patents registered in U.S. and European patent offices, the number of articles published in prestigious, refereed journals, the number of grants obtained from such international science funding sources as the National Science Foundation and European Union Framework Program, and the number and value of research projects conducted in partnership with local and international research institutes. A country would be seen to be making progress toward developing its NIS, building STI capacity, and becoming more "competitive" when its scores on the variables listed above begin to increase and eventually approach levels found in innovative Organisation for Economic Co-operation and Development (OECD) countries. Government policy is frequently oriented toward moving these indicators in the desired direction.

This dimension of STI capacity building draws most of its inspiration from the challenges facing OECD countries and ongoing efforts to benchmark those countries against each other. The salience of these measures for many developing countries is less clear. In fact, attempts of smaller, poorer countries to use this OECD experience as a guide for

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14 The NEPAD Science and Technology Consolidated Plan of Action is available at http://www.nepadst.org/doclibrary/pdfs/ast_plan_of_action.pdf; also see Murenzi (2006).

their own policies may even be seriously counterproductive. Unless policy makers take explicit pains to distinguish and adapt what is relevant, imitation of OECD country experience may lead to inappropriate and ineffective policies.

The problems facing many poorer countries are different from those confronting OECD economies. Examples of significant differences include the following:

- The baseline levels of technology used in the poor country's economy—except for occasional extractive industry sectors—are typically quite low.
- The absolute size of the local economy is quite small.
- Consequently, many poor countries have only modest resources to invest in S&T. Even if they spent 1 percent of GDP on science and technology, this would amount to only several million dollars per country per year. This pales in comparison to the amounts spent in scientifically advanced countries or even to the amounts spent each week by a single innovative private enterprise on R&D activities.

Scale effects will have a major impact on how countries allocate their R&D development budgets. Small countries, with limited existing R&D capacity and budgets will need to decide whether they should focus on cutting-edge research or on research designed to support the economy's capacity to import and adapt existing technology. In addition, they will need to decide what capacity can be built internally and what capacity needs to be built on a regional basis, in partnership with other countries.

However, some developing countries, occasionally dubbed Innovative Developing Countries (IDCs),[15] have sophisticated, well-developed R&D systems. As a result, they have the potential to make significant contributions to the global stock of knowledge. But most IDCs also face many of the same problems that confront non-IDCs. Large portions of the population live below the poverty line, large swathes of domestic industry are not globally competitive, and all too often, the R&D system is an overhead expense rather than a resource for economic development,

15 There is no universally accepted definition of IDCs. The term generally includes Brazil, Russia, India, China, and South Africa. However, countries such as Ukraine, Kazakhstan, Mexico, Chile, Argentina, Malaysia, and Thailand, among others, have the potential to join the club in the foreseeable future. For one method of grouping developing countries by scientific proficiency, based on analysis by the RAND Corporation, see appendix 2 of Watson, Crawford, and Farley (2003).

innovation, and national competitiveness. Even when the R&D system serves as a resource for economic development, it is important to ask "whose development?" Is the R&D system geared to solving the research and technology problems of multinational corporations (MNCs), or is it designed to address the domestic problems of reducing poverty and enhancing economic competitiveness?

In many countries, converting the R&D systems into a resource for economic growth will entail numerous structural reforms in the way R&D is performed and also in the way it is linked to the needs of industry and to markets. For example, experience suggests that modern science functions best when (i) research is linked to teaching; (ii) scientists and engineers from different disciplines collaborate in multidisciplinary problem-solving teams, rather than working alone; (iii) the supposed distinctions between basic and applied research are minimized or eliminated; and (iv) there are close linkages between research scientists and business enterprises.

The current organization of science in many developing countries frequently violates these precepts. For example, (i) at a time when the boundaries between applied and basic research are becoming increasingly blurred, different ministries may be responsible for basic research and for applied research; (ii) teaching and research may take place in separate institutions, with little interaction between the two (the higher education sector may be primarily responsible for training scientists, engineers, and researchers, whereas the bulk of research activities may be performed in separate research institutes); and (iii) research may be organized vertically, with physicists in one institute, mathematicians in another, and chemists in yet another institute, rather than in broader, multidisciplinary problem-solving teams.

In addition, research organizations frequently operate in isolation from each other and, more important, from domestic and foreign markets. Institutes and universities do not collaborate with each other or work closely with local or foreign industry. Research is performed primarily in independent laboratories and institutes that frequently set priorities without regard for market demand, the technology upgrading and competitiveness needs of local enterprises, or the government's own scientific priorities.

Even worse, many scientists mistakenly believe that their institutes have a large stock of inventions that can be easily commercialized, especially if venture capitalists can be induced to provide the necessary financing. Unfortunately, many scientists do not know how to commercialize their inventions nor do they have the connections to global markets that would be needed to mount a successful commercialization effort. Simply put, they do not know how to access markets or how to assess the needs of these markets. Nor do they have a clear idea of what they are trying to sell. Are they marketing an off-the-shelf technology or are they selling their problem-solving research capacity?

R&D capacity building programs need to overcome these structural impediments.

PART II

Forum Keynotes and Sessions

The STI Capacity Building Imperative

With increasing frequency, officials in low- and middle-income countries are coming to the conclusion that their countries *must* build up their science, technology, and innovation (STI) capacity in order to achieve the following:

- Make demonstrable progress in achieving the Millennium Development Goals (MDGs), tackling acute health and nutrition problems, avoiding or mitigating the impacts of natural disasters, embarking on a path of sustainable poverty reduction, safeguarding fragile ecosystems, and improving the quality of daily life for the rural and urban poor.
- Transform their economies from ones based on subsistence agriculture, enclave extractive industries, and simple, low-skilled manufacturing into ones based on the production of more-knowledge-intensive, higher value-added goods and services.
- Raise productivity, wealth, and standards of living by developing new, competitive economic activities to serve local, regional, and global markets.
- Develop appropriate R&D capacity to support technology-based economic growth and to address social, economic, and ecological problems specific to each country.

To achieve these goals, a wide array of governments in Africa and elsewhere are drafting STI policies, establishing ministries of science, establishing science and engineering universities, and devoting more resources to targeted science development programs. In tandem with these national efforts, international organizations such as the World Bank, ADB, IDB, DFID, CIDA, UNCTAD, UNESCO, and the G-77, among others, are developing strategies to support these STI capacity building programs.

The Global Forum was designed to respond to these calls to action. Presenters represented developing and industrial countries, governments, civil society, scientific and academic organizations, and international development organizations. The imperative of STI capacity building and the necessary international response were the topics discussed by the Forum's keynote speakers.

Keynote Speakers

In his keynote address to the Forum participants, Paul Wolfowitz, president of the World Bank, framed the Forum's challenge in terms of the MDGs. The MDGs, he explained, should drive the great majority of the work at the World Bank and other development institutions. But this focus on the MDGs may sometimes foster an attitude—probably more often in the back of people's minds than on the tip of their tongues—that S&T capacity building is a dispensable luxury for developing countries.

> "It is not reasonable to say, 'give up the intellectual excitement that you found in Cambridge or in Washington, or in Paris or in London.' One goal of building STI capacities in developing countries is to find a way to capture some of that intellectual excitement—because while it is nice to get to remittances, it is much, much better to have people come back home to contribute to their country's economic development."
>
> —Paul Wolfowitz, president, World Bank, speaking at the Global Forum

Also in the back of people's minds may be the unspoken view that "these poor countries aren't ready to deal with these advanced subjects. Give them a couple of decades or more, but S&T is for the rich countries."

But this simplistic view is wrong. The MDGs are *an incomplete guide* to poverty reduction. For example, there is no MDG for jobs, and yet jobs are very much at the heart of poverty reduction. This is not a critique of the goals themselves, he stated, just a plea to look a little broader.

So why is STI capacity building so important to the poverty reduction agenda?

First, although much is still not understood about what makes development work, and what makes some countries succeed and others not, there is no question that *education—investing in people—is one of the biggest contributors to growth and poverty reduction*. As recently as 40 years ago, the Republic of Korea was regarded by economists as a hopeless basket case. It had no natural resources, which we have since learned does not matter that much; it had lots of corruption; and it was burdened with a Confucian ethic that taught that gentlemen don't work, but instead they wear white clothes and grow long finger nails to demonstrate their contempt for manual labor. Of course, it is now that same Confucian ethic that is supposed to explain not just the success of Korea but every other country in East Asia.

Korea systematically educated its population and did not stop at fourth grade. The country did not stop at middle school. It did not stop at secondary school. Today, 89 percent of Koreans have some degree in tertiary education, which would make it the highest percentage of any country in the world.

Korea's achievement in education is stunning, and the success of its economy is equally stunning. It went from being one of the poorest countries in the world, to being the 10th largest economy. The cause and effect are clear: it is not possible to have a strong education system if it is focused solely on primary education. While primary education is obviously critical, it is important to have teachers who inspire children in primary school to go beyond basic education. There needs to be a continuum, and there needs to be balance in that continuum, but focus cannot just be on the lower levels of the education system, even if those lower levels are the major concern.

Second, much of STI capacity building is about *applied* S&T, and that has incredible value for development.

Third, countries can now have access to advanced technology without having to develop it themselves. But they have to learn how to use it and exploit it for economic development purposes. Ireland, for example, went from being one of the poorest countries in Europe to one of the most successful by leapfrogging over older technologies to adopt the newest technologies and incorporate them into its economy and society. Today's developing countries must learn how to emulate Ireland.

Fourth, STI activities are magnets for talent. And this highlights one of the biggest challenges: reversing the brain drain. Talented people need to stay in developing countries, to be productive in their countries, and to contribute to their countries.

It is not reasonable to say, "Give up the intellectual excitement that you found in Cambridge or in Washington, or in Paris or in London." So a goal of building STI capacities in developing countries is to find a way to capture some of that intellectual excitement—because while it is nice to get remittances, it is much, much better to have people come back home to contribute to their country's economic development.

Resources are limited. The amount of resources that can be applied by poor countries to S&T is going to be limited. But there needs to be balance. Zero investment in S&T will condemn poor countries to impoverishment and low levels of development, and that is something we cannot afford.

* * *

"Innovation, is about doing different things, and doing them differently. [Through innovation] even the poor can afford better products with lower prices and superior performance."

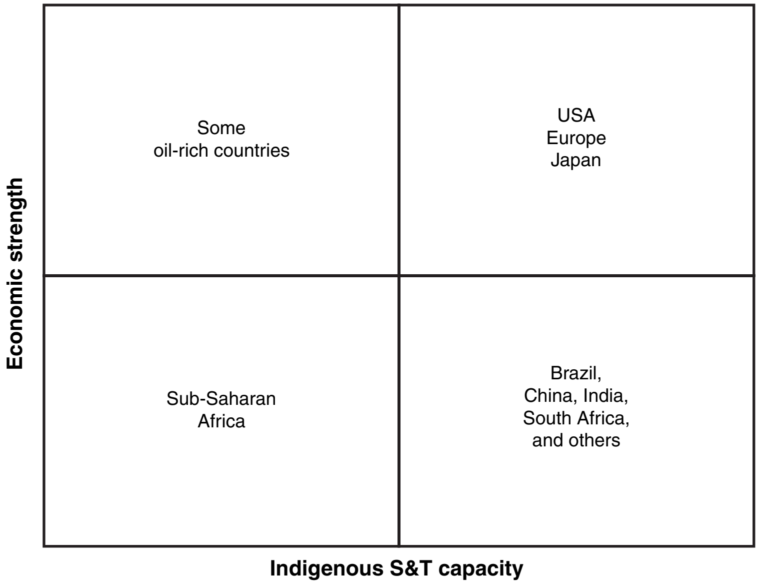
—R. A. Mashelkar, president, Indian National Science Academy, and president, Global Research Alliance, speaking at the Global Forum

R. A. Mashelkar, president of the Indian National Science Academy and president of the Global Research Alliance, observed that the Global Forum was one in a series of moves by the World Bank to become more actively and comprehensively engaged in STI capacity building. He recalled the November 2004 meeting with then–World Bank President James Wolfensohn that confirmed the importance of STI capacity building as a World Bank strategic activity and a priority for socioeconomic development. The events coming out of that initial meeting, including this Global Forum, should presage an expanded involvement by the World Bank and the development community in this critical area of STI capacity building for development.

STI capacity is critical for every country's development. When placing the countries of the world on a diagram with two axes—economic strength and indigenous S&T capacity—the strongest and most developed countries have achieved both and fall in the upper-right quadrant.

Unfortunately, much of Sub-Saharan Africa is in the lower-left quadrant, as illustrated in figure II.1, but other developing countries have recently moved into new quadrants. Some developing countries have achieved high levels of capabilities in S&T that have not yet been fully

Figure II.1. Indigenous S&T Capacity

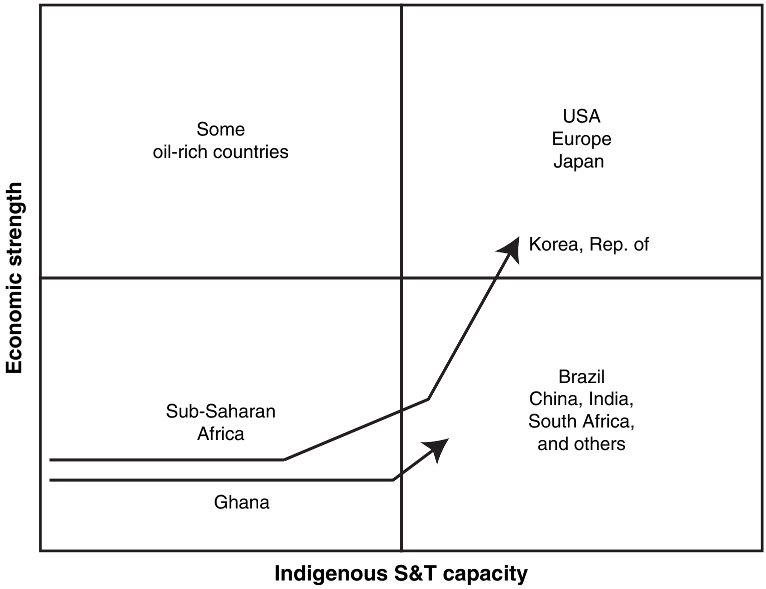


Source: Mashelkar, Global Forum presentation.
Note: S&T = science and technology.

translated into economic strength. He categorized these countries in the lower-right quadrant as Innovative Developing Countries (IDCs). These countries are breaking away from other developing countries and have a good chance to catch up to the advanced nations. Yet, these countries still must apply their STI capacities more effectively to their socioeconomic development to achieve true sustainable development.

The positions of the countries on the figure are not fixed—countries can change their place. A World Bank comparison of economic growth in Korea and Ghana from 1960 to 2000 demonstrated the additional economic growth in Korea versus Ghana over this time period. The high growth in Korea was achieved through investments in STI and knowledge. In 1960, Korea was in the place that Sub-Saharan Africa is now—the bottom left. Yet it moved to the top-right section by advancing its S&T capabilities and, most important, by turning those S&T capabilities into engines for economic growth. There is hope for Ghana, and every other country, to move to this top-right quadrant, as illustrated in figure II.2—if it builds appropriate STI capacity.

Figure II.2. Growth in Indigenous S&T Capacity



Source: Mashelkar, Global Forum presentation.

What should guide countries in developing STI capacity? Mashelkar suggested that STI stands for science, technology, and innovation, but it also stands for solve, transform, and impact. These are the objectives that should guide capacity building efforts, investments, and programs.

- Are we funding *science that will solve the problems of the poor*?
- Are we working on *technology that will transform society and the economy*?
- Are we working on *innovations that will make a real impact*?

With this interpretation, STI can be focused on the problems of the poor: poverty, illiteracy, education, health care, water, energy, connectivity, and others—the problems articulated and addressed by the MDGs. Furthermore, this means thinking of those in poverty as innovators themselves. Innovations generated with inclusion and participation of the communities affected are the most effective.

Innovation, is about "doing different things, and doing them differently." So what does this mean in practice?

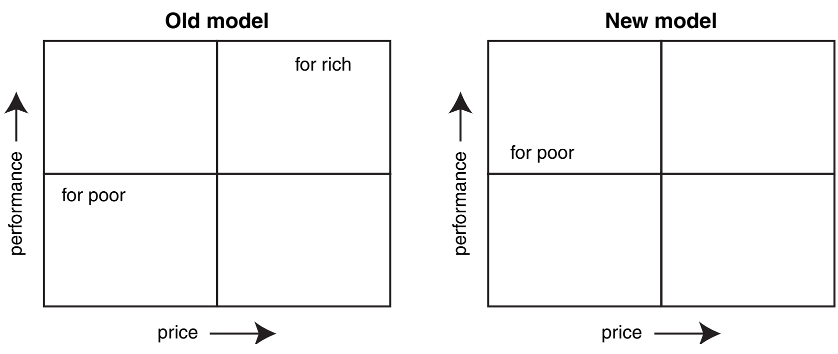
It means that innovation can enable us to rethink the traditional price-performance envelope. Although traditional thinking stated that products with superior performance automatically carried a higher price and products with a lower price were, therefore, of inferior quality, modern technology and innovation allow us to *say even the poor deserve better products with lower prices and superior performance*. Figure II.3 illustrates this new model of product development.

For example, this rethinking has led to the $100 laptop and the Simputer—*offering superior solutions for the poor*. It has led to the Jaipur Foot,[1] an artificial foot used in nine countries that not only costs $30 instead of $3,000, but also offers superior performance—in sand, in soil, and in rain-soaked rice paddy fields.

And this rethinking of innovation has offered new paths for drug development. As drug development times and costs have risen at pharmaceutical companies tied to old methods of drug discovery, new companies are using new methods of drug discovery to bring affordable medicines to the poor.

To accomplish this, a *golden triangle* is being formed between traditional medicine (the strength of developing countries), modern medicine, and modern science. This has led to a *reverse pharmacology* (*drug discovery*) *process*. Traditional medicines, already in use in different cultures, are *validated* with modern science and produced with modern techniques. This has led to *affordable* treatments for psoriasis, type II diabetes, and osteoarthritis, for example.

Figure II.3. Old Model versus New Model



Source: Mashelkar, Global Forum presentation.

1 For a discussion of the innovation behind the Jaipur Foot, see http://www.nextbillion.net/files/JaipurFoot.pdf.

Innovation also means that India could succeed in eliminating illiteracy in its population in five years instead of the projected 20. A technology called Computer Based Functional Literacy, designed by Tata Consulting Services (TCS) and based on theories of cognition, languages, and communication, has already brought literacy to 40,000 persons in five countries and five languages at approximately $2 per person. Large outcomes, therefore, are achievable through small investments, harnessing achievements in S&T. Expanding this technology to the 200 million illiterate people in India would cost less than a half billion dollars.

The challenge is to find ways to get the best minds of both the developing and industrial world to work on the problems of the poor. This can be initiated in several ways:

First, new networks must be formed to bring together scientists and engineers from around the world. The GRA[2] brings together nine institutions and 60,000 scientists from five countries, rich and poor, to work on problems of poverty—providing clean water, access to energy, access to health care, and others. This network brings together geographic and intellectual diversity with scientific credibility to tackle the world's most pressing problems.

Second, new approaches to North-South and South-South collaboration in STI must be fostered. The InterAcademy Council[3] of Science Academies from around the world, for instance, is working to revitalize African universities. And the GRA is bringing together scientists from around the world to work on a regional approach to climate change in Sub-Saharan Africa, where the effects of climate change are expected to be felt acutely.

Third, competitive funding mechanisms specifically focused on the problems of the poor are needed. This coupling of the great intellectual challenges of the problems of poverty with needed financial support can bring to bear huge resources.

The Bill and Melinda Gates Foundation demonstrated this idea with its grand challenges to improve childhood vaccines.[4] These challenges drew interest from the most advanced institutions, from Harvard to Yale to Oxford and Peking University.

Finally, the World Bank and its development partners must innovate in their own support of STI and use STI capacity building as an engine for development.

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2 See http://www.research-alliance.net/.

3 See http://www.interacademycouncil.net/.

4 More information on the Grand Challenges in Global Health is available at http://www.gcgh.org.

For instance, the World Bank has funded well-reviewed industrial technology development programs in India and elsewhere. Can it now move to global technology development programs? Can it move from funding institutions to funding research and technology networks? Can it fund grand challenges in clean water technologies and other areas in a way similar to the Gates Foundation funding for health challenges? Can all the funding agencies represented at the Global Forum band together to fund projects together, on a broad basis? Can STI be integrated into World Bank socioeconomic projects? Can STI for development have primacy in both the World Bank's strategy and structure? Will the development community support the important recommendations of the 2007 African Union Summit, which focused on S&T in Africa?

The World Bank investment of $4 billion over 20 years in 20 countries to support STI capacity building projects is not sufficient to meet today's challenges. The high returns generated by these projects justify a much greater financial commitment from the World Bank and other development agencies. For example, just $2 million given through a World Bank–funded program helped Shantha Biotech, a nonprofit company in India, develop an r-DNA (hepatitis B) vaccine affordable to developing countries. Shantha now produces doses for 18 rupees and provides 40 percent of the United Nations Children's Fund's (UNICEF's) supply.[5]

This combination of the world's companies, countries, people, and wealth represents a model of a new partnership for helping the world's poor. It is a PPPP—a public-private partnership *for the poor*. And it is this combination that will lift up the 4 billion people in our world who still live on less than $2 a day.

* * *

Joy Phumaphi, vice president, Human Development Network, the World Bank, described how scientific and technological advances affected her own childhood in a rural village in Botswana. Many improvements in the day-to-day lives of the community members were made possible only by the application of such appropriate technologies as water pumps and solar power.

The Forum should have three main objectives:

First, Forum participants should seek to learn how the private sector and nongovernmental organizations (NGOs) apply technology to meet development challenges. Today, these organizations are frequently the

5 For an article on the impact of Shantha Biotech's vaccine, see http://www.biospectrumasia.com/content/200807IND4158.asp.

leading innovators in scientific and technological areas. Forum participants should incorporate these lessons into their analytical work and policy advice.

"Over the past 10 years, an explosion of high-quality research and analytical work has effectively demonstrated the importance of STI capacity building . . . in all countries around the globe. The task . . . is to translate this intellectual consensus into concrete capacity building policies and programs."

—Joy Phumaphi, vice president, Human Development Network, World Bank, speaking at the Global Forum

Another objective is to translate the intellectual consensus around the importance of STI capacity building into specific capacity building policies and programs. STI capacity building projects should have immediate, measurable effects on peoples' lives and well-being. This means helping *local communities*—people and firms—build the scientific, technical, and vocational skills needed to bridge the gap between the industrial and developing world. Development partners must design projects to support this local capacity building.

Finally, Forum participants should learn from each other. The Forum brought together a diverse group of inquiring minds representing much of the latest thinking on STI capacity building. It offered a tremendous opportunity to learn from the colleagues, technologists, scientists, and students gathered from around the world. Policy makers from Rwanda and Colombia have much to share and learn from each other.

Three sets of questions should guide the Forum agenda:

- First, how critical is STI to the mission of the development community? If STI is essential for poverty reduction, why isn't STI capacity building a pillar of the development agenda? Why is it not reflected in more PRSPs?
- Second, what precisely do we mean by STI capacity building? Building capacity to conduct world-class R&D or building the capacity of villagers and small businesses to deliver clean drinking water and design, produce, and sell more fuel-efficient cooking stoves? Pushing the global knowledge frontier or solving practical, everyday, local problems?
- Third, what are the operational implications for development organizations? How can local capacity building concerns be incorporated into project design and become inputs into PRSPs? How can donors harmonize their support for STI capacity building? How can countries work together to share STI capacity building challenges?

The objective of the Global Forum is not merely to talk about the importance of building STI capacity for development, but rather, it is to bring about a shift in the way we do business. The Global Forum must explain how this can be done.

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"In today's knowledge-based economy, people represent the most critical national resource, especially in science, technology, and engineering. It is from these disciplines that we can anticipate many new opportunities. So creating the human capital necessary in engineering and technology must be an urgent focus for all countries."

—Wayne Johnson, vice president of university relations worldwide, Hewlett-Packard, speaking at the Global Forum

Wayne Johnson, vice president of university relations worldwide, Hewlett-Packard (HP), provided a private sector perspective on STI capacity building. HP's operating dictum is "think locally; act globally." HP acts globally in the sense that it scours the world for both markets and talent; it thinks locally in the sense that it tries to work with local universities and governments to create a supportive STI capacity building environment—one characterized by mutually supportive relationships between universities, industry, and government. If any one of these links in the chain is weak, the capacity building system will not work effectively. For example, governments need to create clear intellectual property laws and regulations to ensure that the right to commercialize the inventions and discoveries created in the course of private sector–university collaborations is clear and unambiguous.

The "worldwide intellectual equilibrium" is evolving rapidly. Developed countries and regions like the United States, Japan, and the European Union must now compete with rapidly expanding talent pools in developing regions. For example, in 2004, 300,000 engineers graduated from Chinese universities and 200,000 graduated from Indian universities, compared with approximately 60,000 from U.S. universities. Not surprisingly, HP now employs 60,000 people in the United States and 90,000 people outside the United States, where markets and talent reside.

In many parts of the world, including Africa and Latin America, HP's growth is limited by the supply of "trained people to do the work that needs to be done." The limiting factor, in other words, is not local demand but rather the supply of skilled manpower to meet that demand. This manpower shortage applies to technical workers who can maintain and install electronic equipment, as well as to scientists, engineers, and professors who can work in HP research laboratories and train the next generation of scientists, engineers, and technicians. Buzzwords like "downsizing," "rightsizing," "rebalancing," "offshoring," "onshoring," "outsourcing," and "insourcing" reflect the corporate sector's attempt to stay competitive in the face of these market opportunities and staffing shortages. For example, offshoring is really a synonym for creating shareholder value wherever the markets and talent exist.

If developing countries hope to profit from these "unrelenting global changes," they need to develop coherent, effective STI capacity building programs. HP and other corporate partners are prepared to help. For example, the Engineering for the Americas Initiative is an ongoing comprehensive partnership between the Organization of American States, the Inter-American Development Bank, the World Federation of Engineering Organizations, Microsoft, HP, and the U.S. Trade and Development Agency, among others. As the name suggests, the broad objective is to improve engineering education in Latin America. The program is motivated by the belief that engineering education is one of the most critical ingredients for development. With this in mind, HP and other corporate partners hope to launch an Engineering Africa Initiative in the near future.

In conclusion—

- Developing countries face a long list of problems related to water, energy, health, agriculture, and biodiversity, among others.
- Engineers are critical to solving all of these problems. Engineers convert science into marketable products. Therefore, they must be seen as an essential national resource.
- Public policy directs society's investments. Advancing PPPs, especially in the area of engineering education, is a key to sustainable results.
- Public advocacy is required to create a consensus around the importance of education excellence and national competitiveness.

* * *

In his remarks closing the Global Forum, **Calestous Juma, professor of the practice of international development, Kennedy School of Government, Harvard University,** said that the structure of S&T in most developing countries operates below its capacity; the whole is smaller than the sum of its parts. He argued that countries must address three challenges if they hope to integrate innovation into their economic

"STI institutional reforms are so fundamental that it is not financial capital, but political capital, that is most needed to bring innovation into the center of development policy. STI reforms require executive leadership to champion even minor changes."

—Calestous Juma, professor of the practice of international development, Kennedy School of Government, Harvard University

development strategies: (i) targeting STI capabilities to the country's critical development problems; (ii) aligning the institutions governing STI toward economic development; and (iii) mustering the political leadership needed to overcome entrenched opposition to STI governance reforms.

In the current age of technological abundance, Juma stated, the challenge for developing countries is *not* to push themselves onto the frontiers of scientific knowledge, but rather to put readily available knowledge to use. This does not exclude investment in basic research; such research should be part of problem-solving efforts. Why are more countries not developing the capacity to utilize available knowledge? Why are they focusing instead on R&D, even though the volume of readily available knowledge is doubling every year and even though very poor countries have access to more knowledge today than their predecessors ever had?

Too many developing countries are uncritically adopting the OECD model of technological development, and too many development institutions are unwittingly aiding and abetting this process. Technology policies in OECD countries generally focus on expanding the frontiers of scientific research. This OECD model is based on the race to gain a competitive edge by developing new products based on new, frontier technologies. This makes sense for OECD countries, where many firms compete by embedding these emerging technologies in products that are new to the world or by using new scientific knowledge to improve existing products.

This model has been exported to the developing countries, where it has the unfortunate effect of encouraging them to focus on such inappropriate targets as the number of patents filed at the U.S. Patent and Trademark Office or the share of GDP devoted to R&D. These targets are not only inappropriate; they divert attention from using existing scientific and technical knowledge to meet basic needs, improve competitiveness, and protect the environment. What is referred to as S&T in most developing countries is often reduced to R&D, rather than innovation. The process of innovation focuses on the diffusion of existing knowledge through goods and services and often relies on existing knowledge.

To profit from such knowledge, developing countries do not need to devote the bulk of their time and attention to building institutions that produce new knowledge. What they need instead are institutions that have the capacity to find and help governments and private enterprises utilize the existing knowledge embedded in the thousands of patents that expire every month around the world. The XO laptop promoted by the One Laptop per Child Foundation is an example of an innovation model that relies on harnessing existing knowledge and putting it to new uses. This does not exclude basic research; but such research is focused on bringing new education technologies to solve persistent problems in fields such as health, education, and environmental management.

Many African presidents are now developing programs to boost science, technology, and engineering education. This has the potential to be a very positive development. But it is likely to fail if it continues the practice of separating research, teaching, and extension (or commercialization). Under this model, universities teach and government research institutions perform research. Teaching and research must be combined and linked to the needs of industry and society in general.

Unfortunately, STI governance structures in much of Africa reinforce this dysfunctional separation between research, teaching, and extension. Bureaucratic constituencies protect their turf by fighting to maintain this separation and enshrining the status quo in laws that prevent universities from receiving public research funds. Ministries of education and universities frequently resist the establishment of new university models that combine research and teaching. Moreover, ministries of S&T tend to resist reforms that would encourage universities to develop research programs. In many countries, STI functions need to be coordinated with the urgent task of providing basic infrastructure services. This field largely relies on existing knowledge and yet it provides a solid foundation for subsequent technological development. Institutions of higher learning, for example, could contribute significantly to economic development if they were directly linked to infrastructure development projects. Those linkages will also make their curricula, teaching methods, selection of students, and internal governance structures more relevant to local needs.

But much of this will not happen if existing incentive structures in universities are not changed. Laws regulating the registration of new universities need to be reviewed in light of advances in education technologies. For example, many countries still require universities to own large tracks of land (up to 20 hectares) to qualify for registration. The rules specify how much space should be allocated to stacks of books in libraries. But in a modern world, where much of the learning has gone digital, such requirements only serve to stifle the growth of higher education and to banish new universities from centers of economic activity, such as cities where land is scarce but knowledge and business connections are abundant.

Government officials responsible for overseeing such outmoded and detrimental laws are unlikely to seek change because most of them come from conventional universities that provided the initial standards. Many will acknowledge that the laws are restrictive, but they will hardly initiate reform. Overcoming these vested interests requires committed executive leadership by heads of state or government. The focus of the leadership should be to align research and higher education functions with socioeconomic objectives. Over the last 50 years, many newly industrial countries fused their economic policy and their S&T policy.

These fundamental institutional reforms cannot be driven by sectoral ministries of S&T or by education alone. These ministries are typically driven by vested interests and spend much of their time protecting the status quo. In some countries, national research institutes serve as stepping stones for promotion into senior government positions. These institutes serve little economic purposes other than acting as pathways for professional advancement. The impetus for change will not readily come from within such ministries; executive leadership is the most obvious source of reform. Presidents will need to be supported by reformists, not simply by scientists as ministers. Reforming the system will require leaders who understand the legal issues, not simply experts in one scientific discipline or another. The issues may be constitutional, and so knowledge of law may do more for scientific enterprise than mastery of emerging fields of research.

Executive offices need to work on the basis of the best available scientific and technical information provided by designated advisory offices. In other words, presidents and prime ministers must invest the political capital needed to foster change, otherwise the system will continue to be ruled by incumbency and little will change.

It takes political commitment to apply STI successfully to a country's development challenges. STI institutional reforms are so fundamental that it is not financial capital, but political capital, that is most needed to bring innovation into the center of development policy. STI reforms require executive leadership to champion even minor changes.

Without long-term institutional reforms led by committed political leaders, STI will remain marginal to development objectives. Political leaders are needed to advance the agenda discussed at the Forum. Only then will the whole be greater than the sum of its parts.

* * *

Session 1: Reducing Poverty and Achieving the MDGs

The two panels in Session 1 explored the role of STI capacity building in reducing poverty and achieving the MDGs. Panelists addressed the following three questions:

- How can targeted STI capacity building efforts foster the development and diffusion of appropriate technologies that are adapted to local conditions and likely to be adopted by local villagers?
- What sort of technology development institutions and what sort of technology development attitudes are most likely to result in useful, useable, and widely used technologies?
- How can technology development institutions foster local economic development?

Amy Smith emphasized that the key to successful development and dissemination of appropriate technology is to involve local innovators in a process of "co-creation." Technologists must work with local communities and entrepreneurs on problem identification, technology design, and production of goods and services embodying that technology, if there is to be any hope of widespread diffusion and adoption.

Parker Mitchell observed that many widely available, potentially useful technologies are not being adopted by local villagers. This is because these technologies were not developed with the community and the end user's perspective in mind. This perspective may be quite different from those of technology development workers who tend to focus on finding technically optimal, low-cost solutions. Mitchell emphasized the importance of developing an extensive network of field-workers who can spread technologies throughout their communities.

Frans Doorman and Gerard Hendriksen argued that entrepreneurship and small businesses are the keys to successful technology diffusion programs. They noted that many technology development institutions tend to be technology driven with little understanding of, or interest in, the end user's perspectives. These institutions tend to have weak linkages to the private sector. They also have a limited interest in finding an appropriate technology—which can be an existing technology in widespread use elsewhere or a new technology developed in the institution—and transferring it to local entrepreneurs for mass production, distribution, and marketing. Solving this problem will require changing the mind-set, skill set, and incentive structure of workers in technology development institutions.

Andy Hall argued that building innovation capacity entails much more than strengthening the scientific capacity of local R&D institutes. Rather, successful innovation programs entail promoting interactions between research institutes and savvy enterprise managers who are trying to exploit what they hope will turn out to be a profitable market niche. Research has to be driven by the needs of the market, in response to production problems identified by entrepreneurs. It cannot be driven by scientists proceeding on the hope that their research results will eventually be adopted by an entrepreneur.

Charles Gore focused on the need to see STI capacity building policies as part of a broader effort to create and develop productive capacities and productive employment. Productive capacities are the resources and institutions needed for countries to produce goods and services and to grow and develop. They are generated by savvy entrepreneurs working with skilled workers. Building productive capacities creates the demand for innovation, skill development, and technologies. All too often, STI capacity building programs focus exclusively on increasing the supply of research, technologies, credit, and skills. Unfortunately, these well-intentioned supply-side policies will not succeed if they are not complemented by demand-side policies to foster the creation and development of productive capacities. STI capacity building programs need to focus on these demand-side issues as well as on the traditional supply-side programs.

What the panelists said . . .

Building STI capacity is essential for poverty reduction and local economic development, but appropriate STI capacity must be built in the appropriate way if it is to achieve these laudable objectives.

- A technology will not be appropriate if it is not attuned to the user's technical, economic, and social needs. This is not difficult to do in theory, but it is easier said than done, as evidenced by the many failed, but well-intentioned, technology development programs.

(*continued*)

- Technology development and dissemination has to be a process of "co-creation"—engineers, scientists, and technicians working in partnership with local communities and local innovators.
- Local entrepreneurs who are attuned to local needs and economic and socio-cultural requirements should be involved from the outset in the technology development process. They should not be relegated to an afterthought.
- Because technology diffusion and adoption are the critical bottlenecks in the technology development-adoption-diffusion supply chain, STI capacity building should couple the development of technical skills with an emphasis on the development of analytical, commercial, communication, networking, and partnering skills.
- Building innovation capacity goes beyond strengthening research. Institutional change, in the form of new ways of working, is needed. These changes must support stronger patterns of interaction between research, enterprise, and developmental organizations.
- The development of productive capacities should be at the heart of national and international policies to promote poverty reduction and wealth creation.

Important lessons of experience that emerge from appropriate technology programs include the following:

- Developing an appropriate technology is relatively simple and straightforward. The technological know-how needed to solve many common problems is already widely known. The critical challenge is developing an appropriate technology that will be adopted by local communities. Effective STI capacity building programs cannot afford to ignore this facet of the technology development process.
- Technology should not be distributed for free or at subsidized prices. Sustainable economic development can be achieved only if the technology development programs support entrepreneurs in developing, producing, and marketing appropriate technology in a commercial manner.
- In too many countries, universities and government research institutes are not demand driven. They need to become much more demand driven if they wish to become effective instruments of economic growth and poverty reduction.
- Building productive capacities, which creates the demand for technology and skills, is just as important as programs designed to increase the supply of skills and technologies. Sustainable development will be impossible if STI capacity building programs stress one facet of the supply-demand equation and ignore the other.

Session 1, Panel A: Building Local Capacity for Developing and Diffusing Appropriate Technologies

Amy Smith: successful technology development requires co-creation: technologists working with local communities and entrepreneurs

In her presentation, "Building STI Capacity: A Designer's Perspective," **Amy Smith, senior lecturer at MIT,** emphasized that the key to successful technology development and dissemination is to empower local innovators. If engineers and aid workers simply provide technology, villagers are not likely to use it. Technology development has to involve co-creation if there is to be any hope of widespread diffusion and adoption. In the well-known analogy of fishing, technology development should not be limited to giving people fish or to teaching them how to fish. It should also teach them how to make and improve fishing equipment.

There are three requirements for empowering local innovation. The first is *"transparency" of technology*, meaning that the working of the technology must be fully understood and understandable by the local community. Second, innovators and producers must have sufficient *access to the supply chain*, in terms of being able to obtain all needed

Box II.1

Finding an Unexpected Use for an Existing Technology

An example of people recognizing and using tools that are useful in their particular situation—even if those tools are actually designed for other uses—is that of a young Thai woman using light sensors built into a Lego (a toy construction system) structure to switch lights on and off on a fish farm. The girl had learned about the existence of the Lego blocks from a Thai graduate student who had studied at MIT. At the fish farm, the lights are turned on in the evening to attract insects that the fish can feed on at night. The lights are subsequently turned off in the morning. Initially, a young girl had to walk half an hour from her village to the fish farm and back—twice a day—to switch the lights on and off. The information she obtained about the Lego sensors allowed her to apply this technology to solve her particular problem of having to spend two hours a day to switch a set of lights on and off.

Source: Smith, Global Forum presentation.

materials to produce and market the technology themselves (see box II.1). And, third, they must have *access to capital* so that they can finance both the production and purchase of the equipment.

Co-creation is the third paradigm that has been used by the development community to discuss the development and transfer of appropriate technology. The first paradigm involved the intended beneficiary community only at the stage of adoption of a ready-made solution: a technology is developed by outside experts, on the basis of *their* perception of what was needed, and is presented to the intended users for adoption. The second paradigm involved the community in problem identification; however, technology development remained the domain of the external experts. The third and current approach, pioneered by the MIT D-Lab (with projects in six countries, involving more than 20 technologies, with the D standing for development, design, dialogue, and dissemination)[6] involves co-creation: that is, helping communities to develop the technology and tools that they need to solve their problems. The entire design process, from problem identification to idea generation, concept evaluation, detailed design, fabrication, and testing and evaluation, is done with community involvement. This approach is that of evolutionary (rather then revolutionary) design—building on and further developing what has

Box II.2

Water Chlorination in Honduras

The case of water chlorination in Honduras involves the design of a simple system for chlorinating drinking water collected in water tanks. The original chlorination system involved placing a small tank with a chlorine solution on top of the water tank. A flow regulator automatically released small quantities of chlorine into the water tank.

Initially, the regulator did not work properly. As a result, the local plumber who was maintaining the installation was criticized by community members for not doing his work properly. The D-Lab team designed a new regulator made from locally available materials, together with the plumber who, in a process of co-creation, contributed several design suggestions. More important, when the

6 For a discussion of recent D-Lab activities, see http://www.nytimes.com/2007/09/11/science/11mit.html.

D-Lab team returned a year later, they found that the plumber had made several improvements to the original design. In subsequent years, the plumber trained people to make the device—first in his own village, then in a neighboring village, and in following years in 5, 13, and 26 other villages.

Through co-creation the plumber had become an expert, conducting workshops for various target groups and expanding a profitable business in water chlorination—a good example of a local innovator being empowered to produce and market relevant technology in a sustainable manner and on an expanding scale.

Source: Smith, Global Forum presentation.

already been developed. An additional important element is to stimulate local innovators and entrepreneurs, for example, the case of a Honduran technician improving on and marketing a simple drinking-water chlorination system initially developed and applied by D-Lab (see box II.2).

Parker Mitchell: the real challenge of appropriate technology lies less in its design than in its implementation—requiring a re-focus on the end user's perspective

Parker Mitchell, chief executive officer, Engineers Without Borders, Canada, also emphasized the importance of involving the community in the development and implementation of appropriate technology. It is essential to develop an extensive network of field-level workers—an army of practical individuals who can spread technologies throughout the local community. It is not only the *technical performance* of the technology that is important, but also, and perhaps even more so, its *economic* and *sociocultural acceptability*. The key factor in successful technology development and diffusion is the perception of the intended beneficiaries. These perceptions may be quite different from those of development workers who tend to focus on finding technically optimal, low-cost solutions. A case in point is the limited uptake of low-cost bricks in one African country. These low-cost bricks were viewed by the intended beneficiaries as a sign of poverty compared with the more expensive cement blocks, which were viewed as an important status symbol. Another example of the importance of sociocultural factors is that of conservation farming in a rural African community, where increased yields were not seen as the result of the technology, but as that of plain good luck or even witchcraft.

Overall, then, the problem is that potentially useful *technologies exist but are not being adopted*. Ian Smillie has chronicled 30 years of appropriate technology development by over a thousand appropriate technology organizations (Smillie 2000). Thousands of technologies were developed, but only a fraction was actually utilized, especially in Africa. According to Smillie, implementation is usually locality specific—for example, a solution that works in northern Ghana will be different from one that is adopted in southern Burkina Faso. It is also dynamic, meaning that it has to adapt to changing circumstances. Implementation fails because development workers do not sufficiently understand behavior change and how "beneficiaries" react to ideas. There is no recipe to be "handed" to field staff to "implement." Instead, impact is achieved only by understanding a community's particularities and getting to know the users' perspective.

Technology development and diffusion, therefore, must start with the users' perspective, which can be obtained either by embedding outsiders in the community or, even better, by employing local residents as technology agents. Effective development agents require a combination of technical and communication skills, a good sense of development realities, and an understanding of what is happening in the local community. For larger-scale dissemination, a network of frontline workers is required. And required at all levels is an entrepreneurial attitude and approach.

Many technologists do not appreciate the insights that can be gleaned from users. They do not want to hear complaints about their product. And they especially do not want to hear that their product is not what people want. Whereas the entrepreneur starts by identifying needs, demands, and products to sell, all too often, the technology development worker starts with a product that he or she thinks should be useful and then expects it to be adopted. The underlying problem is that technology producers are not as a rule *accountable* to end users and the market, because their funding comes primarily from other sources—whether NGOs or the government. Changing attitudes, therefore, requires creating accountability to end users, and it requires competition, which, in turn, entails bringing such factors as entrepreneurship, markets, and small businesses into the technology development business.

A final obstacle to accountability is supplying free inputs: for technologists it is easier to disseminate technology, even inappropriate or unwanted technology, when it can be given away. This is because performance is often measured by the numbers of units that are distributed rather than the impact of those units in solving concrete problems. Worse, giving technology away creates a culture of dependency by destroying self-initiative: the attitude that one only has to wait for outsiders coming in to do something for free. Yet self-initiative is one of the most important behaviors needed for people to reach and climb the ladder of development. A case in point is a project involving the free distribution of treadle pumps. This undermined both users' and producers' economic incentives, with farmers waiting to receive new, free treadle pumps rather than repairing or replacing damaged ones.

The following strategies address these issues:

- *Promote a change in mind-set* by listening to end users and understanding their perspective. For outsiders, this requires immersion in end user communities. Even donors—including managers and decision makers—should be put in regular contact with end users by (i) immersing in a community for a few days, (ii) "shadowing" community members, (iii) observing and participating in their daily work, and (iv) talking in-depth with frontline development workers. In this way, decision makers can highlight the importance of focusing on end users' needs.
- Realign *incentives* so that *users' needs become the focal point* and entrepreneurs will have an opportunity to diffuse technology. Development worker incentives should be linked to the interests and perspectives of end users. There should be incentives to listen to end users, and performance should be measured in terms of adoption rates. Mechanisms will have to be designed to accomplish this—for example, extension workers could receive performance bonuses or commissions based on the adoption rates of new technologies.
- The focus of technology diffusion should be on *fostering the commercial production and marketing of appropriate technology by local entrepreneurs.* Because successful entrepreneurs would presumably be members of the local community, they should have a good understanding of end users' perspectives.
- NGOs should not distribute technology for free or at subsidized prices but support entrepreneurs in developing, producing, and marketing appropriate technology in a commercial manner. Africa is full of entrepreneurs waiting for the opportunity to spread technology that meets users' needs.

Frans Doorman and Gerard Hendriksen: challenges at an appropriate technology institute in Rwanda

Frans Doorman and Gerard Hendriksen, consultants to the Netherlands Organization for International Cooperation in Higher Education (Nuffic),[7] discussed institutional constraints to the effective development, transfer, and dissemination of appropriate technology by the Centre of Innovation and Technology Transfer (CITT) in Rwanda. There is a significant gap between the day-to-day procedures at CITT and the prescriptions for successful technology transfer and diffusion. In theory, CITT is supposed to start by conducting a needs analysis. Then, in concert with interested SMEs, it is supposed to procure or design appropriate technologies to meet the market needs. SMEs and entrepreneurs would be responsible for the actual production and marketing of these technologies.

CITT practice, however, looks quite different:

- After six years of technology development efforts, CITT has built prototypes of about 30 appropriate technologies and produced these technologies in CITT's own workshop. It has made direct sales of about 10 of these technologies. However, not a single technology has been transferred to a private sector firm for production and sales—the expressed goal of CITT and the key to sustaining the technology's use in Rwanda.
- CITT has had major success in designing and building, in a semicommercial manner, large-scale biogas installations for prisons, schools, and hospitals. In these projects, however, CITT competes with the private sector. CITT thus hinders rather than promotes private sector development.
- CITT has had a limited measure of success with the introduction and training of artisans in fuel-efficient, wood-saving cook stoves. Yet because of heavy subsidies and in some cases incompatibility with end users' perspectives and needs (for example, open fire is used not only for cooking but also for heat and light), the overall impact has been limited, and production and marketing has not taken off in a self-sustaining manner on any significant scale.

When comparing CITT's actual practices with prescriptions for an effective technology development organization, several notable discrepancies emerge:

- At CITT, the choice of technologies that are developed is determined by the personal interests of engineers rather than an evaluation of the end users' needs and perspectives.

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7 The Netherlands Organization for International Cooperation in Higher Education's Web site is http://www.nuffic.nl/.

- CITT rarely factors cost-benefits analysis into its decision-making process. For a government institute with limited resources in a country with huge development needs, getting the "biggest bang for the buck" is of major importance.
- Many potentially useful and effective appropriate technologies already exist and are widely available; the problem is that they are not being adapted and adopted in certain African countries. Unfortunately, CITT rarely engages in systematic searches for available solutions and maintains no links with organizations and institutions that could supply relevant technological solutions.
- CITT does not undertake a market analysis of the technologies it works on, nor does it encourage systematic feedback from end users. In other words, CITT does not take the end users' perspective into account.
- CITT has only very weak linkages, at best, with the private sector and with SMEs.
- Rather than encouraging SMEs to produce and market technologies, CITT produces technologies in its own workshops, thereby competing with the private sector.

To address these problems, CITT could revise its operating practices as follows:

- Set priorities for generating and transferring appropriate technology on the basis of end users' needs
- Systematically identify and assess potentially relevant technologies—irrespective of whether they are produced and developed in-house by CITT or outside CITT and even outside Rwanda—supplied by other technology development organizations
- Systematically test and adapt selected technologies in partnership with SMEs and end users
- Support private sector efforts to mass produce and market the most relevant technologies

To accomplish these new tasks, CITT will need to recruit new staff with "soft" skills in networking. CITT needs to communicate with, and understand the perspectives of, end users and the private sector. New staff should have analytical skills for needs identification (gaining the perspective of end users) and feasibility assessments (technical, economic, social). Other required skills are related to communication and marketing, project identification, formulation and management, and client relations.

Session 1, Panel B: A Sectoral View on Building STI Capacity for Meeting the MDGs

Andy Hall: Building agricultural innovation capacity in developing countries: requirements and lessons

Andy Hall, LINK coordinator at the United Nations University, Maastricht Economic Research Institute on Innovation and Technology (MERIT), argued that building innovation capacity entails much more than strengthening the scientific capacity of local R&D institutes. It primarily consists of promoting interaction between research institutes and savvy enterprise managers who are trying to exploit what they hope will turn out to be a profitable market niche. Policy interventions to promote innovation should have a long-term perspective and give sufficient emphasis to facilitating institutional learning.

Innovation capacity entails the following activities:

- The scientific and other skills and information present in research organizations, enterprises, training organizations, and developmental organizations
- The routines and patterns of interaction within an economy, and the policies needed to create and put knowledge into productive use
- Learning-by-doing whereby organizations engaging in the innovation process continually adapt the operating procedures and routines in response to evolving challenges and opportunities

A recent World Bank report prepared by Andy Hall and colleagues, entitled *Enabling Agricultural Innovation: How to Go Beyond Strengthening Research Systems* (2006), explores the development of innovation capacity in eight sectors in four countries: Bangladesh (shrimp, food processing), India (medicinal plants, vanilla), Ghana (pineapple, cassava processing), and Colombia (cassava processing, cut flowers). The overall conclusion is that *sectors emerge and innovation occurs primarily because entrepreneurs identify new market opportunities and pursue innovations* to gain market access. Research, by itself, almost never promotes innovation. The critical ingredient for innovation is an entrepreneur who finds ways to incorporate the fruits of that research into a business plan.

The cases highlighted in boxes II.3 and II.4 show that simply investing in research is not sufficient for developing innovation capacity. Linkages and patterns of interaction between researchers and entrepreneurs

Box II.3

The Pineapple Sector in Ghana

The pineapple sector in Ghana is a good example of how entrepreneurs are the driving force behind the emergence of an innovative sector. The export market for pineapple and pineapple products was developed in the 1980s by local and foreign entrepreneurs who recognized the potential competitive advantages offered by Ghana's favorable production conditions, low labor costs, and proximity to European markets. Different types of producers emerged: large corporations with their own plantations and processing plants, small companies with a smallholder production base, and also government or donor-supported farms working with a network of small producers. Over the years, firms diversified from raw pineapple to cut and sliced fruits and processed products such as juices. Also, production for the more lucrative and profitable organic and fair trade markets was developed.

In spite of its success, the Ghanaian pineapple industry has remained rather fragmented. Companies have usually looked for technology and know-how on an individual basis, through their own research or by contracting foreign experts. Although an industry-wide association of Ghanaian pineapple producers has a mandate to coordinate research and marketing efforts, it has not worked well in practice. The government has been fairly successful in linking small producers to export markets through the establishment of farmer-owned export companies. But in technical matters—developing new plant varieties, and so on—and the development of the sector overall, Ghana's fairly extensive agricultural research system has played only a minor role.

Innovation has been hampered by a vicious circle. On the one hand, the private sector has a low opinion of the quality of work emerging from government research institutes, and this, in turn, leads to low private sector demand for R&D. On the other hand, the lack of private sector demand leads the research establishment to ignore the needs of the pineapple sector. As a result, formal interaction between the private and public sectors is limited to training in pesticide management and support for compliance with international food safety standards—with considerable support from international donors.

Although the pineapple sector has been fairly successful thus far, strong and growing international competition will require improved cooperation

(*continued*)

between companies and research institutes in such fields as production (in terms of responding to changing tastes and preferences and complying with increasingly strict international food safety standards), quality management and control, certification, and marketing. The task facing Ghanaian authorities is to get the private sector and research establishment to work together to tackle these problems.

Sources: World Bank 2006; Hall, Global Forum presentation.

Box II.4

The Cassava Sector in Colombia

The cassava sector in Colombia offers an example of strong interaction and cooperation between public and private sector players. Over the past two decades, cassava has developed into an important agro-industrial crop as a result of favorable market conditions, a conducive policy environment, and strong cooperation between research institutes and the private sector.[a]

One key player is the government, which stimulated cassava production and processing by creating a favorable environment, including support for the creation of the National Association of Cassava Producers and Processors, an industry association set up to organize and support the commercialization of dried cassava. Yet another success factor was the support from a strong research establishment led by the International Center for Tropical Agriculture (CIAT) and the national agricultural research agency CORPOICA (Colombian Corporation for Agricultural Research). CIAT's interdisciplinary and participatory approach, market development orientation, and linkages with cooperative processing plants all helped bring farmers into the development process at an early stage.

Success factors in Colombia have been the willingness to explore different forms of partnership, a strong tradition of collaboration in the form of cooperatives and industry associations, and the importance given to S&T. Also important have been effective government support for strengthening the interaction and coordination within the production chain.

Source: World Bank 2006.

a. For a discussion of Colombia's evolving Technological Research Institutes, see Fernando Chaparro's presentation in part II, session 2, of these proceedings or the video of the presentation available online at www.worldbank.org/stiglobalforum.

are often missing and need to be strengthened. The corresponding lack of interaction is usually a reflection of deep-rooted habits and outmoded work practices in both public and private sector organizations and civil society.

Consider the following policy lessons:

- *Institutional change is at the heart of innovation capacity development* and requires a long-term commitment. Facilitating institutional learning—new ways of working—could add significant value to STI capacity development initiatives.
- *Competitive research funds* can be used to provide incentives *to build linkages*. However, they are *not a panacea*.
- Incentives for building links and interaction need to be coupled with *substantial investments in skill development (partnering, networking, communication*) to help adjust to new ways of working.

Charles Gore: STI and poverty reduction in the least developed countries (LDCs)[8]

Charles Gore, lead author of "The Least Developed Countries Report, 2007" (UNCTAD 2007), focused on the need to see STI capacity building policies as part of a broader effort to create and develop productive capacities and productive employment. This requires an outward-looking development strategy: prospecting for technologies around the world to identify opportunities for improving production performance (Keesing 1967).

LDCs start with a particularly daunting set of challenges:

- Although real GDP in 2004 of the LDCs as a group grew by 5.9 percent (the highest for two decades) and exports, FDI, and Official Development Assistance (ODA) inflows were at record levels, real GDP per capita declined or grew by less than 1 percent in one-third of the LDCs.
- LDC growth is highly dependent on trends in commodity prices, including oil prices, trends in external finance, and climatic and weather conditions. LDCs as a group are highly vulnerable to growth collapse.
- LDCs are failing to generate sufficient productive employment.

8 Gore's presentation drew extensively from two of UNCTAD's annual least developed countries reports (UNCTAD 2006, 2007).

This is leading to a deepening employment crisis:

- With rapid population growth, agricultural farm sizes are declining and farming is spreading to marginal land.
- As a result, many farmers cannot afford to invest in sustainable intensification of agricultural production.
- More and more people are seeking work outside agriculture, and urbanization is accelerating.
- Most LDCs have not been able to generate sufficient productive off-farm jobs to absorb the growing labor force seeking work outside agriculture.
- Both agriculture and nonagricultural enterprises are severely challenged to compete following in the liberalized, global trading system.

These stylized facts point to the following conclusions:

- The *development and utilization of productive capacities should be placed at the heart of national and international policies* to promote sustained economic growth and poverty reduction in the LDCs.
- *Policies to promote technological learning and innovation* are an essential component of policies to develop and utilize productive capacities.

"Productive capacities" can be defined as follows: "Productive capacities are the productive resources, entrepreneurial capabilities and production linkages which together determine the capacity of a country to produce goods and services and enable it to grow and develop" (UNCTAD 2006, 61). Productive capacities create only a *potential* for production and growth. Whether this potential is realized depends on whether their capacities are fully used, and whether they are fully used depends on demand-side factors. In most LDCs, productive resources and entrepreneurial capabilities are underutilized because of severe demand constraints. Demand stimulus provides the inducement for investment, technological learning, and innovation. However, even with increased demand, productive capacity may be hampered as a result of insufficient capital accumulation and weak human capital formation, caused by substandard tertiary education and the brain drain to more developed countries. Overall this leads to a situation of weak domestic firms supported by weak domestic financial systems and weak domestic knowledge systems.

A strengthened focus on the development and utilization of productive capacities requires a paradigm shift in poverty reduction policies. A lackluster emphasis on the development of productive capacities was a major weakness of first-generation reforms (World Bank 2005).

Second-generation reforms have not rectified this problem: *development of production sectors is still weakly integrated in poverty reduction strategies*. Moreover, economic development strategies contain an excessive focus on promoting exports and FDI and pay too little attention to fostering domestic private investment, domestic markets, domestic linkages, and domestic resources and capabilities. In addition, special international support measures for LDCs are more oriented toward providing market access than to developing productive capacities. The increased attention for MDG-based, poverty-focused aid also comes at the cost of support for developing productive capacities, as does aid focused on direct welfare improvement. Overall, the share of ODA to LDCs devoted to economic infrastructure, and productive sectors decreased from 48 percent of aid commitments in 1992–94 to 32 percent in 1999–2001, and 24 percent in 2002–04.

Policies to promote technological learning and innovation must be incorporated directly into strategies to strengthen productive capacities—in the LDCs as well as in high-income OECD countries. For LDCs, the emphasis should not be on high-tech activities but rather on technological upgrading of existing activities and structural change and economic diversification through the introduction of new products. STI policies need to be adapted to the level of development of a country; for LDCs, this implies integrating STI capacity building into poverty reduction strategies and international development cooperation.

STI capacity building policies need to broaden their focus from building state capacities and improving governance to include measures designed to boost weak private sector capacity for innovation. This is especially important for formal sector SMEs, especially medium-size domestic enterprises (the missing middle). There is a clear need to foster the development of domestic medium-size firms and production linkages. Typically, informal sector enterprises do not develop into formal sector firms and small firms do not grow into large firms. Important elements in such a strategy include strengthening weak domestic financial systems, investing in climate reforms to reduce red tape and costs of doing business, and strengthening knowledge systems.

Improving domestic knowledge systems is a key policy lever for enterprise development. Current problems in LDCs include the disarticulation between traditional and modern knowledge systems, and most important, the failure of modern knowledge systems (universities, national research institutes) to function as an integrated system. Also, as a rule, these knowledge systems are not demand driven and are not well integrated internationally. The main challenges in using STI for developing productive capacities are, therefore, to develop national technology learning strategies to increase access to, and effective use of, foreign technology, as well as to blend modern and traditional knowledge and create linking institutions.

Session 1, Conclusions—Synthesis

The Session 1 presentations lead to the following conclusions:

- With regard to appropriate technology the *main challenge is not its development* in terms of initial design, construction, testing, and adaptation, but the technology's *diffusion* (that is, *implementation*).
- There is a market for a particular appropriate technology only when technology meets all technical, economic, and sociocultural requirements. This requires *a full understanding of the end user's technical, economic, and social needs*.
- These needs may be quite site specific. For noncommunity members, understanding needs, especially in sociocultural terms, requires immersion in the community coupled with well-developed informal information gathering and analytical skills. Such skills are rare, and those possessing them are likely to be in high demand elsewhere. The most effective strategy for appropriate technology implementation is likely to be through *local entrepreneurs.* Because of their background and being part of the community, these entrepreneurs are aware of local needs as well as economic and sociocultural requirements and constraints.
- The key to successful technology development and dissemination is to empower local innovation. If external change agents provide local people with the tools to solve their problems, they will use them. Technology development and dissemination has to be a process of *co-creation*.
- Requirements for empowering local innovation include "transparency" of technology, meaning that the working of the technology must be fully understood and, therefore, understandable. This will allow entrepreneurs and technicians to adapt and thus, further develop the technology. Innovators and producers must have sufficient *access to the supply chain*, in terms of being able to obtain all needed materials for production and marketing. And *access to capital* is required to finance production.
- Effective diffusion (implementation) requires the development of an extensive network of field-level workers to spread technologies on the ground.

- Effective technology implementation on any significant scale will depend on fostering the commercial production and marketing of appropriate technology by local entrepreneurs. The strategy should *not* be to distribute technology for free or at subsidized prices, but to *support entrepreneurs in developing, producing, and marketing appropriate technology in a commercial manner*.
- A change in mind-set is needed especially in government research—for example, appropriate technology institutions, which tend to be technology driven, with little understanding of and interest in end users' perspectives; weak linkages to the private sector; and limited capacity for and interest in "mining" the existing body of knowledge through networking and accessing relevant sources of information. To actually achieve such a change in mind-set will require, in most cases, a major institutional overhaul.
- Given that the key problem in technology implementation is diffusion, *STI capacity building should couple the development of technical skills with an emphasis on the development of analytical, commercial, communication, networking, and partnering skills*.
- Building innovation capacity goes beyond strengthening research. *Institutional change*, in the form of new ways of working, is needed. These must support *stronger patterns of interaction between research, enterprise, and developmental organizations*.
- Interventions need to have a long-term perspective and give sufficient emphasis to investment in institutional learning to bring about new ways of working and *partnering with other organizations*. Development of sustainable partnerships should be supported through *capacity building in partnering, networking, and communication*.
- Capacity to innovate depends on the extent to which organizations are able to *incrementally improve their ability to utilize knowledge and information*, through learning-by-doing, in response to evolving sets of challenges and opportunities.
- The *development of productive capacities*—productive resources, entrepreneurial capabilities, and production linkages—should be at the heart of national and international policies to promote sustained economic growth and poverty reduction in the LDCs.
- Overall special international support measures for LDCs are more oriented toward market access than to developing productive capacities. Economic development strategies contain an excessive focus on exports and FDI and pay *too little attention to developing domestic private investment, domestic markets, domestic linkages, and domestic resources and capabilities*.

- Improving productive capacities requires addressing the present situation in LDCs characterized by weak domestic firms supported by weak domestic financial systems and weak domestic knowledge systems.
- Present tendencies in ODA raise the question whether support is too focused on technology development, science, and science institutions, and not focused enough on building capacities for technology adoption and diffusion.
- Improving domestic knowledge systems is a key policy lever for enterprise development. In LDCs, modern knowledge systems (universities, national research institutes, and so on) are not demand driven and not well integrated internationally. The main challenges in using STI for developing productive capacities are *to develop national technology learning strategies to increase access to and effective use of foreign technology*, as well as *to blend modern and traditional knowledge* and *create linking institutions*.

Session 2: Adding Value to Natural Resource Exports

If countries hope to become more prosperous, they must find ways to reduce the ranks of the rural and urban poor and not merely develop technologies that make life more tolerable for them. Reducing the ranks of the poor must entail creating more productive, higher-paying jobs outside subsistence agriculture and casual urban labor. This, in turn, requires developing new, higher value-added goods and services and finding ways of exporting them either directly or by latching onto supply chain linkages with local firms and transnational exporters. STI capacity building is a critical tool for meeting these challenges.

Policy makers in many low- and middle-income countries all too often believe that their abundant natural resources, fertile soils, and relatively low wages combine to give their countries a natural competitive advantage. In many cases, these countries tend to export natural resource- and labor-intensive goods and services. Their competitive strategies are based primarily on maintaining their status as a low-cost producer rather than striving for quality improvement and innovation (box II.5 discusses some potential shortcomings of this strategy). However, by definition, price reduction without innovation and productivity improvement is not a sustainable, long-term strategy for raising per capita incomes. Experience suggests that if the initial strategy succeeds in raising per capita incomes and wages, new competitors with lower wages and similar productivity levels will enter the competitive fray, producing the same or better goods at a lower cost. In the end, today's low-cost producer will become tomorrow's competitive loser.

Box II.5

The Curse of Natural Resources

The curse of natural resources is based on the observation that many countries with abundant natural resources appear to have lower long-term economic growth rates than countries with poorer resource endowments. But why should abundant natural resource endowments be bad for economic growth? Economists offer several explanations:[a]

1. The inevitable volatility of prices for unprocessed natural resource products is particularly damaging to national economic growth when exports are narrowly focused on one or a few commodities instead of being diversified.
2. The so-called Dutch disease in which expanding natural resource exports causes manufacturing exports to decline occurs either because (i) human and capital resources are redistributed from tradable manufacturing to resource extraction or (ii) domestic manufacturing becomes progressively less competitive because of the appreciating real exchange rates that frequently accompany natural resource exports.
3. Resource-based industries require a less complex division of labor and have fewer forward and backward linkages to other productive activities throughout the economy.
4. Resource-based industries experience slower technological change and productivity growth.
5. Resource-based industries usually generate lower demand for human capital, thus reducing opportunities for skill-based economic growth.
6. Natural resource extraction generates high economic rents that are easily appropriated by governments and special interest groups. The prevalence of rent-seeking behaviors leads to greater corruption and lower bureaucratic efficiency and also provokes fighting among the ruling factions, which leads to higher political instability. Governments are distracted from investing in growth-supporting public goods (for example, infrastructure or public safety). Economic and political institutions remain underdeveloped.

All of these factors, separately or in combination, tend to retard investment and economic growth.

However, the results are not inevitable. According to Daniel Lederman and William Maloney, "Natural resources are neither curse nor destiny for developing countries. . . . Natural resources are assets for development that require intelligent public policies that complement natural riches with human ingenuity. It is

(*continued*)

only through these complex interactions that resource-led growth can take off" (Lederman and Maloney 2007, 10). In other words, explicit and implicit STI capacity building policies determine whether a country exports unprocessed raw materials and simple commodities, in which case natural resources can be a curse, or whether it exports high-quality niche products and processed natural resource–based products, in which case natural resources can be a blessing. In either case, the mere presence of natural resources does not preordain the path and patterns of national economic growth.

Note: a. For a more detailed but still concise overview of these arguments see, for example, Sachs and Warner (1997), 2–10; Lederman and Maloney (2007), 1–3.

> "We find empirical and historical evidence showing that natural resources do spur economic development when combined with the accumulation of knowledge for economic innovation."
>
> —Daniel Lederman and William F. Maloney (2007, 3).

The alternative, and far preferable approach, is to encourage enterprises to focus on producing higher value-added goods and services that are much harder for competitors in lower-wage countries to imitate. This, in turn, entails developing appropriate STI capacity so that private enterprises can shift from competitive strategies based on cost reduction to competitive strategies based on quality improvement and innovation. This is true for natural resource–based economies, agricultural economies, and manufacturing and service economies. In each case, the route to prosperity lies in producing and exporting higher value-added, more-knowledge-intensive goods and services.

One of the main problems with exporting goods that are high in natural resources but low in knowledge and skills is that these goods are commodities already or they tend to be prone to the "commoditization process."[9] To build "retainable industries" (Gomory and Baumol

9 "Commoditization" means that products of various producers become so similar from the buyers' point of view that competition converges solely on price. Because identical commodities have the same price and buyers tend not to prefer one seller over another, they can easily switch from one supplier to another. This creates fierce price competition and a high risk of failure for each individual producer. Global competition has accelerated and expanded this commoditization process. The solution for individual firms is to escape the commoditization process by differentiating their product on the basis of innovation—unique characteristics, quality, services, or brand name, for instance.

2000) that can serve as a foundation for sustainable national development, firms in developing countries need to learn how to avoid and reverse the commoditization of their exports. Learning to supplement natural resource advantage with STI knowledge advantage makes it more difficult for lower-wage but less capable and less experienced competitors to imitate the success of incumbent firms. It also increases consumer willingness to pay higher prices for new and uniquely differentiated goods and services. Innovation, therefore, is far preferable to cost reduction as a long-term competitiveness strategy.

> "Firms do need to begin competing where they have real advantages. And in the developing world, the only real advantages to begin with often appear to be cheap labor and natural resources. Any strategy that begins this way, however, also should contain a clear plan for migrating away from those kinds of unsustainable advantages. . . . The sources of growth for developing countries are hidden behind the abundance of natural resources that so many of them possess."
>
> —Michael Fairbanks and Stace Lindsay (1997, 31, 37).

Innovation is also critical for maintaining economic competitiveness in the face of rapidly changing technology and consumer preferences. The effort to build up an industry to the point at which it can compete for global market share does little for sustainable development if that industry gradually loses its competitive advantage as new and better technologies are developed and employed by producers in competing countries.

Competitiveness crises can also be caused by rapid changes in business or environmental conditions that demand urgent innovative responses. Firms that cannot adapt will not survive. Examples of this unfortunate growth-and-collapse cycle include the palm oil industry in Ghana, which fell victim to changing global demand; the Colombian coffee industry, which lost ground as the Vietnamese industry incorporated better production technologies; and the Peruvian fishing industry, which collapsed because of a water pollution–related epidemic. Although these circumstances may overwhelm even a highly innovative firm's adaptive capacity, higher STI capacity at the firm as well as at the national level can significantly increase the chance of adaptation and long-term success. As developing countries move into even more knowledge-intensive export industries, it is those countries with national STI capacities complementing and supporting enterprise-level innovation that will be able to retain and develop these industries over the long term.

The good news is that much of the initial managerial and technological knowledge needed to increase the economic value of resource-based exports already exists, mostly in high-income countries.[10] The bad news is that this knowledge is not always available to enterprises in poor countries. From this vantage point, therefore, STI capacity building in developing countries needs to focus on the capacity to identify feasible markets for higher value-added products; to find, import, and integrate appropriate technologies into the local production processes; and to help farmers and firms (both managers and workers) develop the skills needed to produce and market higher-quality, higher-value, more-knowledge-intensive goods and services.

Although these challenges are daunting, they are not impossible, as illustrated by the various success stories presented during the session on Adding Value to Natural Resource Exports. These case studies illustrate a variety of competitiveness and capacity building strategies that developing countries have employed to add value to their natural resource exports and generate a competitive advantage in lucrative market niches. These strategies involve such tactics as the following:

- Utilizing exporters' associations, FDI, PPPs, foreign NGOs, and returning members of the diaspora to gain knowledge about foreign markets, to ensure quality control, and to teach farmers how to modernize their production technologies and techniques
- Finding a specialized niche in global export markets
- Enhancing the private sector's capacity to acquire, adopt, and adapt existing foreign technologies to produce high-quality goods and services
- Developing innovative strategies for training unskilled farmers and workers to utilize new technologies and meet exacting quality standards

There is no single correct way to implement these strategies. But the two indispensable ingredients seem to be (i) identifying a source of existing knowledge about modern technologies, production techniques, quality control mechanisms, and global markets and (ii) encouraging entrepreneurs to use this knowledge to organize the production processes, link rural, often semiliterate farmers to global markets, and train farmers and small producers to meet the exacting production and quality control standards required by demanding international customers. Developing these ingredients is an essential aspect of STI capacity building, as the speakers in the session on Adding Value to Natural Resource Exports explained.

10 The opportunity to learn from existing managerial and technological knowledge gives these countries an opportunity to exploit their so-called latecomer advantage. For a more detailed discussion of this concept, see Mathews (2007).

Thomas Dixon described how nontraditional sources of knowledge and expertise—for example, NGOs rather than universities and research institutes—can spur innovation and help farmers add value to their agricultural produce and obtain premium prices for their produce in highly competitive global markets. In Tanzania, for example, the coffee industry was plagued by declining prices and disappearing markets. Tanzanian coffee was in danger of becoming a surplus commodity in global markets. TechnoServe, a U.S.-based NGO, helped to reverse the decline by transferring know-how, technologies, and skills to Tanzanian farmers and newly created farmers cooperatives; identifying attractive niche market segments in high-end specialty coffees that could be supplied by Tanzanian farmers; linking these producers to buyers outside Tanzania; and convincing the government to adopt a more innovation and producer friendly regulatory regime.

Beatrice Gakuba, a member of the Rwandan diaspora, described how the diaspora played a similar role in developing the Rwandan horticulture industry. Her presentation also described how motivated entrepreneurs can identify, develop, and deliver effective worker training programs outside the formal education system as well as innovative social service delivery programs. Expanding the scope of these training social service programs, however, will require innovative PPPs. Seen from this perspective, adding value to natural resource exports, building STI capacity, and making progress toward achieving the MDGs are all closely interrelated. It will be difficult to make sustainable progress on one dimension without making similar progress on the other dimensions. Programs that focus on only one dimension are not likely to demonstrate long-term, sustainable progress.

Hasit "Tiku" Shah discussed how private sector entrepreneurs and foreign investors can innovate and achieve long-term success in the face of a fast-changing market environment. The Kenyan horticulture industry has had to acquire, adopt, and adapt existing foreign technologies to produce high-quality goods and services that meet both the changing tastes of consumers and the health and safety standards of the export markets in the European Union and the United States. A diverse set of actors—entrepreneurs with knowledge of markets and new technologies, industry associations, phytosanitary and sanitary inspection agencies, foreign investors, upstream and downstream business partners, and demanding customers—contributed to the development of an innovative, technologically proficient Kenyan horticulture sector. In an interesting example of South-South cooperation, Kenyan horticulture experts are now providing paid technical assistance to such Rwandan entrepreneurs as Beatrice Gakuba.

Joaquin Cordua explained how an institution for promoting innovation and technology transfer activities (in this case Fundacion Chile) helped the Chilean industry adapt and adopt new technologies, develop new industries, and add value to the country's traditional and nontraditional natural resource exports. Fundacion Chile played the major role in searching for appropriate sources of foreign technologies, demonstrating the viability of these technologies in the Chilean environment, and disseminating this information to private firms. Lessons from this experience include (i) the importance of conducting detailed market intelligence before attempting to transfer technology to the private sector; (ii) the need to disseminate new technologies widely throughout the private sector, rather than to transfer technology only to one or two selected firms; and (iii) the usefulness of establishing pilot businesses to demonstrate market feasibility and promote the diffusion of the latest technology.

Thomas Dixon, Tanzania country director, TechnoServe, presented the case of the Tanzanian coffee industry.[11] As Dixon's discussion illustrates, TechnoServe, an NGO supported by such foreign government agencies as the U.S. Department of Agriculture, the USAID, and the Swiss State Secretariat for Economic Affairs, played the key role in promoting and facilitating technological and marketing innovation. Before TechnoServe arrived on the scene, Tanzanian coffee producers did not have the capacity to identify a profitable market niche for Tanzanian coffee or the technologies and skills that would be required to serve this market. Technoserve transferred this know-how to Tanzanian farmers and newly created farmers cooperatives, which TechnoServe helped to organize. In this way, Tanzanian coffee producers developed the STI capacity they needed to thrive in a new, more competitive environment and escape from the commoditization trap.

As Dixon explained, Tanzanian coffee growers desperately needed to innovate. Despite the growing global demand for coffee, they were suffering from several decades of volatile and declining prices. The most recent decline in coffee prices had been caused mainly by technological innovation and increased coffee production in Brazil along with the emergence of low-cost coffee production in Vietnam.

11 At the time of the Global Forum, Thomas Dixon was Tanzania country director of the U.S.-based nonprofit organization TechnoServe (standing for Technology in the Service of Mankind). The description and analysis of the Tanzania case study presented here draws on Dixon's presentation at the Global Forum as well as information available on the TechnoServe Web site at http://www.technoserve.org/africa/tanzan-coffee.html.

What the panelists said about . . .

Pursuing a strategy for adding value to natural resource exports . . .

- Avoid the "natural resource curse" that can plague resource-dependent economies
- Build "retainable industries" that are less subject to imitation by and price competition from lower-cost competitors
- Compete on the basis of innovation and quality, not on the basis of price and low wages
- Develop skill-intensive jobs commanding higher wages to achieve economic growth with social equity

Successful strategies for adding value to natural resources and commanding higher prices for resource-based goods include . . .

- Identifying the most attractive, least price-sensitive, and potentially most dynamic consumer market
- Building the STI capacity so that producers can stop producing low-quality commodities and switch instead to higher-value products better aligned with consumer preferences
- Learning how to meet the quality standards of the most demanding consumers
- Processing natural resources into high-value goods and services, rather than shipping unprocessed raw materials (this adds value and generates additional revenues and jobs for local producers)
- Differentiating the firm or country's products from those of current or prospective competitors
- Moving up the value chain by producing not only resource-based products but also the more knowledge-intensive, value-added intermediate inputs and services

Building the STI capacity needed to add value to natural resource exports involves . . .

- Teaching news skills to all employees, ranging from top managers to rank-and-file workers. In most cases, specialized staff training, outside the formal education system, will be required.
- Encouraging and empowering aid agencies, NGOs, returning members of the diaspora, and local producer and exporter associations to act as teachers, technology agents, *and* entrepreneurs. They can help rural farmers find and

(*continued*)

utilize appropriate foreign technological knowledge. They can also teach them how to meet health, safety, and quality standards; organize production processes and transport logistics; and gain access to potentially lucrative foreign markets. Unless there is someone to transfer this entire package of critically important know-how to local producers, simply providing workers with formal vocational training and SMEs with loans to acquire modern equipment will not be sufficient to generate value-added exports.

- Providing staff training in the context of PPPs. The most relevant training frequently occurs outside the formal school system, but formal education still played an important role in producing the general skills—literacy, numeracy, and so on—that workers require and employers demand.
- Developing direct links to foreign customers and bypassing intermediate distributors. This will help local producers to better understand the demands and preferences of their customers. This market knowledge and insight are essential if local producers hope to remain competitive and will act as a spur to continuous innovation.

TechnoServe's consultants were able to identify an attractive niche market in high-end, specialty coffee. This niche market accounted for only about 6 percent of global coffee consumption, but it was expected to grow rapidly and continuously. It offered Tanzanian coffee producers the prospect of selling their coffee at considerable price premiums. To access this market, however, they had to provide consistent supplies of high-quality specialty coffee.

In the late 1990s, Tanzanian producers were unable to meet this requirement despite the country's naturally favorable growing conditions. The main problem was that smallholder farmers were processing their harvest at home, using traditional techniques that resulted in broad and unpredictable quality variations. Moreover, the only way to sell coffee at the time was through a state-operated "blind" auction. Under this system, coffee beans were treated as an undifferentiated commodity. There were no quality differentials and buyers did not know whose coffee they were purchasing. Under these circumstances, individual

"KILICAFE is a success story about bringing technology, innovation, and market links to enable remote smallholder farmers to prosper."

—Thomas Dixon, Tanzania country director, TechnoServe, speaking at the Global Forum farmers had no incentive to improve quality or to innovate. Government-mandated coffee-marketing strategies, coupled with technical barriers to production, were the major obstacles facing the sector.

The situation changed radically in 2001, when KILICAFE (Association of Kilimanjaro Specialty Coffee Growers) was founded in Tanzania with assistance from TechnoServe.

This farmer association united about 10,000 smallholder farmers into 93 village-level farmer groups with 20 to 200 farmers in each. With assistance from TechnoServe, these farmer groups obtained new coffee-processing equipment from Colombia and organized procedures for the centralized collection and processing of coffee beans. At the national level, KILICAFE provided market knowledge and infrastructure to help farmers sell their coffee and organized radio programs to teach farmers new ways of processing and handling coffee. For example, farmers were taught to dry coffee beans on raised tables (rather than on the ground as they used to do) and cover them for protection from the intense afternoon sun and nighttime rain. No less important, economic incentives for improving quality were created as KILICAFE replaced the previously prevailing practice of bulking all coffee beans, irrespective of their quality, with a system that provided revenues to each farmer group in proportion to the price received for that group's coffee. This gave farmer groups a strong incentive to focus on quality improvements because revenue would be tied directly to quality. These innovations, along with KILICAFE's company standards, ensured quality improvement and new opportunities for direct export sales of specialty coffee at premium prices.

A special law adopted in 2003 allowed direct export sales of Tanzanian coffee, and KILICAFE became the first organization licensed by the Tanzania Coffee Board to export directly to buyers in the United States, Japan, and Europe. Also in 2003, KILICAFE, supported by TechnoServe, signed a contract to supply coffee beans directly to Starbucks. By 2006 the volume of this direct trade had more than tripled. Another major development was KILICAFE's partnership with Peet's Coffee & Tea, which in 2005 launched the "Tanzania Kilimanjaro" brand of coffee in the United States. The best-quality beans produced by KILICAFE's member farmer groups are used in this specialty single-origin coffee. The participating farmers receive a 50 percent premium over the average coffee price at the national auction.

These marketing and quality innovations increased annual revenues by about $1 million for those Tanzanian coffee farmers participating in the TechnoServe project. But Tanzanian farmers were still exposed to considerable price volatility risk. To mitigate these risks, in October 2006 KILICAFE purchased its first options contracts on the New York Board of Trade coffee futures market. This financial operation was designed to help farmers recover their production costs in the event of a major price decline during the two months between harvesting and marketing the coffee. This is another example of how innovations based on existing knowledge—in this case, knowledge of standard financial hedging instruments—can help farmers increase the value of their resource-based exports.

Beatrice Gakuba, chief executive officer, RwandaFlora, described her experience building a high-quality, skill-intensive, cut flower–exporting business in Rwanda.

Following the 1994 genocide, Gakuba returned to her native Rwanda after a 20-year career working in international development organizations such as the World Bank and UNESCO. She purchased RwandaFlora as it was being liquidated in early 2004 and transformed the small farm into a globally competitive eight-hectare operation that sells premium-quality roses in the Amsterdam flower auction market. To auction flowers in the Amsterdam market, growers must obtain quality certification by fulfilling strict standards of size, color, freshness, and longevity. The success of RwandaFlora in the competitive, high-quality European flower market is all the more inspiring, particularly given Rwanda's landlocked position in Africa. By successfully handling the supply chain logistics of such perishable and delicate products as cut flowers, RwandaFlora shows that geography is not destiny. Skill, knowledge, and business acumen can triumph over impediments of unfavorable geography.

To produce and sell export-grade horticulture products requires specialized technical know-how and business skills. In the case of RwandaFlora, this means that more than 200 workers had to be trained in a variety of farm and postharvest skills and techniques. The skills vary in nature and intensity. Farmworkers must learn to grow plants under controlled greenhouse conditions; to monitor them for proper growth; to prepare the soil with the right mix of fertilizer and water; to prune and harvest the stems at proper intervals; to grade flowers with strict criterion of freshness, color, and size; to sort them according to variety and size; and to box them in special packages bound for overseas market via cargo planes. Also, to satisfy consumer tastes, the firm needs to constantly monitor market trends—for example, what flowers are selling where in what season.

Gakuba acquired this technical, market, and entrepreneurial knowledge during her time outside Rwanda. More important, she then developed techniques for transferring this knowledge to her farmworkers through an extensive training and outreach program. And perhaps just as important, Gakuba provides the entrepreneurial know-how required to (i) organize production for a highly competitive, knowledge-intensive segment of the global market; (ii) link semiliterate, rural subsistence farmers to the global market without pushing them off the land and into urban slums; and (iii) help subsistence farmers generate the cash incomes that will improve their quality and standard of living.

Gakuba explained that she hopes to expand this farmworkers outreach plan via an ambitious PILOT (Pioneering Initiatives Linking Outgrowers to Trade) strategy to engage more than 4,000 outgrowers in the immediate vicinity of the existing RwandaFlora farm. The firm will provide these outgrowers with farm inputs and training and sell their products in local and global markets. The scope of the worker outreach agenda at RwandaFlora far exceeds the technical training agenda. The rural workers—80 percent of whom are women at this firm—would acquire not only productive skills and a secure source of income but also a number of social benefits. For example, workers would get access to health care plans and HIV/AIDS training and their children would receive compulsory education and daycare. On the whole, RwandaFlora lifts rural workers from their subsistence living by offering them better skills, higher incomes, and greater job benefits.

Through entrepreneurship and skills promotion, the RwandaFlora case study shows how the diaspora can be an important ingredient for building STI capacity and reducing rural poverty. As the first horticulture export firm in Rwanda, RwandaFlora started on uncharted grounds. The skills base and managerial know-how needed for running a globally competitive horticulture firm was missing in Rwanda. Gakuba fills this gap with her knowledge of overseas market and of greenhouse production. In acting as the bellwether of skill and entrepreneurship, Gakuba belongs to a small but growing group of expatriate entrepreneurs in Rwanda. These entrepreneurs are among Rwanda's likeliest levers for boosting innovation, capacity, and competitiveness. They scan global markets and pick

> "Our most important investment has been in people . . . training, capacity building, and incentives will be promoted through our Trade Facilitation Centre."
>
> —Beatrice Gakuba, chief executive officer, RwandaFlora, speaking at the Global Forum

trends and niches in sectors in which Rwanda can compete—coffee, flowers, and silk textiles, for example. They arrange the production and training, financing and logistics, and branding and marketing needed to fill those market gaps. They thus connect local producers and farmers to higher-paying foreign markets. Indeed, thanks to this emerging group of expatriate entrepreneurs, Rwanda has started carving inroads in international markets, selling such high-value goods as specialty coffee, fresh flowers and vegetables, and organic silk.

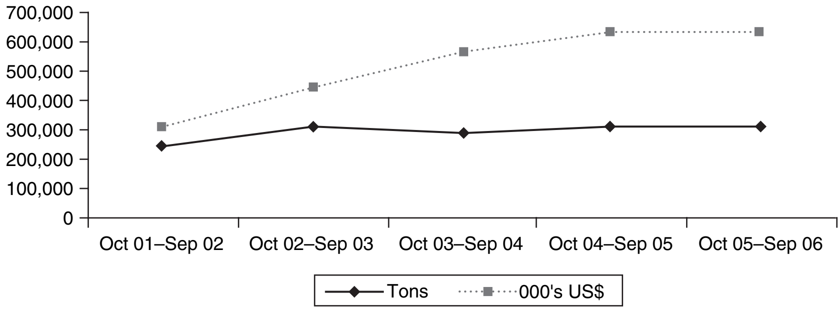
A key policy lesson to emerge from Gakuba's presentation is that the diaspora can be a vital source for business investment, jobs creation, skills development, and higher competitiveness. Strategies for attracting expatriates, offering them incentives for building businesses, and signing social contracts with them can accelerate a country's growth. Another key lesson is that subsistence farmers generally will have difficulty breaking the low-skill, low-income cycle if they cannot produce and sell higher-value goods in higher-paying markets. But this shift—from low- to higher-income activities—is unlikely to happen without an entrepreneur bridging the vast gap between farmers and the foreign markets.

Hasit "Tiku" Shah, managing director of the Sunripe group of companies and chairman of the Fresh Produce Exporters Association of Kenya, described the story of the Kenyan horticulture industry.[12] Horticulture has become the second-largest merchandise export industry in Kenya, behind only tea and ahead of such traditional exports as coffee. Perhaps the most telling sign of success is not that Kenyan horticulture grew rapidly but that innovations introduced in this industry since the 1990s enabled the value of horticulture exports to increase much faster than their volume (see figure II.4). Between 1991 and 2002, fresh vegetable exports from Kenya increased by 75 percent in volume terms but by 400 percent in value. At the same time, the value of cut flowers increased approximately threefold, while the area planted only doubled. It is also notable that prices for Kenyan horticultural exports tend to be more stable than those for tea and coffee.

Kenya's success in horticulture depends only partially on the country's favorable climate and a range of ecological zones that allow year-round production of a number of crops. Most important, it is the story of private

12 In addition to Hasit Shah's presentation at the Global Forum, the text is based on the following sources: English, Jaffee, and Okello (2006, 117–47); Whitaker and Kolavalli (2006, 335–67), and World Bank (2004, 52–55).

Figure II.4. Recent Trends in Kenyan Horticulture



Source: Shah, Global Forum presentation.

sector innovation and adaptability in the face of new challenges presented by a fast-changing market environment.

The export horticulture industry took off in Kenya in the second half of the 1970s, when the tea and coffee booms ended abruptly and Kenya's transport cost disadvantage was aggravated by higher energy prices. Interestingly, this suggests that crisis can be a source of innovation and long-term success if local enterprises have the capacity and acumen to respond appropriately. In the case of the Kenyan horticulture industry, the increased transport cost helped trigger innovation, economic adaptation, and commercial success. During the 1980s, however, many suppliers were actively entering the global horticultural market and driving down prices. As a result, fresh vegetables exports from Kenya were growing faster in volume than in value terms.

By the 1990s, the leading Kenyan firms found ways to avoid price competition with low-cost competitors. In fact, they managed to translate additional challenges posed by the rising standards of the European fruit, vegetable, and flower markets into a competitive advantage. Specifically, Kenyan firms found ways to produce new horticultural varieties preferred by foreign consumers and to establish a reputation for meeting quality, health, environmental, and labor standards. This allowed many Kenyan firms to charge higher prices while competing on the basis of quality rather than only on the basis of price.

Foreign investors and foreign partners were the main source of expertise on export market requirements, innovation opportunities, and advanced production technologies. In 1968, for example, Del Monte (California Packing Corporation) acquired a majority interest in Kenyan Canners (pineapple canning firm). Del Monte brought over its management, technology, and marketing expertise while the Kenyan government gave it a 10-year monopoly on local pineapple processing along with reductions in rail, wharfage, and handling charges. This business started growing rapidly after 1975, and canned pineapples are still the largest single manufactured export from Kenya.

In 1981 a joint venture between the local cannery Njoro Canners and a large French company, Saupiquet, was established to export high-quality canned green beans. Currently, this is the largest private sector contract farming operation in Kenya. It exports canned beans, frozen and dehydrated vegetables, and tomato paste. The industry leader in fresh fruit and vegetable trade—Homegrown—was founded by a British entrepreneur. And more recently, several major supermarket chains from the United Kingdom made large investments in growing "exotic" fruits and vegetables and producing prepared food products under their own brand names.

The cut flower industry, the fastest-growing segment of the Kenyan horticulture industry, was also founded initially by foreign investors. Today, the industry is owned mostly by Kenyans, but it continues to rely on foreign expertise. In 1969 a Danish company, Dansk Chrysanthemum and Kultur (DCK), made a large-scale investment in the Kenyan horticulture industry with the help of a grant from the Danish government. The Kenyan government provided a low-cost lease for land and exclusive growing and trading rights for eight years on several types of flowers, unlimited work permits for expatriate workers, and a 25-year guarantee not to change laws on foreign investor taxation and profit repatriation. Using its European-based experience in flower growing, DCK experimented with chrysanthemums, asparagus plumosus, and carnations before it focused on carnations as the most sturdy and suitable for transportation.

Even though DCK ceased operations in 1976, its original success in Kenya attracted other investors, both foreign and national. The former staff and managers of DCK started many small and medium-size commercial farms, and some of the DCK expatriate experts were retained by these newly established firms. Other large cut flower companies either involved joint ventures with Dutch companies or used technical assistance provided by foreign flower specialists.

In addition to foreign investment and expatriate specialists, Kenyans of Asian and European origin played an important role in marketing Kenyan horticultural products. For example, early export operations benefited from personal connections to Asian communities in Europe. In 1991

Kenyans of Asian descent were estimated to account for 64 percent of Kenya's fresh fruit and vegetable exports. European Kenyans accounted for another 17 percent as well as 25 percent of cut flower exports.

Tiku Shah's firm, Sunripe, was founded by Kenyan Asian families, initially to export Asian vegetables to Asian communities in Europe. It currently employs more than 2,000 workers and exports a wide variety of vegetables to 17 countries ranging from Singapore to Canada. Sunripe was among the first Kenyan companies to switch from bulk vegetables to higher value-added prepacked produce—washed, chopped, packed, and bar-coded for the European market.

The composition of Kenyan horticultural exports is constantly changing in response to the changing global demand and price structure, with floriculture growing particularly rapidly. Higher-price roses, rather than carnations, now constitute 70 to 75 percent of the total flower exports by volume and 70 to 90 percent by value. The technology of production and postharvest operations is becoming increasingly sophisticated, because of the shift to new, higher-value but more capital- and knowledge-intensive products and stricter quality requirements in export markets. To meet the fast-moving international quality standards, the latest production and postharvest care equipment and other inputs are imported from Europe and Israel, including greenhouses and irrigation systems, longlife (modified atmosphere) packaging, food processing, and bouquet-making machinery.

The complexity of technology and the scale of value added in cut flowers and prepacked fresh produce can be even higher than in processed fruits and vegetables, even though the former are classified as agricultural exports and the latter as manufacturing exports. Kenyan horticultural companies employ approximately 135,000 people, mostly semiskilled workers for farms and packhouses, but also many engineers and horticulture specialists. The majority of greenhouse managers are expatriates from Europe, Israel, and India, but the number of Kenyan managers is increasing. Demand for trained and experienced Kenyan specialists to substitute for expatriates appears to be high, and local technological capacity building continues. In 2005 the first class of students graduated from a newly introduced degree program in ornamental horticulture at the Jomo Kenyatta University of Agriculture and Technology. It is noteworthy that experienced Kenyan farm managers are now operating farms in Tanzania, Uganda, Rwanda, Ethiopia, Morocco, and the Arab Republic of Egypt.

In addition to machinery and equipment, planting material is another critical input that determines success in the horticulture sector. Developing new and improved varieties reflecting consumer preferences, as well as local growing conditions, takes considerable R&D expertise and high-risk investment. At this point, all the genetic materials for Kenyan horticulture come from European breeders, including those varieties that are specifically adapted to Kenyan growing conditions. For example, 15 rose breeders in Europe specifically target Kenya. Some of them invest in their own facilities in Kenya to conduct local field trials. Others conduct local field trials by contracting with Kenyan growers. Plant propagation of selected varieties is usually outsourced to larger Kenyan operations to reduce labor and transport costs. But to get access to the best genetic material, royalties have to be paid by producers on every plant cultivated for international trade. Compliance is enforced by the Kenya Plant Health Inspectorate Service, which was formed in 1997 after Kenya had officially joined the International Union for the Protection of New Varieties of Plants (UPOV).[13]

The downstream components of the horticultural value chains—transport, marketing, and distribution channels—are more actively managed and integrated by the largest Kenyan exporters. Many have established direct relationships with European retailers, including large supermarket chains, and some have opened up their own import-export offices abroad. An innovative Tele Flower Auction launched by the leading Kenyan flower producer is now challenging the dominance of the Dutch flower market auctions. This alternative distribution channel, allowing buyers to purchase flowers remotely via computer, now handles 20 to 30 percent of Kenyan flower exports into the Netherlands as well as flower exports from some other countries.

The high capital and knowledge intensity of Kenyan horticulture is leading to increasing industrial concentration. For example, in the cut flower industry, about two dozen large-scale farms account for 75 percent of all exports. At the same time, 4,000 to 5,000 small-scale growers (each owning no more than one hectare of land) face an uncertain future given the growing production and marketing costs and the declining demand for lower-quality flowers. The Kenyan government is taking steps to facilitate the access small farms have to current technological knowledge and export markets, but the costs of compliance with high and changing codes of quality may still exceed the ability of smaller producers to adapt.

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13 The pressure for joining this union came from the larger players in the private industry itself, which had suffered from insufficient access to the newest varieties. At present, smaller producers unable to pay royalties are limited to growing older, non-UPOV varieties.

The role of government in Kenyan horticulture was limited to encouraging initial FDI, promoting foreign tourism (a complementary industry), and, more recently, working with the private sector to implement plant variety protection laws and to help meet international standards. In fact, the government's hands-off policy toward the horticultural industry (which contrasts with the much more active government policies in coffee, tea, and some other industries) is often seen as one of the critical reasons for the success of the Kenyan horticulture industry. The government's laissez-faire approach allows the Kenyan private sector to play the leading role in identifying the most attractive market opportunities and engaging in technological learning from foreign investors, input suppliers, or buyers. This demonstrates the importance of continuing to facilitate rather than regulate horticulture.

At the same time, private horticultural firms would like to see the Kenyan government play a more active role in investing in complementary infrastructure such as a reliable power supply, negotiating with other countries on favorable market access and freer movement of people, encouraging foreign investors and partners, promoting affordable credit services, and funding related R&D activities in universities and research institutions.

It is essential to maintain a constant dialogue between the government, the private sector, and development partners ("PPDP rather than the usual PPP"). The Fresh Produce Exporters Association and the Kenya Flower Council play an important role in this dialogue. In particular, both associations have come up with self-regulating industry codes of practice that meet and exceed local and international legislation. These codes (which tend to undergo annual revisions) supplement a "strong and respected" sanitary and phytosanitary government inspection regime. Taken together, they ensure that fresh produce exports from Kenya comply not only with European and U.S. food safety regulations but also with the conditions of labor and environmental impact standards.

Joaquin Cordua, director of education and human development, Fundacion Chile, presented the case of the Chilean aquaculture industry. Much of the credit for creating a new internationally competitive industry was attributed to Fundacion Chile, a privately owned nonprofit organization whose mission is "to add economic value to Chile's products and services by promoting innovation and technology transfer activities, aimed at taking better advantage of Chile's natural resources and human capital." Acting jointly with Chile's public development agency, CORFO (Chilean Economic Development Agency), Fundacion Chile played a catalytic role by identifying a promising market for farm-raised salmon, importing the necessary equipment and inputs, and launching a successful pilot business. Once Fundacion Chile had demonstrated the technical and economic viability of a farmed salmon business, Chilean and foreign investors provided the private capital that the industry needed to take off. The following points were stressed in the presentation: (i) the importance of conducting detailed market intelligence before attempting to transfer technology to the private sector; (ii) the need to disseminate new technologies widely throughout the private sector, rather than to transfer technology only to one or two selected firms; and (iii) the usefulness of establishing pilot businesses to demonstrate market feasibility and promote the diffusion of the latest technology.

> "Fundacion Chile never invests in any technological works before it is clear that the existing market will pay for the end result."
>
> —Joaquin Cordua, director of education and human development, Fundacion Chile, speaking at the Global Forum

Aquaculture is currently the third-largest exporting industry in Chile (after agriculture and forestry) with annual revenues of more than $2 billion (the following text draws from Katz [2006], 193–223). In salmon farming, Chile is now one of the three global leaders (along with Norway and Scotland), accounting for about a quarter of the total world production. These impressive results were achieved in just over two decades after the first salmon farm was launched by Fundacion Chile in 1982. Economically and technologically, the industry has changed radically during this time. It presently operates on a large scale and close to the global technological frontier. Nevertheless, to continue contributing to national economic development, it needs to deal with new challenges demanding even more sophisticated innovation capacity.

Salmon farming in Chile started as a semi-artisanal industry consisting mostly of family-owned small and medium firms. During this initial stage, all the intermediate inputs were imported. But as the number of Chilean producers and the average size of firms increased considerably during the 1980s, new local industries emerged to provide such critical inputs as salmon eggs, salmon food, and cultivation tanks. These are relatively knowledge-intensive, input supply industries.

A number of supporting value-added services have developed in Chile, including specialized transport, maintenance, veterinary care, labor training, and even software development services, as well as public and private institutions for health and environmental control, regulation, and certification. It is now possible to talk about an aquaculture cluster in Chile; however, compared with respective clusters in Norway or Scotland, the Chilean cluster is still relatively weak when it comes to developing new technology. According to Jorge Katz, "Chilean salmon farming continues to be based on imported machinery, equipment, and know-how, marginally supplemented by ad hoc knowledge-generation and adaptation efforts carried out locally" (Katz 2006, 211–12).

Perhaps the weakest component of the emerging Chilean aquaculture cluster is the link between the aquaculture industry and the Chilean universities that perform agricultural R&D and train biologists, pharmacologists, marine geneticists, and other relevant specialists.[14] Nevertheless, some important developments are taking place in this area. Some universities are involved in cooperative programs with salmon-farming firms or with producers of intermediate inputs, including pharmaceuticals. And a sophisticated system exists to fund such R&D programs from public and public-private sources, often under risk-sharing contracts with industrial companies. In addition to Fundacion Chile and CORFO, funding sources include CONICYT (National Commission for Scientific and Technological Research), ProChile (Export Promotion Office), FONDEF (Scientific and Technological Development Fund), FONTEC (National Technological Development and Production Fund), FIP (Fisheries Research Fund), and others. Annual spending on aquaculture-related R&D is at least $10 million, with about three-quarters of the total coming from public sources.

Unlike the case of Kenyan horticulture, FDI, joint ventures with foreign companies, and expatriate experts were not the initial major source of expertise and technological know-how for Chilean salmon-farming firms. Instead, Fundacion Chile served as the main conduit for transferring existing knowledge to Chilean firms. Fundacion Chile played the major role in searching for appropriate foreign sources of advanced technologies and disseminating this information to private firms. It organized regular study and business missions to Norway, Scotland, England, and the United States for representatives of firms, public agencies, and institutions responsible for technology development. The results of these missions were made widely available through

14 The establishment of Fundacion Chile as a sophisticated technological adaptation and dissemination agency is sometimes believed to have created obstacles to a greater role for Chilean universities as providers of knowledge to industry (Katz 2006, 217).

publication in specialized technical magazines, seminars, fairs, and consulting services.[15]

The current challenges facing Chilean aquaculture are the saturated global market for salmon, increased global competition, and falling prices. Chile's firms must differentiate their products to stave off the commoditization process. The industry's growth potential will now depend on its capacity to reduce costs or to diversify its products and create new markets.

Session 2: Conclusions

The four success stories described above show that it is quite possible for low- and middle-income countries to increase the value of their natural resources by using them in combination with imported technologies to produce high-quality internationally competitive products. Several important lessons of experience emerge from these case studies of how successful developing country exporters adapted foreign knowledge to command much higher prices for their resource-based goods.

- **Correctly identifying the most attractive, least price-sensitive, and potentially most dynamic consumer market** seems to be a first step to success. **Switching to higher-value products**, better aligned with consumer preferences, is the next step. For example, the niche market for Tanzanian high-end specialty coffee was identified by a foreign NGO, the market for Kenyan off-season flowers and fruits was identified by foreign investors, the market for Rwandan roses was identified by a returning member of the Rwandan diaspora, and the market for Chilean fresh fish was identified by the public-private organization, Fundacion Chile. In response to market demand, Kenyan floriculture firms later managed to switch from hardy but relatively inexpensive carnations to rose production, which is more technologically complex and capital intensive. Knowledge of the market, coupled with the capacity to adapt and adopt new, more sophisticated production processes was at the center of these technological innovations. STI capacity building programs need to focus on building this capacity.

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15 This model of autonomous technological learning, drawing mainly from foreign sources of knowledge, may gradually lose its dominance as a result of the acquisition of Chilean salmon firms by large foreign corporations (mainly Scandinavian). In just five years (1994–99), the number of salmon-farming firms in Chile decreased by more than 50 percent and well over half the installed capacity in the sector fell under the control of the world's largest salmon-farming companies (see Katz 2006, 198–200).

- **To succeed in less price-sensitive markets, it is critical that firms learn how to meet the quality standards of their most demanding consumers**. For example, Tanzanian coffee growers not only learned to use improved technologies to process coffee beans, but also learned to certify their beans as organic and fair trade. Similarly, Kenyan horticulture firms certified their output not only for health and safety but also for labor conditions and environmental impact, because this is what European consumers value and are prepared to pay for. STI capacity building for quality improvement must be another objective.
- **Processing resource-based products, rather than shipping unprocessed raw materials, adds value and generates additional revenues for local producers**. For example, Kenyan prepacked vegetables and table-ready flower arrangements command considerably higher prices in British supermarkets compared with bulk vegetables and flowers. Technological learning for additional processing must be another important element of STI capacity building programs.
- All of these steps require employees, ranging from top managers to rank-and-file workers, to learn new skills. In most cases, **specialized staff training** had to be provided. **Foreign consultants** and **foreign equipment suppliers** often acted as the main source of information about the latest technologies (as in Kenyan horticulture). In lower-income countries such as Tanzania, development aid agencies, foreign NGOs, and local producer and exporter associations played the leading role in providing access to appropriate foreign technological knowledge. Finally, in middle-income countries like Chile, staff training and upgrading were provided by PPPs and domestic educational institutions. Interestingly, the most relevant training happened outside the formal school system, but formal education still played an important role in producing the general skills—literacy, numeracy, and so on—that workers require.
- To better understand the demand of the end consumers and to capture a higher share of the goods' final market value, most successful exporters also **developed direct links to their foreign customers,** bypassing intermediate distributors. For example, some Kenyan flower growers managed to contract directly with British supermarket chains. One firm in the Kenyan flower industry, Oserian, even established an Internet-based Tele Flower Auction as an alternative to the Dutch flower auctions. For KILICAFE in Tanzania, contracting directly with Starbucks and Peet's Coffee & Tea was an important step forward that allowed coffee farmers to nearly double the price they received for

their best raw coffee beans. As Fairbanks and Lindsay show in their book, *Plowing the Sea* (1997), creating distribution channels in other countries does not always make business sense for every producer. But in general, "It is true that the closer one is to the customer, the easier it is to understand the customer's purchasing criteria. This knowledge then presents the opportunity to develop products and services for which customers may be willing to pay more" (Fairbanks and Lindsay 1997, 68). So "if exporting firms in developing countries are to have any hope of capturing more of the economic rewards they now create for others," they must learn to optimize their global distribution channels (Fairbanks and Lindsay 1997, 74).

How sustainable are these success stories? Tanzanian coffee growers appear to face the highest risk of being undercut by competitors from other low-income countries because the new technologies they learned to use are relatively easy to imitate. There are relatively low knowledge barriers for new entrants. By contrast, technologies used in Kenyan horticulture are quite sophisticated and difficult to imitate by other developing countries. However, these technologies are developing rapidly. Most originate outside Kenya in countries with fairly sophisticated R&D capabilities. As a result, Kenyan horticulture is reliant on continuous injections of foreign S&T knowledge, which will be forthcoming only if Kenya continues to remain attractive to foreign investors. But what will happen if wages in Kenya rise (which is a desirable development outcome)? Will Kenya be able to continue attracting foreign horticultural investors by offering better-qualified labor than lower-wage competitor countries? Or will Kenyan managers and entrepreneurs be able to compete on the basis of new advances in homegrown technology? Either way, the long-term future of Kenyan horticulture will depend to a great extent on the pace of national STI capacity building that is happening today and must accelerate tomorrow.

To be able to withstand the likely challenges from both lower-wage imitators (competing on costs) and higher-capacity innovators (competing on value), today's successful exporters from developing countries might want to consider some additional STI capacity building strategies. These include the following:

- **Differentiating the firm or country's products from those of current or prospective competitors.** This differentiation allows exporters to avoid the "commodity trap" by simultaneously adding value to natural resources and providing for more retainable—that is, more difficult to imitate—competitive advantages. As long as differentiation focuses on those product attributes that consumers value most, differentiation can lead to premium prices, higher demand, and buyer loyalty. Differentiation has not been a prominent feature in the competitive strategies of any of the case studies examined in the session on Adding Value to Natural Resource Exports. However, as Fairbanks and Lindsay explain, "There is no question that achieving differentiation is difficult, but that is precisely why differentiated strategies tend to be more sustainable" (1997, 126–27).

- **Moving up the value chain by building the STI capacity required to produce not only resource-based products but also the required inputs.** Developing domestic clusters of related and supporting industries and specialized training and R&D institutions will require a coordinated national effort because these tasks are beyond the capacity of individual companies. But such effort can be worthwhile for several reasons. First, such inputs as machinery and equipment or biochemical and genetic materials are much more knowledge- and skill-intensive than most resource-based goods. Engaging in their production rather than importing them means creating better-paying jobs for higher-qualified workers, directly contributing to national wealth and development. Secondly, competitive advantages stemming from strong national clusters are usually much more retainable. Close working relationships between export industries and their home-based suppliers provide for lower input costs and earlier and more reliable access to the newest inputs. Perhaps even more important, these relationships provide for sharing market information, ideas, and R&D results that allow for joint technological problem solving and innovation. Clusters also facilitate the development and upgrading of the specialized human capital needed for technological innovation. Taken together, these benefits can enhance STI capacity and improve the ability of local enterprises to confront new market challenges.[16]

Unfortunately, but not surprisingly, few developing countries have succeeded in establishing knowledge-driven industrial clusters. For example, even though some supporting industries began to grow around the Kenyan floriculture and Chilean salmon industries, the bulk of capital goods is still imported and practically all significant R&D is

16 For a good description of a resource-based but knowledge-driven industrial cluster, see, for example, the case of the Swedish forest industry in Blomstrom and Kokko (2007, 213–46).

done in high-income countries, for example, in the Netherlands and Israel for floriculture or in Norway and Scotland for salmon farming. Analysts point out that Kenya and Chile became globally significant production centers, but not technological innovation centers (Chandra and Kolavalli 2006, 32).

All seven strategies enumerated above require firms to invest considerable resources and effort in building their STI capacities and learning to use more complex foreign technologies. However, the cost and effort needed to apply these seven strategies differ considerably between the first five and the last two. For example, identifying niche markets and switching to higher-value products, improving quality and increasing processing, training staff, and even establishing direct export channels in principle can be performed by individual firms (with some help from external partners). However, transforming successful export industries into strong national clusters capable of differentiating their products and maintaining their competitiveness by means of frontier innovation is a much larger-scale and longer-term undertaking. Most likely, it requires a national vision, followed by coordinated public policies and company strategies.

A final question pertinent to the four case studies discussed in the session Adding Value to Natural Resource Exports revolves around the long-term development impact of these successes. Even if a particular exporting industry does not survive international competition in the long run, will its temporary success have a positive (or negative) impact on the pace of national STI capacity building? This impact can depend on a number of critical factors, including (i) the complexity and flexibility of the STI capacity acquired in the course of learning to export, and (ii) the skills developed during the initial success. Arguably, the acquired knowledge and skills can be particularly valuable and long lasting if they are embedded in new institutions in addition to individual workers and managers. Institutionalized technological knowledge is more likely to survive a specific enterprise or industry and to spill over to other national industries.

For example, the establishment of the Association of Kilimanjaro Coffee Growers in Tanzania might prove to be more consequential in the long run than learning to use new imported equipment and shifting to a new market niche. When the market niche for specialty coffees becomes oversupplied or the recently imported machines become outdated, this association might play a critical role in identifying a new market niche or finding another source of technology. In Kenyan horticulture, new self-regulating institutions such as the Fresh Produce Exporters Association and the Kenya Flower Council appear to be particularly important if their experience with formulating, revising, and enforcing industry-wide codes of practice spills over to other Kenyan industries, thereby aiding their penetration of the global market. And in the Chilean salmon industry, the emerging practice of cooperative industry-university R&D projects with various mechanisms of funding from public and private-public sources seems to be of particular significance with the potential to have a development impact on many other industries beyond fisheries.

"While large-scale, low-paying employment may appear to be good for a nation, choosing to compete in industry segments on the basis of labor rate advantages is a very poor strategic choice. Wealth creation is the object of economic growth; to grow in a manner that actually impoverishes people should not be the objective. Better to develop capacities that enable companies to pay workers well. Economic growth and social equity are no longer inherently contradictory objectives."
—Michael Fairbanks and Stace Lindsay (1997, 31)

Building professional skills and increasing incomes of many can also have a long-term development impact if they initiate the virtuous circle of training, learning, and investing (including investing in training again). For example, the Chilean salmon-farming industry has created 60,000 jobs in the depressed Southern part of Chile, mostly for women with no previous experience of formal employment. But for a fast-growing middle-income country like Chile, creating a large number of low-paying jobs can only be a good first step. It must then be followed by further steps aimed at raising the skill intensity of jobs that would, in turn, lead to increased labor productivity and higher salaries of workers in the industry.[17]

Session 3. Latecomer Strategies for Catching Up: The Role of STI Capacity Building

For developing countries, catching up with global economic and technological leaders requires finding a niche in the global division of labor and using that initial niche to move from less-knowledge-intensive, lower

17 For example, based on Chile's rankings in the Global Competitiveness Index, the World Economic Forum advises Chilean authorities "to focus attention on upgrading the capacities of the labor force, with a view to rapidly narrowing the skills gap with respect to Finland, Ireland and New Zealand, the relevant comparator group for Chile" (Salai-i-Martin and Schwab 2006).

value-added activities to more-knowledge-intensive, higher value-added activities. But devising a strategy to gain a low–value-added foothold in a sector and then to move up the value chain is not a simple or straightforward task. The most critical aspect of the catching-up process is building the capacity to absorb, adapt, and adopt technologies already being used in other countries. This is not a passive process and it is not something that simply happens to an enterprise or an economy. Nor is it simply a question of attracting foreign direct investment (FDI) and then waiting passively for foreign investors to foster the catch-up process. On the contrary, experience suggests that catching up requires conscious, active, coordinated capacity building policies at the level of individual firms, as well as at the level of government agencies, public-private technology development institutions, technical and vocational training institutions, and secondary and tertiary education institutions.

How do firms and countries catch up to technological leaders? How do they learn? Perhaps even more important, how do they learn to learn? And what can they learn from the historical lessons of experience of those countries, sectors, and enterprises that successfully learned to catch up?

The Global Forum attempted to answer these questions based on the experiences of developing countries that have successfully caught up (or closed the gap) with leaders in various high-tech and non-high-tech sectors. The forum examined ways that countries have employed innovative public-private partnerships to support the technology catch-up process and foster local innovation. It also explored what FDI can—and cannot—contribute to the catch-up process and what policies and programs can help countries capture the potential catch-up benefits of FDI.

John A. Mathews noted that "the strategic goal of the latecomer is . . . to move as quickly as possible from imitation to innovation" (Mathews 2002, 471). Fortunately, latecomer firms and latecomer countries have a distinct advantage—that is, the opportunity to identify and use existing advanced technologies rather than devoting time, resources, and effort to develop new technologies from scratch. But this means that firms and countries must develop the science, technology, and innovation (STI) capacity to exploit this opportunity.

Charles Weiss explained that STI capacity building was an integral part of World Bank investment lending during the 1970s and 1980s, especially for big-ticket infrastructure projects. That focus on capacity building fell away, as the Bank shifted from investment lending to policy-based lending. The Bank should recall its earlier history and make STI capacity building an explicit, integral component of all investment projects.

Nanci S. Palmintere described what the Intel Corporation looks for when it selects sites for its foreign facilities and investments. Many countries hope to attract technology-intensive FDI with the expectation that this will generate a steady stream of export earnings, new high-paying jobs, and a foothold in the global high-tech sector. Yet, the economic impact of high-tech foreign investments on the domestic economy depends to a large extent on the number of backward linkages that emerge between the technologically advanced foreign affiliates and their local suppliers and support industries. These linkages will not emerge spontaneously, however. They have to be cultivated as part of an overall STI capacity building program.

Roberto Calvo described Costa Rica's program (Provee), which is designed to help local small and medium enterprises (SMEs) become qualified suppliers to the multinational firms operating in Costa Rica. Sustainable links between multinational corporations and local SMEs do not emerge simply because a foreign investor is present in the country. They require active support from the local government as well as favorable economic policies and a good business climate. The Costa Rica Provee program involves training, a technology assessment, and linking promotion programs designed to build up the STI, quality control, and production capacities of local SMEs.

John Varney explained how successful supplier development programs in the Czech Republic and Serbia helped local enterprises become suppliers to transnational corporations (TNCs). Before local firms are qualified to bid on many supply contracts, they have to demonstrate the capacity to achieve quality and reliability standards that are on a par with existing global suppliers. Therefore, governments interested in maximizing the spillovers and linkages that are potentially available from FDI need to develop innovative public–private partnerships to help local enterprises meet these qualifications.

Sungchul Chung explained how the Republic of Korea's Government Research Institutes (GRIs) helped local enterprises adapt and adopt the technology that they needed to become globally competitive. The GRIs in Korea contributed to laying a foundation for development in Korea by attracting top talent in R&D and nurturing a research culture. Over the 1960s–1970s, technical assistance (identifying foreign technologies, reverse engineering them, and/or negotiating technology licenses with foreign companies), such as what GRIs provided, was far more effective than other government support programs, including financial, tax, and other subsidies. For catch-up economies that lack S&T capabilities, the Korean

GRI can be an effective instrument to promote and facilitate technology adaptation in the early stage of industrial development.

Sergio Trindade described the activities of China's Engineering Research Centers (ERCs). These centers were created as one aspect of a much wider reform of China's S&T policies aimed at improving the productivity and competitiveness of national industries. The ERCs are intended to transform a segment of China's public research institutions and university laboratories into market-oriented, technology transfer institutions, responsive to the needs of industry and capable of accelerating the diffusion, adaptation, and adoption of new technologies. Creating such successful, market-responsive ERCs requires the right balance of market and nonmarket incentives.

María del Pilar Noriega described the work of a successful technology transfer institution, the Plastic and Rubber Training and Research Institute (ICIPC) in Colombia. ICIPC's activities include (i) identifying and adapting foreign technologies for use in Colombia; (ii) conducting applied R&D funded by a combination of government and international grants as well as contracts with private firms; (iii) providing laboratory testing services; (iv) training; and (v) providing specialized consulting services. Besides highly qualified personnel and modern infrastructure, the secret of ICIPC's success appears to be its active networking programs with local as well as foreign academic, R&D, and industrial organizations. ICIPC's success is rooted in its client responsiveness, which is based on its close relationships with its founding member and several foreign industrial associations.

Peter Brimble explained how two industries in Thailand—shrimp farming and hard disk drive (HDD) manufacturing—are benefiting from effective partnerships with universities. These partnerships are taking place in an environment characterized by a general absence of strong university-industry linkages (UILs). The resulting linkages created significant benefits for both sides, including accelerated technology upgrading at industrial enterprises and curriculum improvements and the establishment of new academic units in universities. Strong industrial associations, which can effectively articulate the needs of industry, are an important mechanism and prerequisite for establishing successful UILs.

Regina Lacayo Oyanguren described the operations and experience of the Nicaraguan Innovation Fund for SMEs. This project aims to promote exports and national competitiveness by helping SMEs in traditional sectors find, adapt, and adopt new technologies. The Innovation Fund provides matching grants to SMEs working jointly with technological service providers (including local universities, laboratories, and other technological knowledge producers) to finance innovation-related activities. Many participating SMEs have introduced innovations, started training programs, and increased sales and employment. The network of new technological service centers potentially can support a much broader range of technology transfer and dissemination activities in Nicaragua.

Guillermo Fernández de la Garza described the Mexican Ministry of Economy's TechBA program, designed to help high-tech Mexican SMEs sell their goods, services, and technological innovations to global markets. The TechBA program deliberately focuses on high-tech industries with a high growth potential. Whereas most governments try to achieve these objectives by establishing their own technology parks and incubators, TechBA outsourced these incubation services to such recognized innovation leaders as the Enterprise Network of Silicon Valley and Parque Cientifico de Madrid (Spain). In one of the innovative features of this program, the selected companies eventually move to one of TechBA's foreign offices to access venture capital, search for foreign customers, and establish international partnerships and alliances.

David Kaplan spoke about the South African government's efforts to support exports by high-tech SMEs. Encouraging the emergence of well-performing high-tech companies in South Africa will require addressing such innovation constraints as ineffective intellectual property rights (IPR), underdeveloped technical standards, and a shortage of early stage venture capital. But the key problem is the lack of well-trained, skilled workers. STI capacity building programs in South Africa, therefore,

What the panelists said about . . .

Supporting the technological catch-up process

- Technological catch-up is not a passive process. Technological diffusion and spillovers do not happen spontaneously and automatically when countries open themselves to trade and FDI. On the contrary, diffusion and spillovers require proactive capacity building programs.
- The most critical aspect of the catch-up process is building the capacity to absorb, adapt, and adopt technologies that are already in use elsewhere.

(*continued*)

- The latecomer, catch-up process entails learning how to produce and sell more-knowledge-intensive, higher value-added goods and services. (Anyone can purchase a machine. Not everyone can use it to produce and sell a competitive product in the global marketplace.)
- Entrepreneurship, management, and marketing knowledge are critical dimensions of innovation policy, on a par with enhancing scientific and technical knowledge. Both dimensions are essential elements of a national innovation policy.

Building successful programs for catch-up

- Sustainable linkages between multinational corporations and local SMEs do not emerge automatically as a direct consequence of FDI. They require active capacity building support from national governments as well as favorable economic policies and a good business climate.
- Governments interested in maximizing spillovers and links that are potentially available from FDI should establish programs to help local enterprises enhance their STI capacity.
- Programs to assist innovative enterprises should include provisions to improve the IPR regime; develop technical standards; support the emergence of measurement, standards, and testing agencies; and enhance access to early-stage venture capital.
- Effective STI support programs should include provisions to help local enterprises improve their marketing and market intelligence.
- Innovation in SMEs can be spurred through technological innovation funds offering matching grants to SMEs and technological service providers, such as local universities, research laboratories, and other sources of technological information.

Building successful public and public-private partnership (PPP) institutions for catch-up

- In the early stage of industrial development, technical assistance programs and institutions aimed at identifying foreign technologies and negotiating technology licenses with foreign companies can be far more effective instruments to promote and facilitate technology adaptation than other government support programs, including financial, tax, and other subsidies.
- Local technology parks and incubators frequently fail to achieve their desired results, because they do not have the capacity to help local firms access foreign markets, identify relevant technology, or find early-stage venture capital.

- Establishing partnerships with incubators in international innovation centers—for example, the Enterprise Network of Silicon Valley, the Austin Technology Incubator, and Parque Cientifico de Madrid (Spain)—may improve the performance of local incubators and technology parks.
- Creating successful, market-responsive technology development and diffusion institutions requires the right balance of market and nonmarket incentives.
- Client responsiveness and active networking programs with local as well as foreign academic, R&D, and industrial organizations are important qualities for an effective technology development and diffusion organization.
- Strong industrial associations that can effectively articulate the needs of industry are important mechanisms for establishing successful UILs.

should focus on increasing the supply of highly skilled workers by building up the national system of education and training, creating incentives for foreign investors to pay for their employees' training, and relaxing immigration restrictions so that South African companies can recruit highly skilled labor from abroad. Active STI skill building should be supplemented by building marketing and market intelligence skills. This shortage of entrepreneurial skills is a major obstacle to latecomer catch-up efforts.

John A. Mathews, professor of strategic management at Macquarie Graduate School of Management in Australia, noted that "the strategic goal of the latecomer is . . . to move as quickly as possible from imitation to innovation" (Mathews 2007, 25). But a latecomer firm "starts not from the powerful position of an IBM but from the resource-meager position of an isolated firm seeking some connection with the technological and business mainstream" (Mathews 2002, 471). Fortunately, latecomer firms and latecomer countries have a distinct advantage, if they are skillful enough to recognize it and develop tools and strategies for exploiting it. That advantage is the opportunity to identify and use more advanced technologies rather than devoting time, resources, and effort to develop new technologies from scratch. But this means that firms and countries must develop the capacity to exploit this opportunity. The following three essential and interconnected capacity building strategies can help latecomers:

- *Linkage*. Latecomer firms must link themselves to dynamic firms that already have a successful foothold in the global economy. Such linkages

provide the latecomer firm with a window to the global marketplace and to global technology trends.
- *Leverage*. Latecomer firms must devise strategies and develop the capacity to exploit the knowledge and opportunities generated by linkages to more successful firms.
- *Learning*. Latecomer firms must develop the capacity to absorb and adapt the knowledge generated via linkages and leverage and convert that knowledge into new, more profitable economic opportunities.

This entire process, according to Mathews, must be "buttressed, supported and disciplined by an institutional framework that accelerates and guides their learning. Public agencies and various forms of inter-organizational superstructures create the conditions in which the process of learning and leverage can be applied, over and over again, each time at higher levels of technological and organizational capability" (Mathews 2002, 479).

But how can poor countries start this linkage, leverage, and learning process? FDI is frequently viewed as a critical initial step or starting point. The following experts offer their insight on how FDI can, and cannot, contribute to the STI capacity building process (for further discussion about the linkage between FDI and STI capacity building, see Hoekman and Javorcik 2006; Lall and Urata 2003; Rasiah 2004).

Charles Weiss, distinguished professor, Georgetown University School of Foreign Service, and World Bank Science and Technology Advisor from 1971–86, introduced the panel and discussed ways that STI capacity building could be incorporated into infrastructure and other big-ticket investment projects financed by the World Bank and other development partners. In a previous era, World Bank projects financed tangible infrastructure—including roads, ports, electricity-generating plants, and distribution networks, water and sewage treatment plants, and so on—rather than policy-based reforms. In those days, capacity building and training were explicit components of World Bank projects. This training took place on the job, was conducted as part of a study tour or short course in a foreign country (industrial or developing), or involved graduate degree programs overseas. In the best cases, such training was linked to an explicit strategy of institutional strengthening.

This approach certainly had problems. Training consumed only a small proportion of any given loan, and the design and supervision of those projects inevitably focused on the largest components. Training programs too often were tacked onto projects at the last minute, with insufficient budgets and insufficient attention given to their design or execution. Even so, project-related training, when properly conducted, was an important contribution to the development of local capacity. For example, the scientific staff of the Brazilian Agricultural Research Corporation (EMBRAPA) was built up by the training components of a succession of Bank projects.

This approach not only built capacity in the borrowing entity but, in particular instances, also built capacity among the suppliers of goods and services to Bank projects. A Bank policy in effect from about 1981 to 1997 encouraged foreign consulting firms to enter into joint ventures with local firms. This was not done merely for the purpose of import substitution—that is, of substituting local for foreign services—or of saving money on consultants. On the contrary, because the projects financed by the Bank were among the most expensive and far-reaching infrastructure projects in any given country, it was critically important that local people had the capacity to participate in key planning decisions and ensure that the project was carried out properly. As a result of this policy, local firms in some countries, such as Pakistan and the Philippines, were able to build on the experience they gained in Bank-financed projects, not only to win bids for work in their own country but also to export their services in international competition.

Building capacity requires going beyond improving the "enabling environment" for firms operating in a given sector of an economy. For several decades now the Bank has held to the idea that if it could help its member countries to achieve the right overall enabling environment, the resulting incentives would ensure that people would make the right choices and mobilize the right technologies. The government was to level the playing field, facilitate private investment, and get out of the way. "Capacity building was not viewed as important because many believed it would happen automatically," Weiss explained.

Although improving the enabling environment is important, the enabling environment is never quite right. It can always be better. Therefore, it is essential to look to the supply-side as well—that is, the things a country must do and the obstacles it must overcome to develop its own capacity to use knowledge to further its own development. This requires a micro perspective that looks for institutional and policy interventions to facilitate capacity building in particular key sectors and industries.

From past Bank experience, the critical lessons are as follows:

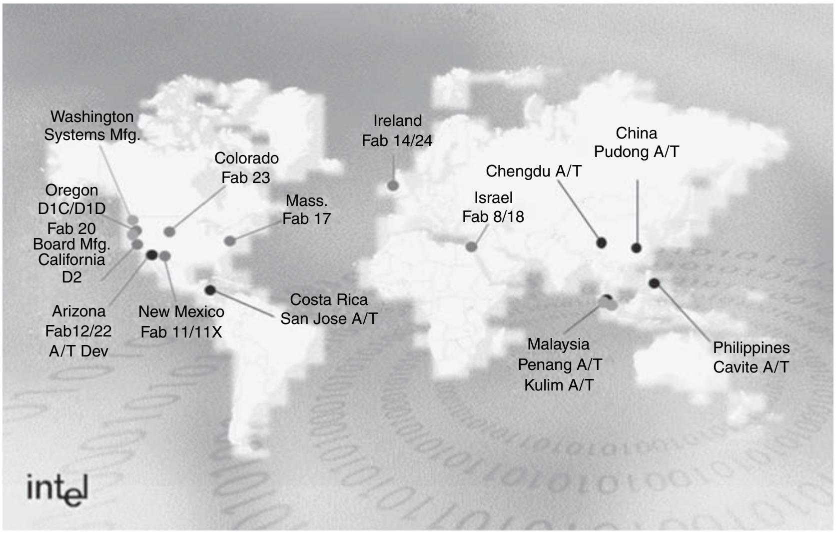
- Capacity building is a critical aspect of economic development.
- Capacity building does not happen automatically.
- The Bank was once strongly committed to building local capacity within its projects.

The Bank should reclaim its earlier history and put a renewed emphasis on capacity building. This would require specific policy commitments on the part of the Bank and the borrower. It would also require a clearly enunciated strategy at both the institutional and project level, specific plans and investments of time and money, and careful design and execution. Given the limitations on the resources available for project preparation and supervision, and the natural tendency to focus on the parts of a loan that consume the most money, it may be wise for the Bank to set up a special fund of administrative resources to ensure that adequate attention is paid to this aspect of Bank lending.

The Bank should learn from the panelists' insights about how investors build capacity among their suppliers in developing countries, and what these investors look for when they select countries and suppliers. These lessons demonstrate how the Bank and government programs can facilitate technical and managerial spillovers from foreign investments and encourage links with feeder industries, rather than accepting foreign-owned firms as self-contained enclaves.

Nanci Palmintere, vice president for finance and enterprise services, Intel Corporation, explained how Intel selects sites for its assembly and test facilities. Intel is a major high-tech TNC, with approximately 300 facilities in 50 countries (also see Spar 1998). It competes primarily by means of its technological leadership in chip design and manufacturing. The complexity of technological processes used to produce computer chips differs considerably between the highly sophisticated, high-skill wafer production and fabrication stages and the much simpler, automated, and medium-skill final stage of chip assembly and testing. According to the world map presented by Nanci Palmintere (see figure II.5), almost all of Intel's assembly and testing operations are located overseas. Only one assembly and test plant is located in the United States (in Oregon), but this is where new testing and assembly technologies are developed and demonstrated. By contrast, almost all of Intel's R&D labs and wafer fabrication plants are in the United States.

Figure II.5. Intel's Worldwide Manufacturing, Assembly, and Test Operations



Source: Palmintere, Global Forum presentation.
Notes: A/T = assembly and test; Fab = fabrication.

Many countries hope to induce Intel to locate a major facility in their territory. They expect that this will generate a steady stream of export earnings, new high-paying jobs, and a foothold in the global high-tech sector. Although most poor countries cannot satisfy Intel's demanding site requirements, more and more developing countries are able to offer large sites for plant construction with well-developed and reliable infrastructure, including easy access to a modern airport with frequent flights to the United States, Europe, and Asia, and a reliable supply of trained workers and technicians. But demonstrating that a country can satisfy these unwavering prerequisites simply means that a country is now eligible to compete for an Intel investment. By no means does it mean that an investment will automatically be forthcoming. During the second phase of the selection process, the cost and the risk of doing business in a country become the decisive criteria.

For example, in the course of its negotiations with the Costa Rican government, Intel used the much lower energy prices available in Mexico as a bargaining tool to gain a special discounted electricity rate from Costa Rican authorities. In addition to infrastructure costs, other major cost factors considered by Intel include wage levels (for the required minimum level of skills), tax treatment (favorable for capital intensive projects), financial incentive packages, and the absence of ownership, capital, and currency restrictions for foreign investors. Because Intel's cost model extends for 10 years into the future, the perceived risks of changes in the political, regulatory, or economic environment also loom large in the final site selection decision. And because the microprocessor industry is highly competitive, with Intel's technological leadership constantly threatened by highly innovative competitors, the factor of speed—in construction, in receiving government permits, or in dealing with customs—is critically important.

Costa Rica was one of those countries that managed to attract a major Intel facility. An Intel assembly and test facility was built in 1997–98, at a time when Intel already had similar facilities in Malaysia, the Philippines, and China. But Intel was interested in diversifying from East Asia to Latin America, and Costa Rica managed to win the regional competition despite its small size (a population of about 4 million people) and limited previous experience with high-tech industries. The main attractions proved to be its political and economic stability, predictable regulatory policies that made no legal distinction between foreigners and local citizens with respect to property ownership and business operations, financial incentives packages available in Costa Rican free trade zones (including 100 percent exemption from profit taxes for 10 to 12 years and from all other taxes indefinitely), and the government's demonstrated willingness to solve any problems that appeared in the course of negotiations. For example, the Costa Rican government agreed to quickly build a dedicated power substation, to improve the site's road access to the airport, to increase the number of flights to Europe and East Asia, and to launch two special education programs (for one and for two years) to ensure a steady flow of trained workers and technicians for the Intel plant.

For Costa Rica, this was a period of shifting priorities in its FDI promotion policies. The country's earlier focus on the textiles and apparel industry proved to be unsustainable because of increasing wages in Costa Rica and intensifying competition from lower-wage countries. The new FDI promotion strategy adopted in the early 1990s focused on attracting electronics firms on the basis of Costa Rica's well-educated but still relatively low-wage pool of workers.

The construction of the $300 million plant was by far the largest foreign investment in Costa Rica. Intel was responsible for about 22 percent of all FDI inflows to Costa Rican industry between 1997 and 2005 and generated 20 percent of the country's annual exports.

The economic impact of Intel and other high-tech foreign investments on the Costa Rican economy depends to a large extent on the number of backward linkages between the technologically advanced foreign affiliates and their local suppliers. To stimulate the emergence of such linkages, the Foreign Trade Corporation of Costa Rica established a special government body called Costa Rica Provee (Costa Rica Provides).

Roberto Calvo, director of Costa Rica Provee, explained that Costa Rica Provee's objective is "to build up the STI and production capacity of local SMEs, improve their international competitiveness, and, as a result, contribute to higher national value-added in the output of multinational firms operating in Costa Rica."[18] To achieve this objective, Costa Rica Provee organizes training and assessment programs to help local SMEs become qualified suppliers to TNCs. This includes training in such issues as International Organization for Standardization (ISO) certification and lean production management. Partly as a result of these efforts, the number of supplier linkages between SMEs and TNCs has grown rapidly—from just 18 in 2003 up to 140 in 2006. The technological complexity of inputs provided by local suppliers has also been increasing. For example, when foreign electronics firms first entered Costa Rica, packaging materials were the only locally sourced inputs. By 2006 local suppliers were also providing a range of metal, plastic, and chemical inputs as well as some services.

TNCs should develop a "culture of local sourcing" and should understand that "local sourcing is not only a sign of their social responsibility, but a competitive issue" resulting in shorter supply chains and lower transportation costs. Alternately, Intel only buys from the most internationally competitive firms, and it usually does not need more than one or two global suppliers for each component. Shorter, more physically compact supply chains and saving on transportation costs are clearly not as important for Intel as ensuring that it receives only the highest-quality inputs.

> "Sustainable linkages between multinational corporations and local SMEs do not emerge automatically as a direct consequence of FDI presence. . . . They require active support from the local government as well as favorable economic policies and business climate."
>
> —Roberto Calvo, director of Costa Rica Provee, speaking at the Global Forum

John Varney, fellow of international business, Newcastle Business School, University of Northumbria (United Kingdom), explained how

18 For additional information on Costa Rica Provee, see http://www.crprovee.com.

he helped local enterprises in the Czech Republic and Serbia qualify to become suppliers to TNCs. "Technology and knowledge transfer from TNCs to suppliers seems only to take place where there is an existing relationship" between the TNC and local enterprise. But even to be considered as potential TNC suppliers, local firms "must have reached a standard for quality which allows them to compete with global suppliers" (the words of Francois Himmelspach, director in Baxtor BioScience TNC, as quoted in John Varney's presentation). Therefore, governments that are interested in maximizing the spillovers and linkages that are potentially available from FDI should establish programs to help local enterprises attain this globally competitive status. This is precisely what the Czech government set out to accomplish.

Specifically, in 2000, the Czech government launched a two-year Pilot Supplier Development Program in the electronics industry. The program was implemented by CzechInvest, a semiautonomous arm of the Czech Ministry of Industry and Trade. The electronics industry was selected because it was second only to the automotive industry in terms of the number of foreign investors operating in the Czech Republic. However, although electronics used to be one of the strongest industries in the Czech Republic during the Soviet period, TNCs were sourcing only 5 percent of their inputs from Czech suppliers, and even these few local suppliers who had won contracts with TNCs were in danger of being supplanted by foreign contractors. The goal of the Pilot Supplier Development Program, therefore, was to help local SMEs deal with international competition so that they could retain existing contracts and, more important, win new, higher value-added contracts. In addition to helping local firms develop commercial supplier links to TNCs, it was felt that a more competitive base of local suppliers would help to embed foreign investors in the Czech Republic, making them less likely to move to lower-cost locations the moment Czech wages began to rise.

Under the terms of this program, 45 of the most promising Czech SMEs were selected for participation based on nominations by partner TNCs, local industrial associations, and industry experts. The Pilot Supplier Development Program worked as follows:

- An enterprise assessment methodology, based on the European Foundation for Quality Management (EFQM)[19] business excellence model was designed to benchmark participating SMEs.

19 For more information about the EFQM model, see www.efqm.org.

- Two simultaneous assessments were conducted of each company: managers were asked to provide their assessment of the company and a team of outside experts was asked to provide a similar assessment.[20] After each group had completed its assessment, the management team of the company and the expert assessing team compared their findings about each company's strengths and weaknesses. The result was a business improvement plan specifically tailored to the unique strengths and weaknesses of each participating company. Each participating company was expected to devote six months to implementing its business improvement plan.
- During this six-month period, business improvement workshops were conducted. This exposed participating companies to the latest techniques in quality control, technology management, personnel training and motivation, and so on.
- A second assessment commenced after this six-month training and improvement period. Companies were reassessed using the same EFQM model and benchmarked against the goals and objectives specified in their business improvement plan.
- Those companies that made the greatest progress received specialized consultancy services from experts in their sector, were introduced to potential clients, and received assistance to achieve highly specific business objectives such as facility redesign, introduction of lean manufacturing, and new approaches to marketing.

The Czech Pilot Supplier Development Program was extended beyond electronics to such disparate sectors as aeronautics, pharmaceuticals, auto manufacturing and engineering. An entirely new supplier development

20 Company managers and expert assessors frequently compiled very different lists of strengths and weaknesses. Company managers believed that outmoded equipment and inadequate access to credit were the greatest hindrances to their efforts to win supply contracts from TNCs. The expert assessors, by comparison, highlighted such issues as (i) the absence of total quality management systems: (ii) deficient or nonexistent programs for training managers and employees in total quality management techniques; (iii) the absence of a strategic planning function to guide the firm's future evolution; and (iv) the absence of a coherent technology improvement program designed to keep the firm on the cutting edge. In other words, while managers decried their outmoded equipment, expert assessors noted that the firms had no capacity to continuously identify, adapt, and adopt new technology. As a result, even if the firms were to receive new equipment, they would quickly fall behind the technology frontier. Weak innovation capacity, rather than the vintage of existing equipment, was the major deficiency that the supplier development program found itself trying to address.

program was inaugurated recently in Serbia and will build on the experience of the Czech pilot.

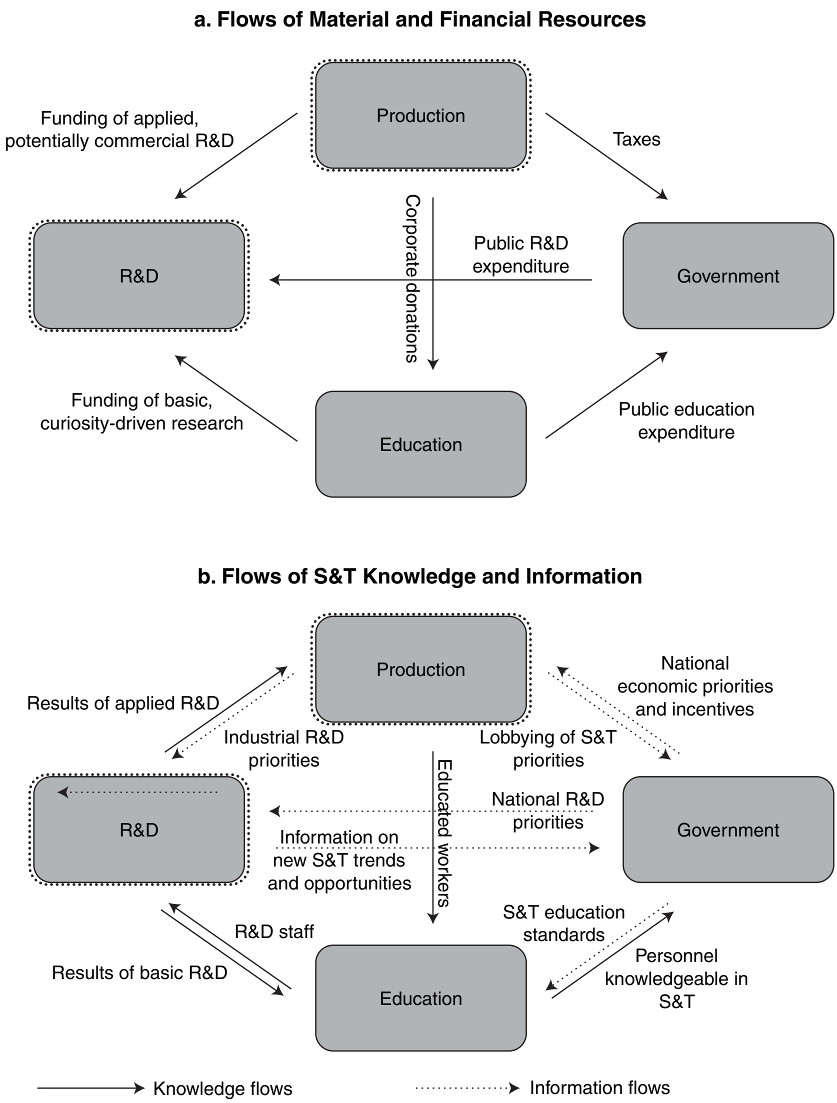
The Czech program was initiated to help local enterprises become qualified suppliers to TNCs. Therefore, it was dubbed a "supplier development" program. However, the program should really be viewed as an innovation and enterprise improvement program designed to help enterprises learn to innovate. From this perspective, even countries without large inflows of FDI can benefit from similar programs. To ensure the long-term viability and sustainability of enterprise improvement and supplier development programs, a special effort is needed to build the local business consulting capacity. This would entail training local personnel to conduct enterprise audits and to help enterprises implement improvement programs. Local universities, especially the business and engineering faculties, should be involved in this process. Although foreign consultants can improve the perceived quality and the prestige of supplier development activities, it is critical to create a legacy system that will continue to function without external support. In other words, building the capacity of prospective capacity building institutions is essential.

Supplier development programs, along with related innovation and enterprise improvement programs, are best designed and implemented as some form of PPP. The second panel in session 3 was devoted to the topic of Building Public-Private Partnership Institutions for Technological Catch-up.

The relative roles played by public and private partners can vary considerably from country to country and from industry to industry depending on the existing and constantly changing balance of capacity between the public and private sectors. The functions performed by PPPs can also differ significantly depending on the needs of economies at different stages of technological development. For example, PPPs have been used to improve the quality of professional and tertiary education, to bolster the private sector's technology acquisition and absorption skills, or to perform R&D to support technological innovation and international competitiveness. Last, but by no means least, by demonstrating the economic viability of a new technology or by sharing in the financial risks of developing and adopting new technologies, PPPs can reduce the private sector's risk of adopting new technologies.

In short, PPPs can be used to strengthen any of the weakest components of an emerging NIS, but they are particularly useful for strengthening the linkages between components illustrated in figure II.6. In designing PPPs for a particular country, historical examples and lessons of experience from other countries can be especially useful. But the institutions and organizational arrangements that work in one country cannot be transplanted without modification to another country. Customizing to account for national traditions and experience will most likely be required (Rodrik and Subramanian 2003).

Figure II.6. National Innovation Systems



Source: Presentation by Tatyana Soubbotina, World Bank STI program 2007.

> "For catch-up economies that lack S&T capabilities, the Korean Government Research Institutes can be an effective model as an instrument to promote and facilitate technology adaptation in the early stage of industrial development."
>
> —Sungchul Chung, president, Korean Science and Technology Policy Institute (STEPI), speaking at the Global Forum

Sungchul Chung, president of the Korean Science and Technology Policy Institute (STEPI),[21] described the Korean experience with "GRIs as Facilitators of Industrial Technology Adaptation." In the space of less than two generations, the Republic of Korea transformed itself from one of the poorest economies in the world to one of the most dynamic industrial economies and one of the global leaders in STI. Since 1961 Korean GNP per capita increased from just $87 to about $20,000 and exports from $55 million to $300 billion. GRIs played a critical role in this transition, "particularly in the early stage of development, when Korea lacked technological capabilities." Moreover, "over the 1960s–1970s, technical assistance, such as what GRIs provided, was far more effective than other government support programs, including financial, tax, and other subsidies."

The first GRIs—the Korea S&T Information Center (KORSTIC) and Korea Institute of Science and Technology (KIST)—were established in the 1960s "in order to make up for the technological weakness of the private industries and help them adapt new technologies" (for more on the role of GRIs in Korea's national technological learning, see Kim 1997). The private sector provided only a minor part of the funding. Especially in the program's early days, the government provided the lion's share of financial support. The GRIs were established as "special nongovernmental corporations" with significant managerial autonomy. The key personnel for GRIs were recruited from among scientists and engineers of Korean descent who were educated or who had worked abroad.

In the 1970s additional specialized GRIs were created, reflecting the industrial priorities of that period:

- Korea Institute of Machineries and Metals (KIMM)
- Korea Research Institute of Standard Science (KRISS)
- Electronic Technology Research Institute (ETRI)
- Korea Research Institute for Chemical Technology (KRICT)

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21 For more information about STEPI, see http://www.stepi.re.kr/english/index.html.

- Korea Research Institute of Shipbuilding and Oceans (KRISO)
- Systems Engineering Research Institute (SERI)

Later, in the late 1980s, the Korea Aerospace Research Institute was created to lead national projects on space technologies, provide satellite technologies to local communication companies, and work with local aircraft companies to develop various types of aircrafts for civilian and military uses.

GRIs initially helped private companies to identify foreign technologies, reverse engineer them, or negotiate technology licenses with foreign companies. At a later date, they began to support the domestic development of pioneering innovations, thereby contributing to Korea's technological leadership in several industries. For example, when the Korean government launched the then-ambitious plans to build Pohang Steel Mill and shipyards, KIST was responsible for technical feasibility studies, basic project concepts, and identifying technologies required for construction. When Japanese companies refused to transfer polyester film production technology to Korea for fear of losing the market, a Korean chemical company, in collaboration with KIST, successfully reverse engineered the technology and Korea became one the major global suppliers of audio- and videocassette tape. And when Corning Glass refused to transfer optical fiber production technology to Korea in 1977, two Chaebol companies entered into a joint project with KIST to develop the technology. In 1983, after seven years of R&D, the locally produced optical cable was tested successfully on a 35-kilometer route. Although the local R&D effort was terminated because of slow progress, it helped Korean firms gain bargaining power to acquire foreign technologies on far more favorable terms.

From their inception through the late-1980s, GRIs primarily helped Korean firms master the use of technology that was widely available in advanced industrial countries. Starting in the late-1980s, however, they switched their focus to helping Korean firms develop cutting-edge global frontier technologies. In 1986 ETRI organized a consortium with four local companies to develop Korea's own electronic switching system for the public telephone—the Time Division Exchange (TDX) system. When the project was successfully completed, the new technology was transferred to participating companies for production and the new system was not only used domestically but also exported. ETRI's other big success was in coordinating the national DRAM (dynamic random access memory chips) development program. Three large companies participated in the project, of which Samsung was the first to announce the completion of designing 4MB DRAM in 1989 and 16MB DRAM in 1990, only a few months after Japan.

GRIs faced considerable difficulties along the way, and these difficulties also illuminate relevant lessons of experience. For example, GRIs were often unfamiliar with technical needs and shop floor capabilities of Korean firms. In other words, they did not always know what local companies needed or wanted. This diminished their credibility in the eyes of private companies, which often preferred getting their technologies in the form of turnkey foreign plants or licenses from experienced foreign firms. In addition, the relevance of GRIs began to diminish in the 1980s as university and private sector R&D capacity began to grow. As the gross Korean expenditure on R&D increased from about 0.2 percent of GDP in 1964 to almost 3 percent of GDP in 2004, the share of public R&D expenditure decreased consistently—from more than 90 percent in 1964 down to just 20–25 percent in the 1990s and early 2000s.[22]

Compared with corporate R&D centers, GRIs were relatively inflexible and less agile in coping with rapid changes in technology and industrial requirements. GRIs were criticized for emphasizing the interests of their sponsoring ministries rather than the national interest and for declining research efficiency caused by interinstitutional barriers to staff mobility. To address these criticisms, the GRI system was reformed in 1999 so that specialized institutes were detached from their ministries, and grouped and placed under three research councils, all under the control of the National Science and Technology Council (NSTC).

Currently, GRIs are still major players in Korean public R&D, accounting for about 40 percent of all government R&D expenditure. However, even though the share of government R&D is now relatively low, this remarkable growth of private sector R&D would not have been possible without extensive public investment in building this national STI capacity in the 1960s and 1970s. GRIs "contributed to laying a foundation for S&T development in Korea by attracting top talent into R&D and nurturing a culture for research" (Sungchul Chung quoted in Kim 2003, 9).

China has its own extensive experience with publicly funded research institutes (PRIs). Specifically, the Chinese system of PRIs was established as a part of a centrally planned, nonmarket economy. It required radical

22 Private R&D expenditure was actively promoted by Korean government policies, including preferential R&D loans, tax incentives, reduced tariffs on import of R&D equipment and supplies, and the exemption of real estate tax on R&D related property (Kim 2003, 11).

reform as the country moved toward a more market-oriented economy. As recently as the 1980s, PRIs received more than 60 percent of government R&D expenditures—35 percent went to the enterprise sector, and 4 percent went to universities (Dahlman and Aubert 2001, 124). Unfortunately, research institutes operated in virtual isolation from the enterprise sector and their research results rarely resulted in any commercial applications. To strengthen the link between the R&D and enterprise sectors, the Chinese government reduced the share of PRI funding coming from central and local government budgets. PRIs were encouraged to make up the funding shortfall by selling their technical services to enterprises. By 1993 less than 30 percent of PRI revenues were derived from government appropriations compared with more than 60 percent in 1986.[23] At the same time, measures were taken to stimulate R&D activities in the enterprise sector so that by the end of the 1990s, the share of R&D performed by enterprises increased to 50 percent of all R&D activities. University-based R&D was also encouraged by government policies (Dahlman and Aubert 2001, 124–25).

The establishment of ERCs was one aspect of this much wider reform of China's S&T policies and institutions aimed at improving productivity and competitiveness of national industries. **Sergio C. Trindade, president of SE^{2}T International, Ltd.,** described the Chinese experience with ERCs at the Global Forum.[24]

China's State Development and Planning Commission (SDPC) began working on a national plan for establishing ERCs in 1989 and started to construct the centers in 1992. By 2003, 95 government-supported ERCs had been established, of which 47 were financed with the help of a $200 million World Bank loan that financed the import of advanced equipment and technological information. The World Bank project operated from 1996 to 2002. It was designed to transform a segment of PRIs and university laboratories into market-oriented technology transfer corporations capable of accelerating the diffusion and adaptation of new technologies in China. In 2003 the 47 ERCs supported by the World Bank loan employed about 6,900 people, more than half of whom had senior

23 In some analysts' view, these radical decreases "have weakened the long-term research capacity of the entire system" as they led research institutions to avoid long-term research projects in favor of projects that would probably be carried out by the enterprise sector. See Dahlman and Aubert (2001, 129), also referring to Liu and White (2001, 1–24).

24 In addition to Sergio C. Trindade's presentation, the following text draws on World Bank (2003).

or intermediate professional titles. The World Bank project focused on three main technological areas: electronic information technology and its application; chemical engineering and new materials; and efficient utilization of energy and environmental protection.

ERCs were created by different sponsoring institutions—PRIs, universities, and enterprises—but were incorporated separately from their parent institutions. All ERCs were encouraged to become financially self-sufficient, with the risk of bankruptcy seen as an important negative incentive for market orientation and economic efficiency. Allowing employees to become ERC shareholders was designed as a positive incentive.

It may be too early to assess the success of the ERC experiment in China, particularly since it encompassed a wide range of sectors and types of parent companies—ranging from R&D institutes to Chinese and foreign industrial enterprises. Differences in the nature of technological activities, relationships with parent institutions, and levels of organizational restructuring resulted in widely varied financial results and prospects for survival. But some indicators of ERC activities appear to be promising. According to the World Bank data, after the first five years of existence, the 47 ERCs transferred to industry about 600 major research results, implemented more than 26,500 technology transfer contracts, and established some 60 subsidiaries, including joint ventures. When in 2001 SDPC organized an ERC exhibit and an ERC Technology and Investment Conference at the Third Shenzen High Technology Fair, contracts worth Y 260 million (US$32 million) were signed with 19 ERCs.

The financial sustainability of many of the ERCs is open to question. ERC managers promoted to leadership positions based on their research achievements often do not have the required managerial skills and entrepreneurial mind-set.[25] Business training financed by the World Bank project probably helped to some extent, but it will take time for a new generation of business-oriented innovation managers to emerge.

At the same time, the excessive focus on financial results created a contradiction between the public and the private goals of ERCs. Many ERCs began to mass produce and market products themselves instead of transferring these functions to the private sector via licensing

25 During the question-and-answer period, Trindade suggested that perhaps only about 20 percent of ERCs are likely to survive in the longer term. But this could still be an acceptable outcome, provided that the surviving ERCs are successful enough.

agreements.[26] As noted in the World Bank's Implementation Completion Report, it is "up to the government to establish guidelines on how far the ERCs could pursue their own financial independency through a manufacturing process" so as not to "defeat the purpose of technology dissemination which is one of the mission objectives of the ERCs" (World Bank 2003).

To have a fully functioning NIS, China needs a variety of institutions capable of performing different R&D activities. Competitive, profit-driven R&D performed by private enterprises is critically important for a market economy. But to be successful, it usually needs to build on precompetitive, generic R&D that is best performed by institutions whose primary mission is technology dissemination. Unfortunately, creating successful, market-responsive institutions interested in wide technology dissemination seems to be a challenge for many countries, primarily because it requires the right balance of market and nonmarket incentives.

María del Pilar Noriega, technical director of the Colombian ICIPC,[27] described an interesting example of a successful technology transfer institution, ICIPC, in Colombia. ICIPC was founded as a non-profit organization. Its mission is "turning knowledge into wealth" by contributing to technological innovation leading to increased productivity and competitiveness of the rubber and plastics cluster in Colombia. Its three founding members were the Colombian Association of Plastic Industries (ACOPLASTICOS), EAFIT University, and a large Colombian plastic company, FORMACOL. The institute started its activities in 1993 and is now widely acknowledged as one of the most successful of the more than 30 technology development and transfer centers currently operating in various Colombian industries.

The portfolio of ICIPC activities is made up of applied R&D activities funded by government and international grants as well as contracts with private firms (about 65 percent), laboratory testing services (about 12 percent), training activities (about 10 percent), and specialized consulting services. The staff consists of just 20 people, of whom 13 have masters of science or doctoral degrees (mostly earned abroad). Employees must have multifaceted skill profiles—researcher, professor, and consultant combined with management and marketing skills.

26 CITT in Rwanda faced similar contradictions. For details, see the discussion of Doorman and Hendriksen's presentation in the session on Reducing Poverty and Achieving the MDGs.

27 For additional information on the ICIPC case, see http://www.wipo.int/sme/en/best_practices/icipc_colombia.htm.

Modern equipment and infrastructure resources allow the staff to provide up-to-date technology transfer, education, and consulting services to a large number of firms, producing and using rubber and plastic products in Colombia and some neighboring countries.

Besides the highly qualified personnel and the modern infrastructure, the secret of ICIPC's success appears to be its active networking programs with local as well as foreign academic, R&D, and industrial organizations. For example, in addition to the founding EAFIT University, the institute has working relationships with four other Colombian universities as well as the University of Wisconsin (United States) and Universidad del Pais Vasco (Spain). As a result, ICIPC is able to offer not only short-term seminars, workshops, and customized training modules for plastic industry enterprises, but also the formal Program of Specialization in Plastic and Rubber Conversion Processes and a masters in engineering of polymer processing (both jointly with the EAFIT University). A postgraduate program is likely to be offered in the near future.

Another secret of ICIPC's success is its active work with existing international databases including those of the United States Patent and Trademark Office (USPTO), Patent Abstracts of Japan (PAJ), Dialogue, Science and Technical News (STN), Science Direct, and others. Performing extensive information searches before any R&D work has been a standard practice in ICIPC since 2003, and this service has become quite popular with its clients (73 enterprises used it in 2003–05).

Searching for existing foreign technologies and adapting them to the needs of local enterprises probably makes up the bulk of ICIPC's R&D activities. This seems to be an appropriate model for any technology dissemination agency, but it is particularly appropriate in a small economy in which the absolute scale of national R&D will, by definition, be quite small relative to the global R&D output (see table II.1).

"Avoid inventing a bicycle by doing state-of the-art information search prior to any research or technological service."

—María del Pilar Noriega, technical director, Colombian Foundation Rubber and Plastic Institute for Training and Research (ICIPC), speaking at the Global Forum

In addition, ICIPC also produces some original R&D results, as evidenced by the nine patents that it has already applied for or received. It intends to license these patents to its client enterprises. Active and successful licensing will be a good sign of ICIPC's interest and success in technology dissemination (rather than just income earning).

Table II.1. Intensity and Scale of National R&D Effort

(selected countries)

	Researchers in R&D per million people		*Total number of researchers in R&D*		*Public and private R&D expenditure as percent of GDP*	
Country	*1997*	*2002–04 (the latest available)*	*1997*	*2003*	*1997*	*2002–04 (the latest available)*
Brazil (2000)	344	—	—	59,838	0.9	—
Chile	395	444	5,858	7,085	0.5	0.6
China	474	708	588,700	926,252	0.7	1.4
Colombia	88	109	3,534	4,829	0.3	0.2
Costa Rica	—	—	—	—	0.3	(2001) 0.4
Czech Republic	1,220	1,594	12,580	15,809	1.1	1.3
Hong Kong (China)	1,055	1,563	6,819	10,639	(2000) 0.5	—
India (1998)	119	—	117,528	—	0.7	—
Indonesia (2000, 2001)	215	—	—	43,779	(2001) 0.1	—
Ireland	1,920	2,674	7,047	10,039	1.3	1.2
Malaysia (1998, 2002)	156	299	1,894	7,157	(2001) 0.5	—
Mexico	224	268	19,894	27,626	0.3	0.4
Nicaragua	73	—	340	—	0.1	—
Korea, Republic of	2,242	3,187	102,660	151,254	2.5	2.6
Singapore	2,621	4,999	9,704	20,024	1.5	2.3
South Africa (2001)	307	—		14,182	0.8	—
Thailand	73	286	4,409	18,114	0.1	0.3

Source: UNESCO Institute for Statistics database 2007.

Note: GDP = gross domestic product; R&D = research and development; — = not available.

ICIPC's success is also rooted in its client responsiveness, which is itself based on its close relationships with its founding member ACOPLASTICOS (about 600 member enterprises) and networking with some foreign industrial associations (for example, Italian ASSOCOMAPLAST and Ecuadorian ASEPLAS). The existence of effective industrial associations capable of defining and expressing the private sector's collective interest in productivity and competitiveness improvement should probably be seen as a necessary precondition for successful R&D-to-industry linkages.

According to **Peter Brimble, president of the Asia Policy Research Company**,[28] the absence of strong industrial associations that can effectively articulate the needs of industry is a major obstacle to establishing successful UILs in Thailand.

Not only are there weak linkages between Thai educational institutions and industrial firms, but there is also insufficient interest in changing this situation. On the demand-side of the equation, domestically oriented local producers are largely protected from competitive pressures and, therefore, have little incentive to innovate and establish linkages with R&D organizations. And local subsidiaries of large export-oriented TNCs get their research elsewhere—primarily from their home office research institutions. As a result, they have little need to turn to Thai universities and research institutes for technology assistance. On the supply-side, academic scientists also have little financial incentive to engage with industrial enterprises.

Despite these systemic weaknesses, Brimble noted that there are several examples of relatively successful UILs in Thailand. These could provide some clues about the circumstances that must be present if these obstacles to stronger linkages are to be overcome. The two Thai industries with examples of successful UILs—shrimp farming and hard disk drive (HDD) manufacturing—are very different. Nevertheless, they have several common characteristics:

- *Industry vulnerability*. In shrimp farming, this vulnerability came from the threat of losing the whole crop to viral diseases (as it already happened to Taiwanese shrimp farming in 1988), while in the HDD case the threat came from intensifying global competition.

28 For additional information on the Asia Policy Research Company, see http://www.asiapolicyresearch.com/index.html. In addition to Peter Brimble's presentation at the Global Forum, the following text also draws on Brimble and Doner (2007, 1021–36).

- *Government interest in promoting the industry's export potential*. Shrimp farming became Thailand's second-largest agricultural export earner by the late 1990s. Microelectronics has long been a major contributor to Thailand's exports (more than 30 percent of total exports), but the share of local value added was relatively low. Developing an HDD cluster became one of the government's priorities.
- *Strong industrial organization or a large leading firm as a way to overcome industry's fragmentation*. Examples include the Shrimp Culture Research and Development Company (shrimp industry consortium), IDEMA Thailand (International Disk Equipment and Materials Association/Thai branch of the global HDD industry association), and Seagate (the largest HDD producer in Thailand).
- *Public or quasi-public facilitator*. Examples include the Thai National Center for Genetic Engineering and Biotechnology (BIOTEC) and Asian Institute of Technology (AIT).

The resulting linkages created significant benefits for both sides, including accelerated technology upgrading at industrial enterprises and curriculum improvements and the establishment of new academic units in universities. For example, supported by BIOTEC, Mahidol University established the Center of Excellence for Shrimp Molecular Biology and Biotechnology (Centex Shrimp). This center developed DNA diagnostic methods and test kits that helped shrimp farmers reduce losses from viruses. Also, the first and only R&D laboratories in two Thai universities (Khon Kaen University and Suranaree University of Technology) were established as a direct result of university partnerships with Seagate in 2003–04.

The final panel of the session was devoted to Supporting Entrepreneurship and Enterprise Innovation and included presentations from three diverse countries—Nicaragua, Mexico, and South Africa. These three countries differ not only in terms of size and technological achievement, but also in terms of their goals, challenges, and objectives. For example, Nicaragua is trying to strengthen SMEs that have little internal capacity to access new technologies and incorporate them into production processes; Mexico is trying to incubate high-tech SMEs; and South Africa is trying to strengthen an innovation system that is already at the world frontier in several critical technologies. Not surprisingly, the government program that each country sponsored was quite different in terms of focus and ambition. These differences should reiterate the adage that "one size does not fit all." STI capacity-building programs require careful customization to meet each country's unique challenges and starting point.

Regina Lacayo Oyanguren, executive secretary of the National Science and Technology Council of Nicaragua (CONICYT),[29] described the recent experience of the Nicaraguan Innovation Fund for SMEs. Nicaragua is a small economy oriented toward traditional commodities with very low value added. More than 40 percent of the population lives in rural areas, exports are relatively small (relative to GDP) and highly concentrated in a few productive sectors (such as coffee, meat, and sugar), and much of the economy is in the formal sector. In addition, the technical and financial infrastructure are both inadequate and the investment climate is particularly unfriendly to innovations. Of the approximately 113,000 Nicaraguan SMEs, about 78 percent are in commerce and services (only 21 percent in industry) and almost 88 percent are microenterprises with just one to three employees. The new project of the Nicaraguan Ministry of Industry and Trade Promotion (MIFIC), called Innovative Technology Support in Nicaragua, aims to "promote exports and national competitiveness by helping SMEs find, adopt, and adapt useful technologies."

To accomplish this objective, Nicaragua established an Innovation Fund that provides matching grants to individual SMEs (6–99 employees) and groups of SMEs working jointly with "technological service providers" (local universities, laboratories, and other technological knowledge producers) to finance various innovation-related activities. The notion of what constitutes an innovation was adapted to the realities and needs of Nicaraguan SMEs and includes the following activities eligible for funding:

- *Technological innovations*. These include such activities as installing capital equipment, acquiring technology, and monitoring technological developments in the sector. Funds can be used for trips to observe how enterprises in other countries are using relevant technology, for technical training, for incorporating ICT into production processes, for R&D, and for developing new products and processes.
- *Organizational innovations*, such as introducing new management models, implementing technical norms and standards, and building managerial capabilities to acquire and use new technologies.
- *Market development activities*, such as market intelligence research, strategic planning, or participation in international trade fairs.

29 For additional information on CONICYT, see http://www.conicyt.gob.ni.

The matching grants are designed as an incentive for both SMEs and the collaborating institutions. On the one hand, they encourage SMEs to invest in the various forms of innovation described above. On the other hand, they encourage research and education institutions to provide SMEs with such technology transfer services as staff training, laboratory testing capacity, applied R&D, and market studies. To improve the UILs, universities are encouraged to establish special Technological Service Centers with technological facilitators included as part of their staff. These technological facilitators visit interested SMEs, provide them with a brief technological diagnosis, and help formulate innovation proposals. These facilitators are the key to the project's success. In effect, they are the linkage mechanism between SMEs and education and research institutions. Without these facilitators, little spontaneous communication and interaction would take place. The facilitators are the critical catalyst facilitating communication.

In the first year of the project, US$3 million was allocated to reimburse 90 SMEs and 13 technological service providers for their innovation activities. The size of matching grants was limited to US$30,000 for a single SME and US$100,000 for a group of SMEs or a technological service provider. The beneficiaries were required to make matching cash contributions of between 20 and 40 percent of the grants, and the total size of these grants was not to exceed 40 percent of the beneficiaries' annual incomes.

After one year, the results appear encouraging. Most participating SMEs introduced some sort of innovation and provided their staffs with some kind of on-the-job training. In addition, participating SMEs added an average of six employees and increased their sales by 33 percent. Nonparticipating SMEs registered much lower growth rates and smaller employment increases. If the trend continues, after eight years the government expects increased sales tax revenues to more than offset the cost of the program. Even more important, the network of technological service centers that is being created can potentially support a much broader range of technology transfer and dissemination services in Nicaragua.

Guillermo Fernández de la Garza, president and chief executive officer of the U.S.-Mexico Foundation for Science (FUMEC),[30] described the Mexican Ministry of Economy's new program, the Technology Business Acceleration (TechBA) program,[31] which is administered by FUMEC,

30 For additional information about FUMEC, see http://www.fumec.org.mx.

31 For additional information about TechBA, see http://www.techbasv.com.

a nonprofit organization sponsored by the United States and Mexican governments. Whereas Nicaragua's program was explicitly designed to help SMEs in traditional sectors find, adapt, and adopt existing technology, TechBA was designed to help high-tech Mexican SMEs sell their goods, services, and technological innovations on global markets. And whereas most governments try to achieve similar objectives by establishing indigenous technoparks and incubators, TechBA outsourced these incubation services to such recognized innovation leaders as the Enterprise Network of Silicon Valley, IC2 of the University of Texas at Austin (United States), Inno-Centre in Montreal (Canada), and Parque Cientifico de Madrid (Spain).

The TechBA program deliberately focuses on such high-tech, high-growth potential industries as information technologies and wireless communications, multimedia and education services, biotechnology and bioinformatics, life sciences, microsystems, advanced materials, and robotics. The goals of the program include the following:

- Helping the participating Mexican SMEs "reorient their capacity" to global markets, link up to the most innovative technological clusters, gain access to foreign angel investors and venture capital, and integrate into global supply chains
- Contributing to faster development of Mexico's high-tech regional clusters by providing them with business intelligence mechanisms and wider opportunities for international networking
- Facilitating Mexico's participation in international science, technology, education, and business collaborations

To ensure the quality and readiness of the companies that become members of TechBA, the Ministry of Economy of Mexico and FUMEC, in collaboration with local organizations in Mexican regions, organize a once-a-year selection process in which a committee composed of international and Mexican experts in business, technology, and venture capital selects the most promising Mexican companies. The selected SMEs then participate in workshops to receive guidance on such issues as IPRs, quality certifications, venture capital processes, and other issues. Participants are also provided with specialized consulting in developing business proposals aimed at penetrating global markets, and these proposals are assessed with the help of the "TechBA Market Finder methodology." Finally, and in what is perhaps the most innovative feature of this program, the selected companies move to one of TechBA's foreign offices to access venture capital, search for foreign customers, and establish international partnerships and alliances.

More than 500 SMEs participated in three evaluation and selection rounds and more than 100 were selected to participate in the final "acceleration" stage. As of November 2006, of the 105 TechBA companies, 69 (the majority) were specializing in software development, 7 in multimedia, and 23 in manufacturing (including biotechnology, health and nutrition, medical equipment, electronics, and robotics). After two years of operation, more than half of the 55 Mexican SMEs participating in the Silicon Valley TechBA center had already incorporated in the United States. Their international sales add about 17 percent to their sales in Mexico and their total employment increased by about 8 percent. Despite these initial successes, it is still too early to determine what impact the program will have on the emergence of high-tech regional clusters in Mexico.

David Kaplan, professor of business-government relations, University of Cape Town, spoke about the South African government's efforts to support exports by high-tech SMEs in the IT and software industries. The focus of his presentation was on creating a national business climate that would be generally supportive of a wide range of high-tech companies.

Several South African high-tech companies have already become global technological leaders in their specific sectors. For example, Sasol is a global leader in producing liquid fuels from coal and natural gas. It is building plants in Qatar, Iran, China, and several other countries. Most impressively, nearly all its pioneering R&D is conducted in South Africa.

Another example of homegrown technology with significant future export potential (up to $3 billion per year) is the Pebble-Bed Modular Reactor (PBMR), designed to be used in small-scale nuclear power plants. Nuclear reactors using this technology are expected to be much safer than conventional reactors. South Africa is at the forefront of developing this technology. The project employs the largest number of skilled researchers, engineers, and technicians (about 550 overall) and enjoys significant state support.

By contrast, the South African software industry receives little state support. Nevertheless, some companies have achieved global success. Thawte, for example, became a global leader in encrypted digital certificates and was eventually sold to the U.S. company Verizon for $600 million.

Why are there not enough well-performing, high-tech companies in South Africa? There are many innovation constraints that need to be addressed such as ineffective IPR, underdeveloped technical standards, unavailable early-stage venture capital, and government programs in need of better implementation. But the key problem is the low supply of high-level STI skills. The shortage of this critical input explains why only a few South African companies can succeed in high-tech competition.[32]

> "We just do not have enough skilled people in our national innovation system."
>
> —David Kaplan, professor of business–government relations, University of Cape Town, speaking at the Global Forum

The way to "get the priorities right" would be to focus government policies on increasing the supply of highly skilled workers by building up the national system of education and training, creating incentives for foreign investors to pay for their employees' training, and even relaxing immigration restrictions so that South African companies can recruit highly skilled labor from abroad.[33] In the absence of such measures, new government programs and financial support for innovation may not result in any innovation acceleration. Active STI skill building should be supplemented by building marketing and market intelligence skills, the shortage of which often constitutes an additional obstacle to the latecomers' catching-up efforts.

Session 3: Conclusions

What seems to bring all of the different presenters together is their clear understanding that technological catch-up is not a passive process. Technological diffusion and spillovers do not happen spontaneously and

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32 This opinion is corroborated by the recent survey data from the World Bank's Investment Climate Assessment (ICA). According to this data, "skills and education of available workers" constitute the major business constraint, which is particularly severe for the most innovative firms (the other two major constraints reported were "crime, theft, and disorder" and "macro instability"). ICA data also showed that South African firms experience difficulties with recruiting skilled technicians—the average number of weeks it took to fill the most recent vacancies for skilled technicians was reported to be more than five weeks on average and closer to six weeks for large exporting firms, compared with three to five weeks in India.

33 South Africa is probably the only country in Sub-Saharan Africa that already benefits from skilled immigration, mostly from its neighboring countries. For example, of the 1.3 million immigrants to South Africa in 2000, about 19 percent were recorded as having tertiary education. At the same time, more than 5 percent of the South African labor force with tertiary education emigrates to other countries every year, which is lower than in 1990 (about 7 percent) and lower than in most other African countries, but it is still a big loss, given the shortage of high skills in South Africa (see Docquiera and Marfouk 1999–2000).

automatically when countries open themselves to trade and FDI. On the contrary, diffusion and spillovers require proactive capacity building programs. Different countries adopted different capacity building strategies, depending on their starting point and national circumstances. But every successful country adopted a coherent strategy. In other words, technological development is not simply a question of passively accumulating stocks of FDI, licensing technology, importing high-tech products, and so on. There is a big difference between active technology innovation promotion programs, on the one hand, and passive accumulation of technology inputs, on the other.

At its core, technological progress is really about learning how to produce and sell more knowledge-intensive, high value-added goods and services. (Anyone can purchase a machine. Not everyone can use it to produce and sell a competitive product in the global marketplace.) This is where entrepreneurship, management, and market knowledge enter the equation. Someone has to see a market niche, organize production to meet the needs of the market, train workers to produce the requisite goods and services, find the appropriate technology, incorporate it into the production process, and market the finished product. And someone also has to figure out how to go from the bottom rung of the technological ladder to progressively higher, more sophisticated rungs. This is the job of the entrepreneur, who in many ways is the engine of technological progress and diffusion. Without the entrepreneur, a country can only have some idle or low-productivity stocks of land, labor, and capital. Experience suggests that proactive capacity building programs—education, training, R&D, supplier development, and so on—are required to facilitate the learning process, and PPPs are needed to support entrepreneurs.

Session 4: The Role of R&D in STI Capacity Building

As previous sessions discussed, the vast majority of technologies that developing countries need to reduce poverty, add value to natural resources, and upgrade the technological proficiency of local industry have already been invented. They are typically in widespread use in many industrial countries. The problem is that they are not widely used in many developing countries. This suggests that the major STI capacity building task entails building a developing country's capacity to find, adapt, and use existing technologies. For the most part, this requires developing engineering, technical, and vocational skills, rather than conducting frontier-level R&D.

> "A country arriving late on the industrial scene is able to access advanced technologies that have been developed elsewhere and put them to business use at lower cost than advanced firms themselves—sometimes at lower cost, and faster, than the very firms that developed the technologies in the first place."
>
> —John A. Mathews, *World Bank Development Outreach* magazine (January 2007)

Moreover, total annual R&D spending in many developing countries from all public, private, and foreign sources is a fraction of the annual R&D spending by one large U.S. or European corporation. Thus, even if developing countries boost R&D spending (as a share of GDP) to the U.S. or European average, vastly improve the targeting and efficiency of their R&D spending, and commercialize a large share of those technological innovations, they will still be a minor player in the global R&D arena. It is inevitable, therefore, that most of the economically relevant knowledge that developing countries will need to boost productivity and compete internationally will be produced elsewhere. Especially at the initial stages of development, their success will depend on their ability to scour the world for knowledge, import it, adapt it for local use, and integrate it into local production processes.

This does not mean that there is no role for R&D in developing countries or that these countries should not devote any resources to building their R&D capacity. However, it does mean that building R&D capacity needs to be seen as one component in a much broader STI capacity building program. Furthermore, in building R&D capacity, developing countries need to ask three critical questions:

- How can they ensure that their investments in R&D capacity building are relevant to the economic and social needs of the country?
- How can they maximize the quality of the R&D capacity that is built? This does not necessarily mean achieving world-class status. However, it does mean adopting policies that will, gradually over time, bring the country's R&D capacity closer to world-class status.
- How can universities contribute to building a high-quality R&D system that contributes to economic growth?
- How can countries with smaller numbers of scientists collaborate to form regional networks—both to conduct scientific research and provide postgraduate education? In other words, how can these countries join together to benefit from economies of scale?

Panelists in the session on the Role of R&D in STI Capacity Building addressed these questions.

Fernando Chaparro explained how Colombia is enhancing the quality of its R&D and making it more relevant to the country's needs by changing the emphasis from basic research to innovation and by measuring quality in terms of its impact on the local economy. Research in Colombia remains important. The questions are now "What drives research?" and "Who sets the agenda?"

Claudio Wernli explained how the World Bank's Millennium Science Initiative (MSI) project,[34] which was implemented in Chile during the period 2000–05, helped to advance both the quality and relevance of R&D activities conducted in Chile.

Wole Soboyejo discussed how high-level S&T education can accelerate the development of a knowledge-based economy—an economy that requires a critical mass of well-educated workers who can operate in globally competitive industries. World-class S&T can be a driver of economic development in Sub-Saharan Africa—the concept behind the African Institutes of Science and Technology (AIST), which will establish Institutes of Science of Technology that are similar to the Massachusetts Institute of Technology (MIT) in the United States or the Indian Institutes of Technology (IITs). The challenge is that there are only 83 scientists and engineers per million people in Africa versus 1,000 per million in the developed world.

Jeffrey Fine noted that strategies for revamping and expanding higher education, a key component of STI and R&D systems, must address inherent structural weaknesses as well as the legacy of past efforts. Strengthening STI in Africa requires that far more attention be given to higher education and the huge gap in postsecondary professional and vocational training. Building Africa's higher education system and enhancing the quality of its R&D will require significant collaborative, regional efforts—efforts for which he presented a number of new ideas.

Phillip Griffiths reinforced the opinions of the other panelists, stating that many of today's challenges in African S&T, including oceanography, water, power, transportation, and geothermal resources, are best

34 The Millennium Science Initiative (MSI) in Chile is described at http://www.mideplan.cl/milenio/home_eng. The World Bank's review of the MSI Chile project is available at http://www-wds.worldbank.org/servlet/WDS_IBank_Servlet?pcont=details&eid=000094946_03051504020260.

approached on a regional level. A regional approach overcomes the isolation of individual R&D institutions, provides for a critical mass of researchers in fields that increasingly require multidisciplinary approaches, enables multiple perspectives, strengthens each individual institution or "node" in the regional network, and enables institutions to retain talented scientists and bring back the diaspora to participate. A Regional Initiative in Science and Education (RISE) for training new African scientists and faculty was outlined to address these issues.

Sonia Plaza noted that working on S&T solutions for local problems is critical to making R&D effective and relevant to a country's needs. Regional networks and cooperation pay off because modern-day R&D requires interdisciplinary teams and a critical mass of researchers to achieve results. The Eastern African Dialogue on Policymaking on Biotechnology, Trade, and Sustainable Development has achieved success, and there are a number of ways to move forward with regional initiatives in Africa.

What the panelists said about . . .

Pursuing a research and development agenda in developing countries

- Reverse the brain drain—"brain gain, not brain drain"
- Strengthen education institutions
- Become a part of the global, knowledge-based economy
- Promote economic growth in agriculture, biodiversity, energy, environment, health, information and communications technologies, the oil and gas industries, and more
- Adapt and create technologies suited to addressing local problems

There are significant requirements for success:

- Sufficient funds and sufficient time—a consistent stream of funding from idea to market
- Limited bureaucracy, coupled with autonomy, flexibility, and direct funding to research teams
- Rigorous, competitive, merit-based selection processes
- Focus on people—scientific excellence and outstanding scientific teams are more important than the particular scientific or technological area pursued

- Promote links with industry
- Regional, international, and multi-institutional networks and collaborations
- Although global competitiveness is important, solutions to local problems are as relevant and often more attainable
- Focus on complementarities—one institution cannot do all—a multitude of institutions working together can strengthen all
- Good government and political support, coupled with buy-in from all of the principal stakeholders—scientists, government, industry, and the public

There are significant challenges:

- Addressing the need for more doctoral-level faculty and researchers
- Engaging leading scientists from individual country's diaspora
- Changing the mind-set of current educators and researchers—moving their focus from teaching and basic research to innovation and impact
- Evolving large institutions into a new culture of small R&D institutions closely connected with the end user and industry
- Eliminating isolation—building networks, interdisciplinary and interinstitutional projects, sharing faculty—and overcoming feelings of proprietorship
- Obtaining buy-in from scientists, government, industry, and the public
- Establishing metrics to measure progress

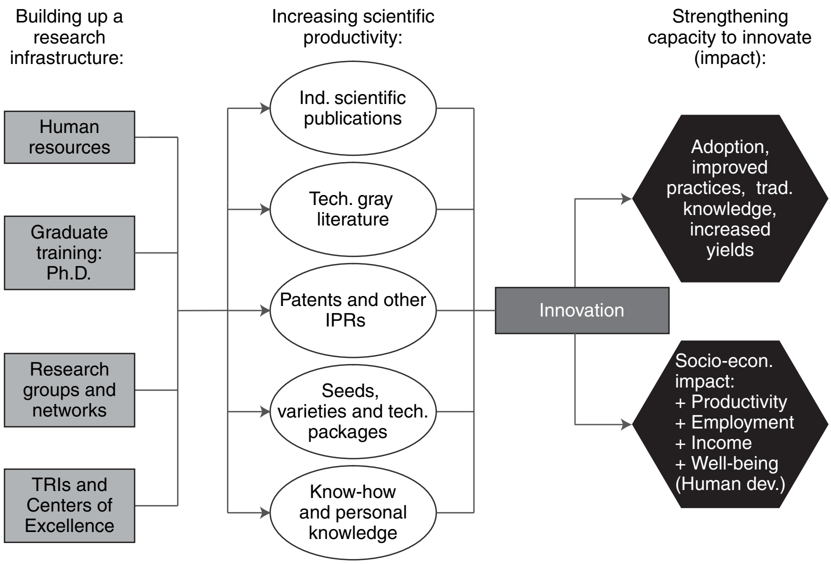
Fernando Chaparro: Changing emphasis from basic research to innovation and impact on the local economy

Colombia established eight Centers of Excellence in the 1980s, but today, as **Fernando Chaparro, director of the Knowledge Management and Innovation Center, Universidad del Rosario, former director-general of COLCIENCIAS (the Colombian Institute for the Development of Science and Technology), Colombia,** reported, Colombia is enhancing the quality of its R&D and making it more effective and relevant to the country's needs by changing its emphasis from basic research to innovation and impact on the local economy. Figure II.7 illustrates this shifting emphasis from research to innovation.

"Can developing countries rely on imported technology to solve their problems? In some cases yes . . . in other cases, I . . . contend no."
—Fernando Chaparro, former director, Colciencias, Universidad del Rosario, Colombia

An emphasis on innovation does not mean research is not important. Instead, this emphasis raises such questions as "What drives research?" and "Who sets the research agenda?"

Figure II.7. Phases in Research Capacity Building



Source: Chaparro, Global Forum presentation.

The links from S&T capacity and research infrastructure to innovation and impact, such as the impacts on employment, production, and the actual use of technology on farms and in businesses, are difficult to measure. These metrics to measure impact in the real world need to be further developed. As an example, the research institute CORPOICA (described in more detail below) has been shifting its indicators from technologies to impacts. Instead of measuring the number of new varieties of seeds and theoretical yields, it now measures the use of new seeds by farmers and the actual changes in farm yields, as shown in table II.2

Colombia is responding by *redefining its centers not along traditional academic disciplinary lines but rather around problem areas, such as water, energy, and biodiversity*, bringing in interdisciplinary teams and researchers from various Colombian universities to work together—a problem-specific approach to multi-institutional research cooperation that benefits all participants. These centers have had positive effects on university-company linkages in Colombia as described in box II.6.

An additional issue in Colombia is that in the 1970s, large, public research institutions funded entirely by the state were created to focus on broad areas of research and education. It is now difficult for these

Table II.2. Old versus New STI Indicators

Old STI Indicators (Technologies)	*New STI Indicators (Impacts)*
• Clean seeds derived from biotechnological processes • New agricultural and soil management practices, improved water management • New varieties (Milenia 1) • Biological pest controls (Baculovirus) for increase sustainability • Organization of potato growers and training	• Use of certified seeds increased from 1 to 8 percent • Substitution of 750 hectares (ha) of "Páramos" dedicated to seed production through traditional means • Increased yields: from 17 ton/ha to 40 ton/ha (average) • 52 percent reduction in production costs • 15,000 ha with CORPOICA seeds; target: 30,000 ha • 500 potato growers being reached

Source: Chaparro, Global Forum presentation.

Box II.6

University-Company Relationships in Colombia

In Colombia, another one of the region's most active economies, relationships between universities and companies have become a great deal stronger over the last decade under the leadership of Antioquia University (in the city of Medellin), which establishes direct ties between groups of the most qualified researchers, research associations, and companies.

According to Hugo Macias Cardona, coordinator of the University of Medellin's Center for Economic, Accounting, and Administrative Research (CIECA), there is a growing awareness within universities that "research processes must respond not only to professors' academic interests and initiatives but also to the needs of the business community and to the country's developmental needs."

In Colombia, four Centers of Excellence have recently been created, bringing together high-level research groups via a network set up within the national system of science and technology. "Each one of these centers works on areas of research that have previously been identified as strategic for national development, not only from the viewpoint of production but also [from the point of view of] the well-being of the people," said Macias Cardona.

Companies have also begun to get closer to universities, especially those companies involved in information technology. This process enables their products and services to be used and recognized by faculty members and students. Students have access to training that qualifies them for jobs where they can use these tools.

Source: Universia-Knowledge@Wharton, November 29, 2006. The full article is available at http://www.wharton.universia.net/index.cfm?fa=viewfeature&id=1265&language=english.

institutions to be flexible and reactive to new areas of S&T, such as biotechnology, ICT, and newly emerging industrial methods in agriculture, health, and mining. Chaparro noted that it is important to restructure these research institutions because imported technologies may solve some problems; however, in many other cases, local technologies, developed through local research, innovation and development, are more effective, better adapted to local problems, and less expensive.

Colombia's objective today, in order to make its R&D more effective and relevant to the country's needs, is to decentralize the large, publicly funded institutions through public-private joint ventures with industry, such as those described by **María del Pilar Noriega**, directora técnica, ICPIC, Colombia, in the session on Latecomer Strategies for Catching Up.

Two types of research institutes are developing in Colombia today (see box II.7):

- CENIACUA is one of a new breed of Technology Research Instititutes (TRIs) that are small, have close ties to industry, are largely privately funded, and are focused on a specific problem.
- CORPOICA is a large public research institute that is evolving. It is representative of the large agricultural research institutes created over the past 20 years in Latin America, Africa, and other developing regions.

Chaparro noted the many challenges in developing CORPOICA. One has been the development of strategic alliances between small producers and agribusiness, as illustrated in figure II.8. Another has been integration into regional innovation systems and global knowledge networks.

Box II.7

Evolution of Colombian Research Centers

Aquaculture Research—CENIACUA

CENIACUA emerged in response to a clear challenge to the shrimp and aquaculture industry in Colombia. In the mid-1990s, the Taura virus was wiping out the shrimp industry with 70 percent death rates in shrimp ponds, effectively destroying the competitiveness of the industry. Over a five-year period, CENIACUA undertook an R&D program, in alliance with universities and Centers of Excellence, and was able to develop a genetically improved variety of shrimp that was resistant to the Taura virus. This increased the survival rate to 75 percent in the Caribbean coast shrimp ponds of Colombia, putting these farms back into a competitive standing. Notably, this same technology was not effective in the Pacific Coast ponds, so a different virus-resistant shrimp was created for that region.

Forty-seven companies were able to benefit from the CENIACUA research. The industry is once again thriving with $50 million in export earnings and 5,000 directly employed persons in the Caribbean farms. CENIACUA's mission has evolved to focus on new ways to help the industry compete in the face of Chinese competition and decreasing world prices for shrimp.

Seventy percent of CENIACUA's work is funded by companies. The other 30 percent is funded through a public-private cofunding mechanism or is seed money provided by the state for limited time periods to attract private funding.

Agriculture Research—CORPOICA

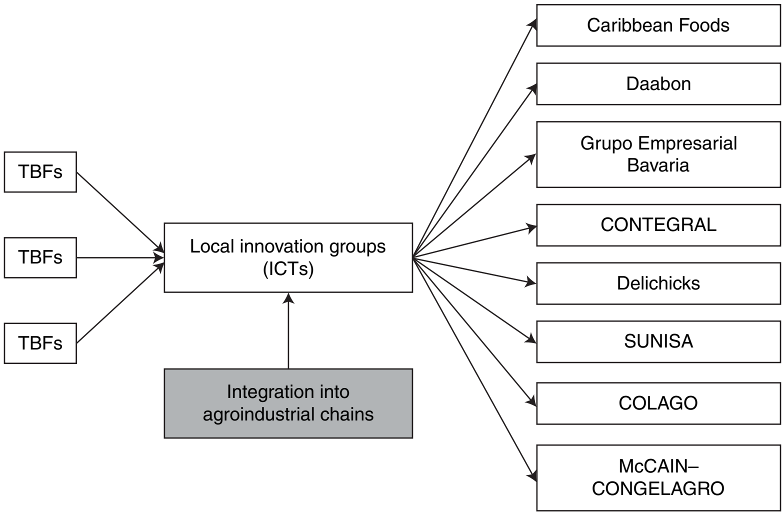
In contrast to CENIACUA, CORPOICA has evolved through an institutional learning process:

1. Research has become more participatory—researchers work shoulder to shoulder with the end users, and experimentation has increasingly moved from the research center to the farm.
2. Market demand is beginning to drive research—a difficult shift for a public research institution. This requires training to look beyond research ideas to market opportunities.
3. Public funding is being focused on long-term goals—areas too risky for the private sector.
4. Institutional networks, both local and global, are enabling researchers to tackle more complex, multidisciplinary problems.
5. Metrics have been revised to be both more quantitative and more reflective of impact.

One of CORPOICA's projects is to develop "super-elite" seeds and biological pest controls for regional businesses. This concept is to move beyond developing technologies to delivering business opportunities to local entrepreneurs. The project has required CORPOICA to add entirely new elements to its portfolio, including management training, provision136 of market information, and credits for the creation and growth of rural enterprises. Fourteen technology-intensive rural enterprises have been created as a result of this program.

Source: Chaparro, Global Forum presentation.

Figure II.8. Strategic Alliance between Small Producers and Agribusiness



Source: Chaparro, Global Forum presentation.
Note: TBF = technology-based firms.

Integration into the regional innovation systems has required CORPOICA staff to be trained in such ancillary subjects as access to credit, technology commercialization, and market intelligence.

Another important dimension of the learning process has been to learn how to tap and use global knowledge networks, such as CGIAR (Consultative Group on International Agricultural Research), GFAR (Global Forum on Agricultural Research), commodity chains and associations (both regionally and globally), and other scientific networks of various types.

As a result of these trends, a significant part of agricultural research in CORPOICA and similar institutes is shifting from the traditional experimental stations to the laboratory and the farm. Creation of innovation groups has led to the increasing importance of strategic alliances with universities and Centers of Excellence, both nationally and globally. Moreover, the expertise required is no longer limited to science and engineering, but includes the expertise required to establish new enterprises, evaluate markets, understand social systems, and manage businesses. A business orientation and capacity to develop these strategic alliances is essential for the success of these research institutions.

All told, a significant change in the organizational structure of agricultural research centers in Colombia is taking place. Knowledge management is critical. Core budget support is being replaced by competitive funding. Impact is increasingly measured using real-world impacts. And, a strategic view of R&D as a tool for tackling the real-world challenges of industry and society is required for success.

In sum, the R&D restructuring program in Colombia has followed certain key strategies:

- Arranging research and innovation around country's needs rather than around academic disciplines
- Measuring the impact of research by its capacity to produce innovation
- Training staff to meet technical and management challenges
- Linking with local business and focusing on its problems
- Tapping and using global knowledge networks

Claudio Wernli: Advancing the quality and relevance of R&D activities

Claudio Wernli, executive director, Millennium Science Initiative, Chile, presented the experience and lessons learned from the development of Centers of Excellence for fundamental scientific and technological research, under the MSI in Chile during the period 2000–05. According to Wernli, the Chilean Centers of Excellence were established to reverse the brain drain to industrial countries and to strengthen Chile's education and research institutions. The specific development objective of this project is to demonstrate significantly improved scientific performance and commercial relevance of research performed by interdisciplinary teams of scientists selected through transparent competitive processes. The project also helps link Chile's R&D capacity to national and international technology markets. Chile's significant experience, gained during the development and implementation of this program, is now being shared with MSI programs under way in Brazil, Mexico, and República Bolivariana de Venezuela and getting started in Uganda and Nigeria.

"The high level of acceptance and enthusiasm sparked by the MSI in the science and technology community has created a propitious environment for increased investment in the sector."

—Claudio Wernli, *World Bank Development Outreach* magazine (January 2007)

The Chilean MSI Centers of Excellence have enhanced the quality of R&D in Chile by integrating and improving the R&D capacity of all institutions in Chile. Chilean centers were established outside of the national education and research establishment—an effort that encountered significant resistance at first, as universities feared losing their best scientists. But, the value of the program is now recognized as a methodology to increase the strength of all institutions through an integrated approach.

The Chilean Centers of Excellence were selected on the basis of the following criteria:

- Their potential for conducting world-class scientific research
- The relevance of that research to the current or future scientific and economic development of Chile, including potential relevance to Chilean industry or the possibility of forging research partnerships with local or foreign business firms
- Their plans for teaching graduate and undergraduate students and for providing fellowships to train and attract the next generation of scientists
- Their potential for and interest in conducting multidisciplinary research
- Their proposals for outreach activities to universities, secondary schools, and the general public

The Chilean Centers of Excellence make Chilean R&D more effective and relevant to the country's needs by establishing the centers around groups of scientists, including associated researchers, senior scientists, young scientists, students, postdoctoral students, and support staff, and by establishing two types of centers:

- Institutes, which have about 50 staff, including 10 associate researchers, are established for five years, renewable for an additional five years after a competitive performance review. Institutes are funded at about US$1.2 million per year.
- Nuclei, which have about 25 staff, including three associate researchers, are established for three years, renewable for an additional three years after a competitive performance review. Nuclei are funded at about US$270,000 per year. The nuclei's focus is primarily the development of young scientists.

The centers also promote regional cooperation through networking and outreach among other institutions both nationally and internationally and by administrating the program through a Board of Directors and an International Program Committee, which consists of eight leading foreign experts, who provide proposal review and some scientific oversight.

Another unique aspect of the Centers of Excellence program is to provide funding directly to the scientific teams. This provides for simplicity, flexibility, and an autonomy for the teams that enhances their ability to follow new creative directions and pursue unique areas of leading-edge research.

There are no predetermined technical priority areas for scientific research. The program focuses instead on the qualifications of the proposing teams and scientific excellence. Secondary consideration is given to gender and region. The board sets the third priority, which usually has followed the previous criteria.

The bidding process for new centers is carried out via short preproposals, followed by full proposals from those selected in the preproposal round. The finalists are interviewed and visited directly by the foreign Program Committee. Decisions are made by the Board of Directors on advice of the Program Committee. Renewals are carried out on a competitive basis.

Monitoring and evaluation is carried out by foreign experts. After the first and second years of operation, panels of international experts were brought in to evaluate the program. In its third year, 2003, the program reported to the World Bank. In 2005 each individual center was evaluated.

The program has proven to be quite successful, so much so that many aspects of the program are now being adopted by other Chilean programs.

The Chilean Centers of Excellence program's keys to success include the following:

- Rigorous, competitive selection process for which excellence is the primary criterion
- Sufficient funding levels
- Limited bureaucracy and controls—autonomy and flexibility for the scientists
- Good government support, yet a minimum of political influence and interference
- Strong links with industry and with education
- Sharp focus on international partnerships
- Constant monitoring and evaluation

Wole Soboyejo: The African Institutes for Science and Technology (AIST) offers a model for regional cooperation in S&T education

Wole Soboyejo, professor of mechanical and aerospace engineering, Princeton University, and chair of the African Scientific Committee, discussed how high-level S&T education can accelerate the development of a knowledge-based economy—an economy that requires a critical mass

"Science and technology is proposed as the engine of economic growth . . . businesses [and] industry are the drivers, government is the catalytic converter and academics are the fuel."

—Wole Soboyejo, *World Bank Development Outreach* magazine (January 2007, 14–16)

of well-educated workers who can operate in globally competitive industries.

World-class S&T can be a driver of economic development in Sub-Saharan Africa. Furthermore, it is important that people in Africa begin to recognize S&T as an engine of growth, rather than a commodity to be purchased. The challenge: there are only 83 scientists and engineers per million people in Africa versus 1,000 per million in the developed world.

The quality of African R&D could be enhanced and capacity could be built by developing a relatively small number of high-quality institutions or centers of excellence. The AIST is one such approach.

AIST (www.nmiscience.org/aist.html) will develop Africa's human capital; improve Africa's education system; provide for the development, incubation, and dissemination of knowledge; and enable Africa to build respected, world-class technological research universities, thereby building and enhancing the quality of Africa's R&D.

The concept behind AIST is to establish Institutes of Science of Technology that are similar to MIT in the United States or to the IITs in India. Such institutions have transformed the United States and India, respectively. The goal, therefore, is to develop institutions that can have similar effects on the African economy within the next few decades.

AIST objectives include academic freedom; rigorous, independent admission processes; world-class faculty and leadership; and strong links to industry. AIST will significantly advance African collaboration in higher education and R&D.

Five AIST institutions are planned—an AIST Campus in Abuja, Nigeria; an AIST Campus in Tanzania; a center for water and environmental engineering in Burkina Faso; a center for mathematical modeling and computing in South Africa; and a center for offshore petroleum engineering in Nigeria.

The first AIST institute is located within the Abuja Technology Village—a planned cluster of leading research institutes and high-technology companies, located on a 1,000-hectare campus near the city center of Abuja, Nigeria.

AIST-Abuja will make R&D effective and relevant to Africa's needs through an initial focus on graduate student programs in areas in which they can have an impact: petroleum and gas engineering in the Gulf of Guinea; ICT and applied mathematics; materials science; biotechnology; and water and environmental engineering. The first class at AIST-Abuja began in September 2007. AIST Tanzania and Nigeria will follow shortly—land has been acquired and plans are being developed.

AIST will engage scientists regionally and globally. In addition to the interactions with the local students and faculty, the AIST-Abuja campus will be strongly influenced by the African Scientific Committee (ASC) and an International Scientific Advisory Board (ISAB). These two independent groups were established to provide scientific and technological input to the AISTs.

The ISAB includes a group of highly accomplished international scientists and engineers. It provides scientific oversight to the AIST Board of Trustees.

The ASC oversees the academic curriculum, research, and innovation efforts within the AISTs. It is a group that includes 70 members selected from Africa and the diaspora. The group represents 32 key fields that span the complete range between science, engineering, and the humanities. The objective of the ASC is to develop the framework for the knowledge-based transformation of Africa. As such, the group is open to interaction with the AISTs as well as interaction with other institutions. Ongoing activities of the ASC include efforts to develop curriculum and research for the AIST-Abuja campus; research collaborations with selected African universities; and AIST development in other African countries, such as Burkina-Faso, Tanzania, Rwanda, Ghana, South Africa, and Egypt. In these activities, the Africans in Africa and those in the diaspora are working together to build a platform for sustainable African development.

In addition, many of the initial faculty for the AISTs will come from the diaspora, where there are African professors teaching at leading universities in the world—30 to 40 have been identified so far. In addition to a core faculty of permanent faculty, visiting professors from African universities will have the opportunity to teach and do research at the AIST. This combination of visiting and permanent faculty will ensure the highest-quality standards in teaching and research.

The AISTs will also be connected to other African universities. Students and faculty from these institutions will have the opportunity to benefit from the programs at the AIST. For the students, this will include access to education resources and research facilities, while in the case of faculty, visiting professorships and education and teaching facilities will

AIST campuses will build off many of the universities and networks existing today:

Modeling and ICT

- African Mathematics Millennium Science Initiative (www.ammsi.org)
- African Institute for Mathematical Sciences (www.aims.ac.za)
- High Performance Computing Facilities (www.chpc.ac.za, hpc.ilri.cgiar.org and others)

Earth sciences and petroleum engineering

- Alliance for Earth Sciences, Engineering, and Development in Africa (www.aeseda.psu.edu)

African materials network

- U.S.-Africa Materials Institute (usami.princeton.edu)
- Nigerian Nanotechnology Institute (cf., http://usami.princeton.edu/news/071606a.shtml)

Lasers

- African Laser Center (www.africanlasercentre.org)

Water engineering

- École Inter-États d'Ingénieurs de l'Équipement Rural (www.eieretsher.org)

Social sciences network

- Council for the Development of Social Science Research in Africa (www.codesria.org)

be provided to ensure that local academics have direct access to the facilities and resources of the AIST.

The AIST campuses will be fully integrated systems to take ideas from the laboratory to market.

Integrated, interdisciplinary approaches will be taken to engage new science and new technologies. Because the campuses are new institutions, this can be built in from the start in areas such as water purification, energy production, and telecommunications. The campuses will perform leading-edge research and not simply be a consumer of developed market goods.

At every level of the AIST, the goal will be to create an exciting environment that stimulates innovation. Therefore, there will be design and innovation competitions, and students and faculty members that come up with new ideas will receive awards and will be encouraged to start companies that commercialize such ideas. Venture capitalists will be invited to campus to interact with such innovators in ways that will stimulate the transfer of technology from the AIST to the marketplace. In this regard, the location of AIST-Abuja within the Abuja Technology Village (ATV) will provide a natural environment for the incubation of new companies.

Beyond the nucleation of new companies, the AISTs will promote regional cooperation by developing strong links with many of the industries and businesses within Africa. These links will include industrial advisory boards to guide the activities of departments and interdisciplinary institutes, sponsorship of research and development, sponsorship of innovation, and technology transfer to industry. As such, an office of technology transfer and licensing will be developed to manage the relationships between AIST-Abuja and industry in Nigeria and the rest of Africa. The hope is to have a push-pull relationship, with industry pulling the AIST into new fields, and the AIST pushing the frontiers of industry through innovation and the supply of students.

In sum, the development of AIST as a world-class training and research institution is based on the following key strategies:

- Rigorous criteria for selection of students and faculty
- Tapping the diaspora to bring faculty from leading universities around the world
- Strong regional cooperation with other African universities
- Laboratory-to-market approach to R&D
- R&D to satisfy the business needs of industry

Jeffrey Fine: Strengthening STI in Africa requires far more attention to higher education: Building Africa's higher education system and enhancing the quality of its R&D will require collaborative, regional efforts

Jeffrey Fine, consultant to the Partnership for Higher Education in Africa (PHEA),[35] noted that strategies for revamping and expanding higher education, a key component of systems of STI and R&D, must address inherent structural weaknesses as well as the legacy of past capacity building efforts.

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35 The Partnership for Higher Education in Africa Web site is http://www.foundation-partnership.org/.

With few exceptions, national systems of higher education in Africa are not only small, in terms of overall enrollment and number of institutions, but also "undifferentiated." Typically, a few publicly funded universities are expected to discharge a wide range of functions. Growth has been reflected principally in rapid expansion of undergraduate education, rather than in a deepening of the overall system through greater institutional specialization.

Strengthening STI in Africa requires that far more attention be given to higher education. Of particular importance in this regard is a huge gap in postsecondary professional and vocational training, as exemplified not only by weak, underfinanced institutions, but also by their lack of links to institutions specializing in academic education as well as to firms in the private sector.

Whereas in rapidly growing economies the private sector is an important source of applied training and experiential knowledge, the private sector in most Sub-Saharan African economies is small and generates little direct demand for research. Larger firms typically look elsewhere for the knowledge and skills needed to solve their problems. Links to publicly financed research bodies, for example, agricultural institutes and universities, remain weak. And references by governments to PPPs are often interpreted as demands for private sector support, without any real prospect of direct benefit to the companies in question.

Building Africa's higher education system and enhancing the quality of its R&D will require significant collaborative regional efforts. Cutting-edge research in highly specialized fields requires expensive equipment, expansive facilities, and a multidisciplinary spectrum of scientific researchers. Quality graduate education, especially at the doctoral level, will thus require collaboration across institutional and political boundaries.

Investment in higher education and research in Africa also requires investment in secondary education. Enrollment in fields requiring a sound foundation in mathematics and sciences is low by international standards, and qualified teachers, who must first be trained or retrained at the university level, are required. Governments are exploring various solutions, including the use of distance education (open universities) and purpose-built institutions, but this will all take time.

At the university level as well, there is a shortage of qualified staff and an emerging generational gap because of cutbacks in doctoral education over the past two decades in conjunction with an aging generation of academics, who are set to retire over the coming decade.

Fine noted that efforts, such as Centers of Excellence and the AIST, have been tried in the past, but the landscape is littered with defunct physical centers. Centers cry out for funds, but what is needed is to make education and R&D effective and relevant to a country's needs. This offers a path to sustainability, but it will require new investment.

Regional networks and collaboration is the way forward to build and enhance education and research in Africa.

> "Today, ICT makes the development of regional networks quite possible, but institutions must get on board. First on their agendas should be to bring their Web sites up to date. The core of global, collaborative research today is the ability to search and communicate via the Internet. If your institution cannot be found on the internet, you will not participate in the global revolution in research and development."
>
> —Jeffrey Fine, consultant to the Partnership for Higher Education in Africa

One initiative, the African Economic Research Consortium (AERC),[36] has proven highly successful, not only in sustaining core capacities, but also by expanding them through quality research, a collaborative master's degree program, and, more recently, doctoral education programs. The AERC has yet to be successfully replicated in other fields.

Another model, cited by the New Partnership for Africa's Development (NEPAD), features networks of Centers of Excellence, with electronically linked scholars coalescing around shared problems. Importantly, the aims and activities of such networks must be adapted to African needs and circumstances. In Canada, for example, such a network provides the opportunity to apply skills from different disciplines toward the solution of specific problems. This presumes that participating researchers already possess the required cutting-edge skills and knowledge in their respective disciplines. In Africa, however, most researchers still need to acquire the requisite high level of competence in their respective disciplines.

A final component required to attract investment in STI is a steady stream of sound projects—projects that will attract investors because of their aims, outputs, design, financing, commitment, and capacities. As elsewhere in the world, such projects will increasingly take the form of collaborative initiatives transcending institutional boundaries and national frontiers. Moreover, key constraints must be overcome—a lack of vetted information, inadequate resources, the absence of support

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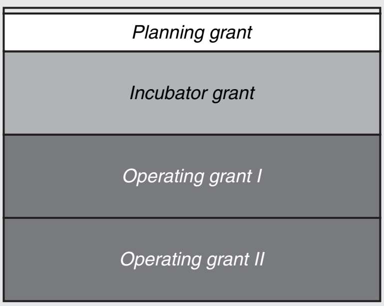
36 See http://www.aercafrica.org/home/index.asp.

Box II.8

Vetting Research and Learning Networks

1. Maintain database on collaborative activities
2. Document staff activities in research and postgraduate education spanning institutional and political boundaries
3. Further develop the database
4. Use the database for strategic planning by universities, governments, and regional authorities, as well as for the formation and financing of collaborative activities across Sub-Saharan Africa

Incubating projects



- Design sound projects
- Secure local buy-in
- Reduce perceived risks
- Use competitive funding
- Require collaboration

Source: Fine, Global Forum presentation.

by national governments, the need for strong administrative and managerial skills, difficulties in sharing various risks, and concerns about an eventual exit.

Fine proposed a methodology for creating such "deal flow" based on two principles. The first principle is to address the need for vetted information concerning potential initiatives, as well as for emerging institutional and individual capacities in various fields of research and learning. The second principle is a structured approach for incubating projects to the point at which they can secure longer-term financing from either individual investors or investment funds (see box II.8).

There is a new wave of collaboration in research and postgraduate education in Africa—a wave that transcends institutional and national boundaries. Some of the collaborations documented by the study for the PHEA display promise and creativity to generate new knowledge, to reposition their home institutions within regional and international systems of research and innovation, and to pioneer new modes of learning. Undoubtedly, the study overlooked other collaborations because they are still in nascent form or because they have yet to be documented. The underlying trends, global and Africa specific, suggest that there will be more in the future, as effective collaborations are becoming an integral feature of both research and learning, especially at the postgraduate level.

Phillip Griffiths: Regional networks overcome the isolation of researchers and offer benefits to graduate education in the sciences and engineering

Phillip Griffiths, chair, Science Initiative Group, and professor of mathematics and director emeritus, Institute for Advanced Study, noted that many of today's challenges in African S&T, including oceanography, water, power, transportation, and geothermal resources, are best approached on a regional level.

A regional approach overcomes the isolation of individual R&D institutions, provides for a critical mass of researchers in fields that increasingly require multidisciplinary approaches, enables multiple perspectives, strengthens each individual institution or "node" in the regional network, and enables institutions to retain talented scientists and bring back the diaspora to participate.

Moreover, strengthening human resources in modern science and engineering is increasingly recognized as an essential component of development. Yet, despite burgeoning enrollment in institutions of higher education throughout Sub-Saharan Africa, little systematic attention is being paid to graduate education or faculty development (see box II.9).

Griffiths noted that when 15 African university vice chancellors gathered for a forum sponsored by the PHEA in Cape Town, South Africa, in November 2006, almost all said that the single most-urgent need of their universities was well-qualified faculty to teach, conduct research, and help strengthen their departments and institutions.

Regional cooperation is required. Most countries in Sub-Saharan Africa lack a critical mass of expertise in important scientific specialties or disciplines. Even in the larger countries that may have many scientists, there tends to be an inadequate concentration of active scientists in any given discipline at any one university.

Regional research networks are the solution. Existing research networks have been successful in enabling researchers to work at their home universities and collaborate with peers in other geographic locations. There also are many traditional scholarship and fellowship programs in Africa, notably those supported by Scandinavian governments and by the

Box II.9

Addressing University Faculty Shortages in Africa

When the World Bank was preparing for the current Millennium Science Initiative in Uganda several years ago, it found that nationwide, fewer than 10 new doctoral degrees were awarded annually in sciences and engineering. At the University of Nairobi, the need for basic science faculty is so great that graduate students are sometimes granted tenure before receiving their doctorate.

The reasons are complex and systemic: too few teachers for too many undergraduates, leaving insufficient time or resources for research or mentoring; inadequate pay; little respect for the academic profession; poor job prospects. The issues cannot be resolved by a single initiative, but the combination of several current and nascent efforts, with complementary emphases on people, institutions, infrastructure, and university-government-industry linkages, could have a profound effect on the teaching and utilization of science and technology in Sub-Saharan Africa.

Source: Science Initiatives Group 2007.

Third World Academy of Sciences (TWAS). Existing "sandwich" programs allow students to spend time at universities in countries outside of Sub-Saharan Africa.[37] But few programs are devoted to training graduate students in the sciences in Africa with the primary goal of building capacity for university science and engineering departments. Those programs that do exist are mostly in the areas of agriculture and public health.

Regional research networks in Africa are proliferating:[38]

- International Center for Theoretical Physics (www.ictp.trieste.it)

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37 Sandwich programs enable doctoral or master's students to spend a semester or one or two full academic years studying and conducting research at a university, research institute, or laboratory other than their home institution. This enables students to take advantage of the often greater resources and opportunities to establish professional networks available at the second institution, while still building the locally relevant scientific and technical knowledge and local professional network important to a successful transition to the job market in their home country postgraduation. For more details, see Szanton and Manyika 2002.

38 For an extensive list of regional research and training networks, see the Africa Regional Networks database, hosted by the Partnership for Higher Education in Africa, available at http://www.foundation-partnership.org/networks/.

- Africa Institute of Science and Technology (www.nmiscience.org/aist.html)
- Africa Economic Research Consortium (www.aercafrica.org)
- University Science, Humanities, and Engineering partnerships in Africa (Ushepia, www.uct.ac.za)
- African Mathematics Millennium Science Initiative (www.ammsi.org)
- African Institute for Mathematical Sciences (www.aims.ac.za)
- U.S.-Africa Materials Institute (usami.princeton.edu)

An advantage of networks is their ability to link researchers who are isolated professionally and geographically. A 2004 study by the InterAcademy Council, *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology*, recommends that "regional cooperation in S&T training that leads to doctoral degrees, together with postdoctoral programs, should be promoted."

To address many of these issues, *Griffiths introduced RISE, whose inaugural phase will be funded by Carnegie Corporation of New York. RISE will build and enhance the quality of education and R&D in Africa* by helping to produce a professoriate capable of educating scientists and engineers needed for Africa's development.

RISE will prepare doctoral and masters-level scientists and engineers in Sub-Saharan Africa through university-based research and training networks in selected areas. Its primary emphasis will be on training science faculty to teach in universities, where the shortage of qualified faculty is acute, although some RISE graduates may choose careers in which they can apply their skills directly in the private or public sector.

Initially, RISE will consist of three competitively selected scientific research and training networks chosen from among proposals in targeted basic science disciplines (materials science, mathematics, chemistry) or problem-driven areas (ICT/instrumentation, renewable energy, safe drinking water). Consideration will be given to exceptional proposals in other fields. Each network will include three to five nodes in university departments or other locations where research and training take place. Additional linkages with universities and research institutes outside Africa will be strongly encouraged.

RISE will provide African students with a comprehensive graduate training program, in which they will receive degrees from any one of the degree-granting institutions in the network. Students will spend periods of time at other institutions, both in and outside the network, that can provide complementary instruction and research opportunities. At the end of six years, assuming a three-year demonstration and three-year follow-up phase, the goal is to have trained 40 to 60 doctoral and masters of science students, the majority of whom will be employed as faculty members at universities in Sub-Saharan Africa.

In sum, a regional approach toward research and training in Africa will meet following goals:

- Help overcome the isolation of R&D centers
- Build a critical mass of trainers, students, and researchers
- Increase professional and geographic mobility of trainers, students, and researchers
- Improve the overall quality of research and training in Africa

Sonia Plaza: Ways to move forward with regional initiatives in Africa

Sonia Plaza, senior economist, World Bank, noted that working on S&T solutions for local problems is critical to making R&D effective and relevant to the country's needs. It is not only world-class research that is important, but also buy-in of farmers, politicians, and the local population. Regional networks and cooperation pay off because modern-day research and development require interdisciplinary teams and a critical mass of researchers to achieve results. Thus, research institutions must focus on their complementarities and strive to work together to enhance the quality of their R&D, to achieve economies of scale, and to coordinate funding and donor support.

There are many challenges to creating a regional network, including overcoming inexperience in regional planning and harmonizing national policies and strategies; finding a recognized institution to catalyze development of a regional network; mediating between regional versus local ownership of processes and results; sharing data and other information; and covering transaction costs. Yet, there are a number of excellent, successful examples in Africa.

One such example is the Eastern African Dialogue on Policymaking on Biotechnology, Trade, and Sustainable Development, which is organized by the International Centre for Trade and Sustainable Development[39] and the African Technology Policy Studies Network,[40] and is co-hosted

39 See www.ictsd.org.
40 See www.atpsnet.org.

by the African Union and NEPAD. The challenges in this program have been addressed through joint research and development activities, joint standard setting, joint risk assessments, joint monitoring of impacts and benefits, and the development of a regional biosafety clearing house.

Areas that could benefit from a regional approach are S&T, biosafety, quality standards, and IPRs. In this regard, the World Bank and other international funding organizations could support a regional effort in STI and R&D. The effort could harmonize national policies and strategies for a regional agenda, including trade facilitation; provide a common forum to formulate strategy, articulate and prioritize issues, and develop joint negotiating positions; and set up a process of consultations to promote coherent interaction among the regional, national, and global players.

Session 4—Summary and Conclusions

Panelists in this session considered the role of R&D in developing countries and asked the question "Should developing countries devote any resources to building their R&D capacity?"

The answer was an overwhelming "yes," but it was strongly tempered by the knowledge that building R&D capacity, by itself, will not solve many of the most pressing development challenges facing these countries.

In summary, the panelists agreed to the following:

- There are good reasons to pursue an R&D agenda, provided that the R&D is made relevant to a country's economic and social development objectives.
- Good-quality R&D requires training and retaining human resources as well as rigorous peer review and competitive selection systems for selecting and renewing projects.
- Universities can build effective R&D systems, contributing to a country's economic growth, by using a lab-to-market approach to R&D.
- Regional cooperation is essential for mobilizing shared resources to solve shared problems.

1. There are good reasons to pursue an R&D agenda, provided that the R&D is made relevant to a country's economic and social development objectives.

Homegrown R&D can address many of the significant issues facing the developing world today, and it can bring the developing world into the mainstream of modern society. R&D can also have significant impact on economic growth in agriculture, biodiversity, energy, environment, health, ICT, the oil and gas industries, and more.

Solid education and professional development systems must be available if a country is to develop in the twenty-first century. This includes systems for R&D, and the development of doctoral-level education is essential.

Wole Soboyejo discussed how high-level S&T education can accelerate the development of a knowledge-based economy—an economy that requires a critical mass of well-educated workers who can operate in globally competitive industries. In Africa, the Abuja-AIST will make *R&D effective and relevant to Africa's needs* through an initial focus on graduate student programs and on areas in which they can have an impact: petroleum and gas engineering in the Gulf of Guinea; ICT and applied mathematics; materials science; biotechnology; and water and environmental engineering.

Fernando Chaparro reported that Colombia is enhancing the quality of its R&D and making it more effective and relevant to the country's needs by changing its emphasis from basic research to innovation and *impact on the local economy*. When attempting to answer "What drives research?" and "Who sets the research agenda?" from the perspective of Colombia's experience, it is the needs of the local population and local industry.

Imported technologies may solve some problems, but in many other cases, *local technologies, developed through local research, innovation, and development, are more effective, better adapted to local problems, and less expensive*. Colombia's objective today is to decentralize its large, publicly funded institutions through public-private joint ventures with industry.

"We need much better links between researchers and users—not just discoveries, but innovations that are actually used. We also need research on why the answers don't get through, why health services often don't work, why farmers don't use modern crop varieties, and what can be done in different political circumstances to change these situations."

—Dylan Winder (2005)

2. Good-quality R&D requires training and retaining human resources as well as rigorous peer review and competitive selection systems for selecting and renewing projects.

Training and retaining human resources are essential to maintaining effective R&D quality. There are only 83 scientists and engineers per million people in Africa versus 1,000 per million in the industrial world. And many of the best African scientists, engineers, and educators depart for the developed world seeking both financial and professional success.

Phillip Griffiths noted that strengthening human resources in modern science and engineering is increasingly recognized as an essential component of development. Yet, despite burgeoning enrollment in institutions of higher education throughout Sub-Saharan Africa, little systematic attention is being paid to graduate education or to faculty development. When 15 African university vice chancellors were asked, almost all said that the single most-urgent need of their universities was well-qualified faculty to teach, conduct research, and help strengthen their departments and institutions.

Claudio Wernli explained how the Centers of Excellence supported under the auspices of the MSI project in Chile helped to *reverse the brain drain to industrial countries* and to *strengthen Chile's education and research institutions*. Moreover, the Chilean Centers of Excellence make Chilean R&D more effective and relevant to the country's needs by establishing them around multidisciplinary groups of scientists, educators, and students and focusing them on specific problems of relevance to the country, the local population, and local industry.

On the question of limited funding for R&D, **Jeffrey Fine** noted that efforts, such as Centers of Excellence and the AIST, have been tried in the past and the landscape is littered with defunct physical centers. Centers cry out for funds, but what is needed is to make education and R&D effective and relevant to a country's needs. This offers a path to sustainability, but it will require new investment. The AERC has proven highly successful, not only in sustaining core capacities, but expanding them through quality research, a collaborative master's degree program, and, more recently, doctoral education programs.

An important strategy for directing limited funds to good quality R&D is to build rigorous and competitive peer review processes for selecting and renewing R&D projects. Monitoring and evaluation should also be an important part of this process. As recounted in the Chilean case study, the program focuses stringently on the qualifications of the proposing teams and scientific excellence. Secondary consideration is given to gender and region. Grant renewals are also carried out on a competitive basis, while monitoring and evaluation are carried out by foreign experts.

3. Universities can build effective R&D systems, contributing to their countries' economic growth, by using a lab-to-market approach to R&D.

A labs-to-market focus on academic research in developing countries will ensure that research does not happen for the sake of research, and that the *limited financial resources of the country are used in a way that produces maximum economic benefits.*

As the AIST plans to accomplish, high-level S&T education can accelerate the development of a knowledge-based economy. A university can act as the catalytic core that can develop Africa's human capital; improve Africa's education system; provide for the development, incubation, and dissemination of knowledge; and enable Africa to build respected, world-class technological research systems, thereby building and enhancing the quality of Africa's R&D.

At every level of the AIST, the goal will be to create an exciting environment that stimulates innovation. Venture capitalists will be invited to campuses to interact with such innovators in ways that will stimulate the transfer of technology from the AIST to the marketplace. In this regard, the location of AIST-Abuja within the ATV will provide a natural environment for the incubation of new companies. A sharp focus on innovation, that is, commercial application of research, therefore seems a crucial strategy for building world-class research universities.

4. Regional cooperation is essential for mobilizing shared resources to solve shared problems.

There is a need for R&D capacity, if it can be made effective and relevant, *and* if resources are available. But *it was widely agreed that regional cooperation is essential for success—locally, regionally, and globally*.

Many of today's challenges in African S&T, including oceanography, water, power, transportation, and geothermal resources, are best approached on a regional level. A regional approach overcomes the isolation of individual R&D institutions, provides for a critical mass of researchers in fields that increasingly require multidisciplinary approaches, enables multiple perspectives, strengthens each individual institution or "node" in the regional network, and enables institutions to retain talented scientists and bring back the diaspora to participate.

Regional networks and cooperation pay off because modern-day research and development requires cross disciplinary teams and a critical mass of researchers to achieve results. Thus, research institutions must focus on their complementarities and strive to work together to enhance the quality of their R&D, achieve economies of scale, as well as to coordinate funding and donor support.

The Eastern African Dialogue on Policymaking on Biotechnology, Trade, and Sustainable Development is one such example of a successful regional initiative.

"For researchers in developing countries, the benefit of joining a global network, even if only by linking to a neighboring country, is that they are just a 'handshake' away from other members of the network. These networks create links in science so that researchers are only three or four steps away from each other in a broad global network of knowledge creators. These links increase the chances of knowledge exchange in multiple directions, from advanced to developing countries, and vice versa. Local links also increase the likelihood that knowledge creation focuses on issues relevant to the developing countries rather than on issues that concern only scientists in advanced countries."
—Caroline S. Wagner (2006)

Centers of Excellence promote regional cooperation through networking and outreach among other institutions both nationally and internationally.

Strengthening STI in Africa, however, requires paying more attention to higher education. Of particular importance in this regard is a huge gap in postsecondary professional and vocational training, as exemplified not only by weak, underfinanced institutions, but also by their lack of links to institutions specializing in academic education as well as to firms in the private sector. The speaker stated that *regional networks and collaboration are the way forward to build and enhance education and research in Africa*.

AIST will engage scientists regionally and globally. The AIST-Abuja campus, for example, is strongly influenced by the ASC and ISAB. Furthermore, five AIST institutions are planned—the AIST Campus in Abuja, Nigeria; an AIST Campus in Tanzania; a center for water and environmental engineering in Burkina Faso; a center for mathematical modeling and computing in South Africa; and a center for offshore petroleum engineering in Nigeria. And, the AISTs will also be connected to other African universities. Students and faculty from these institutions will have the opportunity to benefit from the programs at the AIST.

Keynote Session: The Gender Dimension of STI Capacity Building

This panel was invited to explore the gender dimension of building STI capacity in developing countries for sustainable growth and poverty reduction.

Over the past decade, much has been learned about the centrality of gender to development. The World Bank policy research report *Engendering Development through Gender Equality in Rights, Resources, and Voice* declared unambiguously that gender inequalities hinder development (Mason and King 2001). The authors concluded that ignoring gender disparities negatively affects sustainable well-being, growth, governance, and poverty reduction; that myriad policy instruments are available to promote gender equality and development effectiveness; and that gender issues must be integral components of policy analysis, design, and implementation. Organizations such as the Gender Advisory Board[41] focused on the gender dimensions of S&T policy and development and highlighted the positive connections between gender-focused approaches to S&T policies and development.

In the past decade, much of the gender-related work on S&T targeted equity for women and focused on such issues as access to training, opportunities to conduct research, and equal opportunities to pursue other aspects of successful S&T careers. Recently, this somewhat narrower emphasis on gender equity has been replaced by the broader issue of ensuring that everyone in society—men, as well as women—has access to quality S&T education and training and career opportunities. The driving issue is no longer gender equity, per se, but inclusion in the sense of mainstreaming gender considerations into all aspects of S&T capacity building for sustainable development.

The main consideration for the Global Forum's panel then was *how important is the issue of gender in STI capacity building? As developing countries attempt to "catch up," do men and women have equal access to education and training? Does this have implications for absorbing and using new knowledge and technically superior solutions? Finally, if serious gender-related obstacles hinder technological development, should a major emphasis be placed on finding ways to mitigate differential access to education and training?*

41 The Gender Advisory Board (GAB) was established in 1996 to provide advice to the United Nations Commission on Science and Technology for Development (UNCSTD), and to follow up recommendations submitted to the 1995 Beijing World Conference on Women. Three Regional Secretariats, for Africa, Southeast Asia, and the Americas, (i) act as nodes to support national governments; (ii) facilitate the development of National Committees on Gender, Science, and Technology, which work with a range of national stakeholders, and (iii) promote regional activities supporting the mainstreaming of gender, science, and technology (GST) into national and regional policy and programming. The GAB Regional Secretariat for Africa is hosted in Kampala, Uganda, by the Association of Women Engineers, Scientists, and Technicians in Uganda (WESTU). The Regional Gender, Science, and Technology Secretariat for Southeast Asia (RESGEST) is hosted by the Indonesia Institute of Sciences (LIPI) and the UNESCO Office in Jakarta; the Americas Secretariat is hosted by York University in Toronto, Canada. The board was supported by the Ministry of Foreign Affairs of the Netherlands.

The panel described models and programs for gender-related capacity building at various scales of effort. This included the following:

- The Gender Advisory Board, which has worked at the global level through the United Nations and at the regional level through four regional centers
- National programs in Egypt and India that have regional implications
- The need for integrating the programs operating at these different scales

The panel also drew lessons for the way forward to integrate gender with sustainable development and in informing approaches that target beneficiaries based on gender.

Panel on the Gender Dimension of STI Capacity Building

Shirley Malcom: Global policies connected with local actions: targeting and mainstreaming gender for sustainable well-being

Shirley Malcom, head, Education and Human Resources, American Association for the Advancement of Science (AAAS), emphasized that *a gender perspective is essential for analyzing issues, solutions, and policies for promoting sustainable well-being.* The MDGs cannot be met without taking a gender perspective, because gender is at the center of each of the goals. The achievement of sustainable well-being depends heavily on economic, sociopolitical, and environmental conditions and processes, and on their interconnections. Progress needs to be thought of in terms of improving the human condition in all of these dimensions—environmental, sociopolitical, and cultural as well as economic. Sustainability should be thought of as making these improvements in ways and toward goals that are consistent with maintaining the improvements indefinitely. This is a challenge for developing countries where large swathes of the population still lack the most basic ingredients of material and social well-being. It is also a challenge for industrial countries where many of the current consumption and production practices are not sustainable in resource and environmental terms and where widening gaps between rich and poor within countries, and fraying social safety nets, threaten sociopolitical sustainability.

According to the United Nations Economic and Social Council (UN/ECOSOC), gender mainstreaming means "assessing implications for women and men of any planned action, including legislation, policies, or programs; in any area and at all levels . . . [and] . . . making the concerns and experiences of women as well as of men an integral part of the design, implementation, monitoring and evaluation of policies and programs" (United Nations 1997). Thus, *gender mainstreaming is not only about women*.

Recognizing the importance of gender mainstreaming and the centrality of gender issues for sustainable well-being, the International Council for Science prepared a report, *Science Education and Capacity Building for Sustainable Development*, in preparation for the 2002 World Summit on Sustainable Development (International Council for Science 2002). The report highlights the importance of education (at all levels), training, access to facilities, tools and resources, employment, international cooperation, science communication, R&D agenda setting, policy development, and leadership. The important lesson is that once men and women are in science, women are the least likely to stay in the field, and that if they are in science, the problem becomes keeping them in the field and using their talents. The issue is one of providing incentives for recruiting and retaining women in science. The key is providing employment opportunities that use the talent base and identifying areas in which women have a special role.

The institutional innovations for dealing with gender issues are evolving, and the Gender Advisory Board has provided an important model for ensuring that gender issues received high-level attention. The board has overseen activities that supported national governments and UN agencies in implementing recommendations leading up to and following the 1995 UN Women's Summit, provided support and advice to agencies for mainstreaming gender concerns in S&T, and liaised with other UN agencies through UNCSTD, as well as served as the principal advisor to UNCSTD on gender issues.

Gender disparities are ubiquitous, so board members have learned from each other about best practices for mainstreaming. One of the outcomes of this sharing of best practices has been an innovative model for identifying local problems (identified by women themselves) and global problems (embodied in the MDGs) and establishing an intermediate capacity support structure. This recognizes that unsuccessful programs are characterized either by a design or implementation failure caused by insufficient or missing infrastructure. The group evaluated the challenges of addressing the human needs embodied in the MDGs, the role of science and engineering in addressing these challenges, and the tools required for success.

The institutional outcomes include establishing national committees (for example, in Brazil, Egypt, India, Indonesia, Kenya, Philippines, Rwanda, Tanzania, and Uganda) that highlight the issues and implement national programs. Other initiatives include information sharing, regional secretariats to coordinate efforts, and global learning activities, such as technological connections, partnering arrangements, and person-to-person networking. These organizations look first at the gender dimensions of national development and then consider the various sublevels of each (for example, race by sex issues), the importance of data collection (for example, understanding that "what gets measured gets done"), and the university linkages (for example, enrollments, degrees, facilities, and distribution of resources between men and women).

The last formal meeting of the Gender Advisory Board was in December 2006 at UNESCO in Paris to assess the first 10 years of its work, as well as to evaluate the status of the international movement for gendered S&T for development. It considered UN system activities and policies in the areas of gender, S&T for development, research activities in the area of gender, and current global trends and issues.

The greatest challenge for mainstreaming gender is in selling the story in the women's community. Convincing women in the development community that there is a role for S&T in development is more difficult than getting scientists and engineers to pay attention to women as a talent base. To highlight the importance, AAAS produced a report in 2000, *Linking Science and Technology to Women's Needs*.[42] Many other documents and programs have articulated the connections between addressing basic human needs and the role of S&T and gender, including *Beyond Barriers and Bias* (National Research Council 2006); the ADVANCE program of the U.S. National Science Foundation, which supports institutional transformation;[43] the InterAcademy Council's report *Women for Science* (2006), which recognizes the importance of "elite" institutions, such as national academies, in serving as advocates for women in science, engineering, and health fields; and the 2002 International Council for Science's report *Science Education and Capacity Building for Sustainable Development*, prepared for the 2002 World Summit on Sustainable Development (International Council for Science 2002).

The STI Global Forum should consider gender as fundamental to the "context" of development, to the protection and utilization of natural

42 See the American Association for the Advancement of Science, *Linking Science and Technology to Women's Needs*, available at http://ehrweb.aaas.org/archives/UN.pdf.

43 For details of the ADVANCE program, see http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383.

resources, and to strategies for building and using the R&D talent base and connecting it with the national, regional, and global economies. Gender considerations require a systemic approach—for example, hiring one or two highly visible leaders or university presidents, or one or two faculty members, does not address the problems. What is necessary is to understand the underlying policies and structures that guide programs and actions in all dimensions and to disaggregate the data collection that enables gender impact assessments to illuminate the best practices and interventions.

Farkhonda Hassan: Successful programs respond to the needs of local people and problems: bringing a gender perspective into the design is essential but not well understood

Farkhonda Hassan, chair, Commission on Human Development and local administrater of the Shoura Assembly (Egyptian Parliament), in her presentation "Women, STI for Poverty Reduction in Developing Countries," emphasized that the most important investment in endogenous S&T capacity in developing countries is the development of human resources so that each society has the capacity to utilize S&T to address its unique needs. Technologically prepared people will fuel innovation for countries to meet the MDGs and reduce poverty. The centrality of women to poverty reduction means that S&T capacity building should target women. In other words, the primary focus of S&T capacity building should be on women because of their importance to successful development strategies for poverty reduction. She emphasized that there is no one model for successful S&T capacity building in developing countries. But if there is to be one guiding principle, it should be that programs must be responsive to, and tightly connected with, the needs of the people being served, the local problems needing solutions, and the existing institutions supporting progress. This includes understanding how the local context not only shapes the development agenda but also the ability of local scientists and researchers to seek and find solutions.

The overlap of gender, S&T, and economic development is an underexplored area of human activity. Even after a decade of focused efforts of the Gender Advisory Board and after much reported success in empowering women as local entrepreneurs, the importance of introducing a gender perspective into the design of STI tools and interventions is not properly understood. Egypt's National Council for Women (NCW), established in 2000 by presidential decree to advance the status of women in Egypt, is attempting to change this dynamic and prove the importance of the gender dimension to society, policy makers, planners, and decision makers through various programs in agriculture, health, and ICT sectors. The Science and Technology for Development Project, which is implemented by the NGO Scientific Association for Egyptian Women (SAEW), aims to bring the benefits of S&T to the grassroots level. Programs target both the women-headed households in rural and poor areas as well as the unemployed and scientifically trained women university graduates. These programs include the following:

- Introducing locally made solar systems for heating water, cooking, and preserving vegetables and fruits (with the goal of dehydrating surplus peak harvests, thereby preserving their nutritive value, minimizing wastes, and generating income to local women), and distilling salt water to provide isolated coastal communities with regular potable water supplies
- Promoting the introduction of biogas technology in Manawat village in Giza governorate
- Conducting a national campaign to raise public awareness of the possible harmful effects of artificial coloring and flavoring in food additives (this was augmented by the introduction of natural substitutes that were developed by women scientists working in the National Research Center and led to a government ban on the use of artificial chemical substances in the food supply)

NCW also conducted several programs targeting ICT training and application. More than 1,000 people have been trained (some 300 obtaining international certificates) and subsequently employed by reputable companies. Some trainees opened their own private small businesses in Web design and development. In March 2005 President Hosni Mubarak inaugurated SME Online (www.afkargadida.com), which provides information on investment opportunities for SMEs, on legal procedures for women entrepreneurs to start or expand small businesses, and on commercialization, export, and exhibition opportunities. It also supports feasibility studies for selected projects.

In May 2005 First Lady H. E. Suzanne Mubarak launched Cleostore (www.cleostore.com), an e-marketing Web portal to capture electronic business for small businesses run by women entrepreneurs in Egypt. By displaying online catalogues of quality products, it also helps women entrepreneurs market their products in national, regional, and international markets. Many women have successfully entered markets in different parts of Egypt and in other countries such as Morocco, Pakistan, the United Arab Emirates, and Germany. With the addition of a resource center that provides online courses with an effective e-learning tool, users can learn about and be tested on entrepreneurship. A compact disc of the Legal Rights Project translates IPR and other legal issues into colloquial languages and makes these discs available through local women's clubs, local cultural centers, and NGOs spread across more than 4,500 villages of Egypt. And, finally, in response to a national need to preserve the heritage of embroidery and in response to research demonstrating that 80 percent of national heritage is in the hands of women, a partnership between NCW and UNESCO established a project to amass electronic records of traditional stitches and provide women in rural villages with computer training and skills to use the records (and clearly, skills that might have broader applications). The result was that IT empowered local women by providing them with the practical guides, the archive for future generations, and the tools for reproducing and marketing embroidery.

These efforts face several ongoing challenges, including the following:

- *Funding impediments to scaling up* the projects to a meaningful level. These projects all relied on donor contributions, and political will and presidential leadership did not necessarily translate into a national budget for these efforts.
- *Female illiteracy, particularly in rural areas, hampers capacity building.* Scattered efforts at illiteracy eradication that frequently include financial and social incentives show good results, but resources for these programs are still quite scarce.
- *Linking research to local needs for economic development*. Many successful STI capacity building efforts are not always geared to the development needs of local, underprivileged people.
- *Shifting from a protected economy to an open-market economy and privatization*, and the concomitant *reluctance of private sector companies to invest in capacity building programs* that would create a workforce able to meet quality standards, and to harness R&D to solve local problems.

To address these issues, the World Bank should promote better linkages between STI policies and the elements of Poverty Reduction Strategies, and build more gender sensitivity into these strategies.

Sudha Nair: Women in science and science for women: moving forward in an inclusive approach

Sudha Nair, program director, M. S. Swaminathan Research Foundation, India, in her presentation, "The Gender Dimensions of STI Capacity

Building," stressed the need to find more creative ways of embedding inclusiveness in the process of developing and carrying out STI capacity building programs, policies, and partnerships. People-centered sustainable development "should ensure women's equal access to economic resources, including land, credit, S&T, vocational training, information communication, and markets" (Universal Declaration of Human Rights 1948). Including the perceptions of end users, especially women, is critical when planning and implementing projects. Do they see a particular technology as providing benefits to the local community? End users should participate equally in the assessment of projects. Will a particular technology deliver what is needed or is it suited to local needs? The intellectual and land property rights of end users should be considered in drawing up plans. A water storage and irrigation system that requires access for maintenance has little utility for farmers and communities that do not own the land or have access rights to the land.

Inclusive approaches mean that women are seen not only as end users (science for women) but also as innovators (women in science). To ensure that more women enter and stay in science and engineering professions and become innovators, science and engineering must be more visible to women—participating in science panels, agenda-setting efforts, and policy forums. In India, two reports provided the foundation and the data for moving these issues into the policy agenda within view of decision makers. The first, an India Science Report, *Science Education, Human Resources and Public Attitudes toward Science and Technology* (Shukla 2005), found that the IT revolution has pushed all students, including women, away from science and toward ICT applications. The Council of the Indian Academy of Sciences report, *Science Careers for Indian Women* (2004), reviewed issues related to access and retention of women in scientific careers. The study found several areas needing to be addressed, including the following:

- Retention—focusing efforts on catching students at the secondary and tertiary level
- Recruitment—providing equal opportunities for women to encourage continued participation
- Re-entry—retraining and developing policies that enable institutions to take back returning women scientists after a hiatus
- Research and development—providing women scientists with proposal-writing skills

- Recognition and reward—establishing awards to recognize achievers to serve as role models for recruitment
- Remuneration—developing different models for entrepreneurship and promoting self-employment opportunities

The "process innovation" in response to these reports was to establish a national committee within the Indian National Science Academy to improve the visibility and effective participation of women in science. The committee is garnering ministerial attention and responds to requests for advice.

To ensure that science pays attention to the needs of rural women, end users need to be more visible to innovators and planners (science for women). Using S&T, research, and policy in a gender-sensitive manner to empower women to meet their needs is a major component of sustainable development. Modern science can validate women's knowledge and skills arising from their role in food production, traditional healing practices, and management of natural resources. When programs are aimed toward employing this indigenous knowledge and engaging technologies that enhance it, women's unskilled labor turns into skilled labor and, as they enter the marketplace, they learn to be entrepreneurs and to market their skills.

Producing science for women entails developing policies, programs, and partnerships that place women at the center of a bottom-up participatory approach. By providing women with access to information, technology and skills, and financing, they are able to utilize science to add value to indigenous knowledge for economic development. Examples provided by the M. S. Swaminathan Research Foundation, in the field of biodiversity and biotechnology, include biovillages, bioresource complexes, and bioparks. The models focus on innovative delivery systems (for example, value chain end-to-end models), utilize partnerships (for example, university, government, NGOs, international technical agencies, financial institutions), and aim to empower local women and enable them to become entrepreneurs.

The Biovillage Project is a partnership between the foundation, the government of India, and international agencies (the Food and Agricultural Organization of the United Nations, the United Nations Development Programme [UNDP], and the International Fund for Agricultural Development [IFAD], which provide funding and technical assistance.[44] The biovillage paradigm pays concurrent attention to

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44 For more on the Biovillage Project, see http://www.unesco.org/courier/2001_01/uk/doss27.htm.

natural resource conservation, productivity improvements, and poverty eradication. It embraces job-led economic growth rooted in the principles of ecology, equity, energy efficiency, and employment generation. Approximately 20 villages with teams of 25 project specialists operate in areas such as vermicomposting, Azolla production, biocontrol production, mushroom cultivation, biopesticide and biofertilizer production, papermaking from waste, coir rope tying, and others. Technical assistance—for example, drawing on the mushroom cultivation model, includes (i) introducing simple technologies for land preparation, harvesting, and storage; (ii) demonstrating enhanced horticultural gardening practices, such as trickle irrigation and raised-bed cultivation; (iii) developing craft industries to find a market within the tourist trade; and (iv) providing technical how-to guides—is aimed toward helping to establish profit-making enterprises. Mentoring and knowledge transfer are provided by Regional Technical Centers and Rural Business Hubs.

Bioresource complexes are a cluster of several contiguous villages in which economically viable and ecologically compatible biotechnologies are provided to the people.[45] These are initiated at five locations in partnership with state governments, agricultural universities, banking institutions, and NGOs. An example is a bioresource complex devoted to producing pharmaceuticals and medicinals. Another example is the biotech parks, which aim to bridge the rural urban divide. The Biotech Park for Women in Chennai, for example, provides various services to first-generation women entrepreneurs, including assessment counseling, technology sourcing, and marketing advice. In 2005 the Indian Ministry of Science and Technology's Department of Biotechnology reported that some 53,000 families have benefited from these programs, which are designed to use biotechnology to empower women and communities. As a percentage of population, however, this number is quite small.

The way forward includes scaling up the programs, sustaining political will, improving and increasing PPPs, ensuring equitable investments in STI to ensure inclusion, establishing an early technology development fund, providing equity funding for technology leapfrogging, and tapping into traditional knowledge. The perpetual challenge is funding, particularly mechanisms to provide financial support directly to women.

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45 For more on bioresource complexes, see http://www.dbtindia.gov.in/programmes/biotechsocietal.html.

Gender Session, Conclusions—Synthesis

Several synthetic issues emerge from these presentations, including the following:

- *The centrality of women to poverty reduction means that STI capacity building should target women in strategies to achieve the MDGs.* Most of these efforts are focused on *acquiring and using existing knowledge and adapting it to local circumstances (applying modern science and engineering to solving local problems)*, initially focusing on rural poor (for example, Indian and Egyptian models) and making links between rural and urban centers (for example, the Indian Biotech Park for Women in Chennai). These programs are not gender-neutral, because there are implications for men (for example, competition for microcredit, family and child issues, and so on) that must be factored into planning and implementation.
- When the STI capacity building program is aimed at training and producing scientists and engineers *to produce and use new knowledge* and to establish and sustain a research and innovation structure, *gendered approaches provide the best means to attract and retain both men and women into S&T careers and to develop the innovation necessary for countries to "catch up."*
- *Successful STI capacity building models* (drawn from the Indian and Egyptian examples), *primarily designed for gender mainstreaming or for women's inclusion*, have several elements in common with each other and with successful models in general, including (i) connecting interventions with *national development strategies*, (ii) establishing mechanisms to ensure bottom-up approaches that *match local problems and local infrastructure*, (iii) matching training and skills development with local needs, (iv) engaging with *S&T institutes or universities* to connect the researchers with local problem solving, and (v) working with *NGOs* to help set local needs in the broader national (or rural to urban) context and to help sustain political will.
- Gendered approaches demonstrate a mix of *horizontal policies* (those that level the playing field) and *vertical policies* (those that target capacity building). Enlisting *gender champions* in each dimension and across all programs and policies is a critical ingredient for successful programs that lead to social transformations.
- *NGOs are critical for diffusion*. They need to work creatively with R&D institutes and local communities. Building up the skill to find,

deploy, and utilize more sophisticated technologies depends on NGO links with R&D institutes and universities. The Indian models show the importance of these partnerships between government, NGOs, universities, and locally trained participants. Missing from many of these projects, however, is the link with the private sector.

- *Networking* is essential for sharing experiences and developing successful models. The Gender Advisory Board provides a mechanism for engaging national leadership attention, for sharing experiences to develop narratives of best practices, for identifying gender "champions" and their inclusion at all levels of discussion, and for ensuring that gender considerations enter into all discussions of programs and policies for promoting sustainable development.

Mainstreaming gender into STI capacity building for sustainable growth and poverty reduction

The objective of the World Bank's gender and development policy is "to assist member countries to reduce poverty and enhance economic growth, human well-being, and development effectiveness by addressing the gender disparities and inequalities that are barriers to development, and by assisting member countries in formulating and implementing their gender and development goals" (Mason and King 2001).

Mainstreaming has also been identified as a priority in reports of many UN agency efforts, the IDB, and other international financial institutions, for example, UNDP's efforts, notably the Inter-Agency Committee on Women and Gender Equality (IACWGE), the United Nations Development Group (UNDG) Sub-Group on Gender Equality, and the OECD Development Assistance Committee (DAC) Working Party on Gender Equality. *The focus of these gender mainstreaming efforts is on equity and workforce issues in general, not specifically about developing STI capacity through targeted approaches directed at women or about introducing gendered approaches to policies related to STI capacity building.*

The World Bank report *Engendering Development—Through Gender Equality in Rights, Resources, and Voice* (Mason and King 2001) proposes a three-part strategy to promote gender equality, including the following: (i) institutional reforms that promote equal rights for women and men; (ii) policies for sustained economic development; and (iii) active measures to redress persistent gender disparities.

From the above, the following policy recommendations can be drawn:

- A more thorough assessment of lessons learned from gendered approaches to STI capacity building is needed from which to draw conclusions and best practices. It will be useful to evaluate lessons learned from applying modern science to solving local problems, especially programs targeting women in poverty reduction strategies. An important part of the evaluation is not only what additional training and skills are needed but also what are the most appropriate delivery systems—for example whether vocational training is possible using local research institutes, universities, or IT-mediated distance learning, and so on.
- Much has been written about the broader assessment of gendered approaches to STI capacity building aimed at producing new knowledge via R&D. As noted by all three speakers, there is a need to disaggregate data and demonstrate quantitatively the value added of gendered approaches, particularly in developing countries attempting to "catch up." The Gender Advisory Board's report *Gender, Science and Technology for Sustainable Development: Looking Ahead on the Next 10 Years* (2006) reaffirms this point and provides suggestions for moving forward. The problem is that much of this work on gender dimensions of STI capacity building is decoupled from other gender and development efforts of the Bank and U.N. agencies. As described in more detail in the above synthesis, there is a need to integrate these efforts.

PART III

Government and Development Partner Perspectives

Government Perspectives

Ministers and senior policy makers from five governments described the following:

- Their governments' views on the importance of STI in national development strategies
- Ways in which STI was incorporated into the national policy-making process in each country
- Lessons of experience based on the successes and failures they experienced in the course of implementing these programs and policies
- What support, if any, they would like to receive from the various development partners attending the Global Forum

> "If Mozambique is to raise income levels and standards of living it is a necessity to find new ways to add value to all its natural resources, not just to exploit unprocessed raw materials."
>
> —Venâncio Massingue, minister of science and technology, Mozambique

Venâncio Massingue, minister of science and technology in Mozambique, explained that Mozambique emerged as a peaceful nation in 1992 after 26 years of conflict and instability. Since 1992 Mozambique has enjoyed stability, economic growth and social development. Its economy relies on a variety of natural resources, including hydroelectricity, gas, coal, minerals, timber, fertile agriculture, and a long coastline. It successfully exports sugar, cashew nuts, tea, coconuts, and aluminum, timber, and sea products. But Mozambique also has a per capita GDP of just $320 and high rates of illiteracy (53.6 percent overall). If Mozambique is to raise income levels and standards of living, it must find new ways to add value to its natural resource exports, rather than simply exporting unprocessed raw materials as it does today.

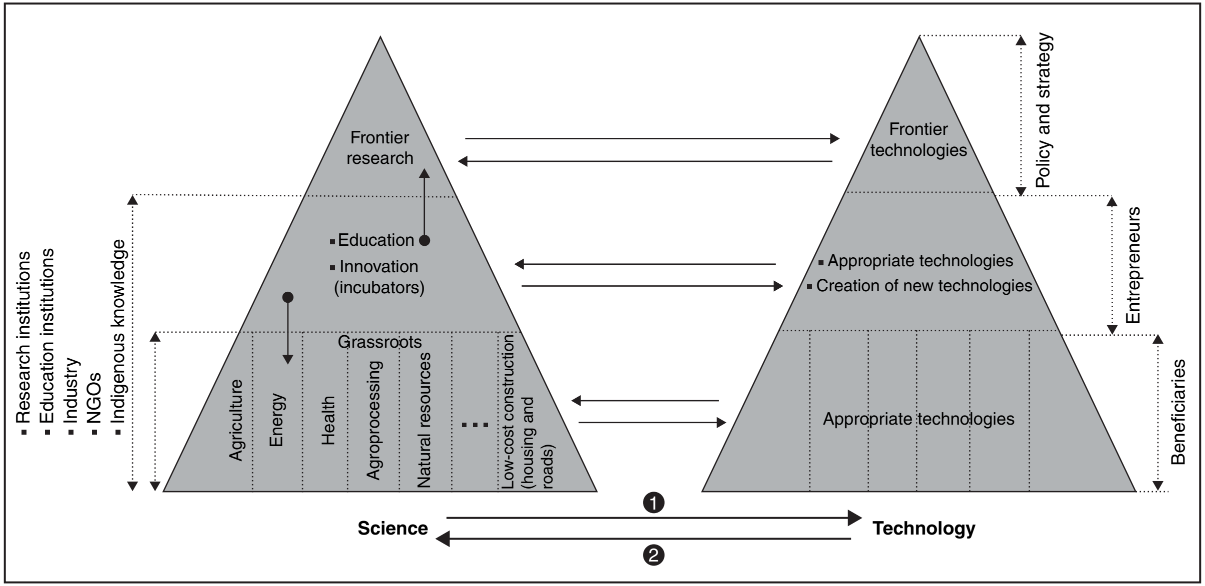
Mozambique has both the *political will* and the *vision* to build the STI capacity required to meet these challenges. Mozambique's President Armando Guebuza has declared that developing the country's STI capacity is a top priority. In the wake of this declaration, the government prepared a *Science and Technology Vision*, which is intended to turn the idea of a knowledge-based economy and society into a reality (see figure III.1). However, the challenge now is for the government to deliver on this vision.

To accomplish this, the government is—

- Focusing most of its STI capacity building efforts on the grassroots areas of the economy, including agriculture, energy, health, agroprocessing, natural resources, and low-cost construction. This means targeting the 80 percent of Mozambique's population of 20 million that lives in rural areas. The main failures of scientific development and technology transfer in Africa are due to the weak linkages between the needs of local communities and the technology that is imported or developed to address these needs.
- Promoting innovation and private sector development, including incubation of technology-based businesses. This will help Mozambique create economic growth rather than simply alleviate social problems resulting from the lack of growth and income.
- Supporting the development of frontier scientific research and frontier technologies. While important to maintain frontier activities, this objective receives the smallest amount of funding, because it generates the fewest tangible, immediate development benefits.

A key step for Mozambique was incorporating STI into the country's Poverty Reduction Strategy Paper (PRSP). STI was made a crosscutting pillar of the PRSP because it is an essential input for achieving all the other objectives specified in the paper. Including STI in the PRSP was an important and necessary step for obtaining development partner support for the national S&T strategy.

Figure III.1. Mozambique Science and Technology Development Concept



Source: Massingue, Global Forum presentation.

The international development community faces four challenges:

- Establish an international agenda in which S&T is the *driver* for socioeconomic development.
- Establish financing mechanisms for S&T. Especially in the poorest countries, *S&T competes in the national budget for high-priority poverty alleviation programs in health, water, and other areas.*
- Promote the development and implementation of national S&T strategies linked to national development programs; *implementation is more important than simply writing the strategy document*.
- Establish S&T indicators for economic growth and wealth creation. *Putting the conditions in place for wealth creation is as important as using S&T for poverty reduction*.

* * *

> "A key to convincing Ministers that S&T is not a luxury or unnecessary competition to line Ministry budgets . . . has been convincing Nigeria's politicians to use S&T for economic development [in the areas of each line Ministry], rather than viewing it as an expense in the national and state budgets."
>
> —Turner Isoun, minister of science and technology, Nigeria

Turner Isoun, minister of science and technology of Nigeria, began his presentation by declaring that Nigeria has been a victim of the curse of oil resources and that it has misused some of its oil wealth. While the country has always been interested in *sharing* the revenues from oil resources with its citizens, it has ignored until recently, the opportunity to *invest* these revenues in programs that would build the STI capabilities that Nigeria needs to create a truly sustainable diversified economy.

Nigeria, along with many developing countries, made the historical mistake of convincing itself that S&T are luxuries that poor countries could not afford. This mistake was reinforced by the advice and policies of the international development institutions.

Since 1999, however, Nigeria has seen a major shift in its S&T policy. As one indicator of a renewed commitment to STI capacity building, 1999–2007 was the longest continuous period of existence for the Ministry of S&T. During this period, Nigeria has achieved the following:

- Recognized at all levels of government that STI capacity is a tool for economic development; and

- Determined that STI should not *compete* with other ministries, such as agriculture, for funding. Rather, STI is a crosscutting activity that supports and in many cases leads the other areas of the economy.

A key to this shift in policy and philosophy was convincing Nigeria's politicians to see S&T as a tool for economic development, rather than as simply another line-item expenditure in national and state budgets.

Highlights of specific actions that Nigeria has taken to advance its strategy include the following:

- The launch of two satellites and the development of a long-term space research development program. This program has developed a modern physical and institutional infrastructure and trained more than 70 researchers. It has served to attract and retain Nigerian scientists and engineers. It should soon lead to a new export industry for bandwidth.
- Development of traditional medicines and documentation of indigenous knowledge.
- Support to the 77 universities and polytechnics in Nigeria.
- Research into energy diversification from such sources as hydro, gas, solar, and nuclear power. Biofuels and ethanol are also being developed.
- Development of the postbasic education system, which is being financed over the next four years by a $180 million World Bank loan.
- Plans to establish a national science foundation with a $5 billion endowment. It is hoped that this will provide a reliable and sustainable source of funds for research, development, and innovation.

Drawing lessons from Nigeria's policy-making experience, following are recommendations to other countries that are preparing to embark on a similar process:

- There must be *political will and conviction*. This requires a policy champion and a policy patron. In Nigeria, this champion was President Obasanjo himself. A commitment from the president is essential (and solves 50 percent of a minister's problems in financing STI programs).
- *Policy must be homegrown with all stakeholders participating* in its development and ownership. External partners should *not* lead the development of the policy. If they do, local ownership will be compromised.
- Anchor STI priorities on the country's strengths and areas of comparative advantage. To secure public funding, STI must be made relevant to the nation's socioeconomic needs.

Many parts of Africa now have the financial resources to support S&T. Political will and conviction are also emerging. This political will must now be supported with sound strategies, pragmatic implementation, and cooperation between governments and their development partners.

* * *

"Countries are advancing their STI capabilities with or without the development institutions. The Bank and other development organizations must, therefore, find their place in this changing world and define . . . whether they are truly adding value in helping those in the developing world to use S&T to permanently escape from poverty."
—Derek Hanekom, deputy minister of science and technology, South Africa

Derek Hanekom, deputy minister of science and technology in South Africa, began by pointing out the dichotomy in the macroeconomic picture of the South African economy. It is a country of 47 million people and has the 22nd largest economy in the world ($227 billion GDP). Yet it has one of the most unequal income distributions in the world and is ranked 120 out of 170 countries in the United Nations' Human Development Index (HDI). It also struggles with the legacy of apartheid, which prevented the majority black population from accessing advanced education.

The government of South Africa is dedicated to achieving the objectives originally defined in its 1994 Vision of Reconstruction and Development. These include economic growth, job creation, and meeting the poverty reduction targets set forth by the MDGs. The government recognizes that a well-functioning NIS is essential for meeting these economic and social objectives.

The development of the NIS is guided by a 1996 white paper on S&T, which led to an S&T "Vision 2014," and also by a 2002 R&D strategy. This R&D strategy supports five areas: (i) biotechnology, (ii) advanced manufacturing technology, (iii) indigenous knowledge, (iv) nanotechnology, and (v) ICTs. Each of these areas has a comprehensive implementation plan that the government is now implementing.

The following factors were used to select these areas of focus:

- **Geography.** South Africa has natural advantages that benefit fields such as astronomy.
- **Criticality.** Capacity in ICT and biotechnology are viewed as absolutely necessary for any country that wishes to compete in the global economy.

- **Existing competitive advantages.** South Africa seeks to develop areas in which it has an existing technological or economic lead, such as deep-level mining.
- **Self-selection.** The need to tackle pressing social and environmental challenges compels South Africa to become involved scientifically and technologically in areas such as HIV/AIDs and climate change.

South Africa has a vanguard role to play in advancing regional and continental STI initiatives on the African continent. This includes sharing South Africa's STI capacities with other African nations. It also means continued participation in regional efforts in water, biosciences, mathematics, and other fields.

What should the World Bank and development community do to better support STI capacity building? Countries are advancing their STI capabilities with or without the development institutions. The Bank and other development organizations must, therefore, find their place in this changing world and define their own role. This requires thinking critically about whether they are truly adding value in helping those in the developing world use S&T to permanently escape from poverty.

* * *

"The economic performance of any country is closely tied to the application of science and technology. . . . It is important that the Vision Strategy which is being developed is geared towards enhancing Kenya's scientific and technological capacity, inculcating scientific culture, and integrating science and technology in our production and services sectors."

—Mwai Kibaki, president, Republic of Kenya, on the occasion of the official launch of Kenya's Vision 2030 in October 2006

Crispus Kiamba, permanent secretary in the Kenyan Ministry of Science and Technology, explained that the president and the National Social and Economic Council (NSEC) recognize the crucial role that STI capacity must play in Kenya's national economic development.

Without this leadership from the very top, it is very difficult to make progress on building STI capabilities. To promote buy-in and ownership across the national government, the Ministry of Science and Technology made two important decisions. First, an Inter-Ministerial Taskforce on STI was established to promote communication and input from all government ministries. Second, Sector Working Groups were established to determine how STI interacted with key economic sectors, including the following: ICT, health and life sciences, trade and industry, agriculture and related services, natural resources management, mining and energy, manufacturing, and physical infrastructure.

Each of these Sector Working Groups was led by an institution familiar with that sector of the economy rather than by the Ministry of Science and Technology. For example, the Kenya Agricultural Research Institute led the Agriculture Working Group's study and the Ministry of Energy led the Energy Working Group's study.

The Sector Working Groups identified a number of issues that inhibited the effective mainstreaming of STI in the various sectors, including the following:

- Ineffective high-level S&T leadership and ownership
- Lack of a long-term strategic planning perspective
- Absence of a strong and explicit legal and policy framework for STI development
- Poor understanding and utilization of existing knowledge, technologies, and capacities
- Weak or nonexistent links among private enterprise, communities, and R&D institutions
- Poor capacity to acquire global knowledge and ineffective linkages between Kenyan scientists and engineers, on the one hand, and their global counterparts, on the other hand
- Unfavorable national STI environment characterized by limited funding and limited public awareness of the role of STI in development

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Manuel Hinds, the former minister of finance of El Salvador, provided a rather different perspective, both geographically and bureaucratically, to the discussion. El Salvador's Ministry of Finance has been involved in efforts to make technological learning and access to knowledge key aspects of the country's economic policy.

In 1995 the government of El Salvador made a decision *not* to compete on the basis of low wages, but rather on the basis of "true competitiveness." To achieve this, the government sought to lower all costs in the economy except wage levels, modernize the state, and modernize and privatize the public sector. The objective was to develop a knowledge-based economy and build competitiveness by generating innovation.

"Latin America lacks a passionate political voice for science, technology, and innovation, despite the vocal concerns about globalization and liberalization. This stands in sharp contrast to the situation in countries that have thrived during globalization — including Korea, Singapore, and China. Politicians in these countries speak passionately about becoming the best in the world in S&T, producing wealth (rather than fearing it is being taken from the country), and finding opportunities in globalization."

—Manuel Hinds, former minister of finance, El Salvador

The innovation agenda of El Salvador was done in parallel with various critical macroeconomic, business environment, and investment climate reforms. For example, El Salvador made the necessary reforms to promote fiscal stability and achieve investment-grade status, stabilize the macroeconomic environment and inflation, reduce tariffs and nontariff barriers, introduce full competition into sectors that had operated as government monopolies, and privatize strategic industries including telecom and electricity. The government also modernized the public sector by reducing the absolute size of the government, halting government interventions in the private sector, and concentrating government spending on human capital, health, and education. The government also invested in making El Salvador an international logistics center for the region, thereby lowering the costs of financial, transportation, and distribution services for domestic firms.

Knowledge economy reforms were the second part of the government's strategy. This strategy was based on the principle that firms in El Salvador (and countries at a similar level of development) do a poor job of applying already existing knowledge and technologies. So the initial emphasis was not on R&D. Rather the emphasis was on creating connectivity to provide people and firms with access to information and knowledge. This initiative involved (i) creating a competitive telecom market before its privatization; (ii) building telecenters that provided access to the Internet; and (iii) e-government to produce the initial content of the telecenter network. The government has more recently moved to develop a series of technical schools to develop the technical skills of the labor force.

These reforms produced several beneficial outcomes. For example, privatization created two kinds of entrepreneurs in El Salvador. First, are entrepreneurs who wish to return to the system of government subsidies. The other type of entrepreneur runs the small up-and-coming firms that are applying knowledge and constitute the majority of exporting firms in

El Salvador. The success of these firms shows the potential for firms to compete successfully in global markets, even in a developing country such as El Salvador.

Latin America lacks "a passionate political voice" for STI, despite the vocal concerns about globalization and liberalization. This stands in sharp contrast to the situation in countries that have thrived during globalization, including Korea, Singapore, and China. Politicians in these countries speak passionately about becoming the best in the world in S&T, producing wealth (rather than fearing it is being taken from the country), and finding opportunities in globalization. Latin America, the Middle East, and for a long time Africa, have had politicians who do not understand that S&T is the source of new wealth and seek instead to merely protect existing wealth and resources.

Today's global economy is based on horizontal structures that emphasize connectivity and empowerment of individuals and innovative firms. In contrast, developing societies still have largely *vertical structures* based on protection, cozy arrangements between the state and private firms, and powerful bureaucracies. As these societies change, firms that are accustomed to being directed by the state and rely on subsidies will either adapt or fail. The firms that will succeed are those that wish to compete on the basis of work and innovation. Yet to change these societies, it is necessary to overcome entrenched interests. These include politicians (who see a crucial source of patronage disappearing with liberalization), bureaucrats (who see their power diminishing as the government renounces its ability to control the economy), and the general public (because in these countries, the bureaucrats and politicians have captured the support of the general public).

There are three essential elements for STI capacity building. The first is convincing the people that there is only one way to develop and that is through the application of knowledge. If you are not applying knowledge and technology, you are going backward. The second is scaling down operational objectives but not long-term ambitions. The important thing is to apply easily available knowledge, rather than generate basic research and new scientific discoveries. This also implies not trying to transplant institutional arrangements from the industrial to the developing countries. For example, it makes little sense to ask universities to help companies innovate if the local university is incapable of producing or finding useful innovations. In other words, do not design projects that require a degree of institutional development that simply does not exist. Third, focus on small pilot projects to generate an emulation effect. Large, complex projects can sink simply as a result of bureaucratic incompetence.

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Development Partner Perspectives

The Forum also heard from development institutions that are actively working on STI capacity building initiatives.

Joseph Eichenberger, vice president, African Development Bank (ADB), delivered a statement on behalf of President Kaberuka, emphasizing the importance of STI capacity building for Africa's development:

> Today, Africa faces the best opportunity for growth in its past 30 years. Across countries, pessimism is being replaced with greater confidence, assertiveness and optimism. But that is not enough. To sustain this growth, the continent needs to harness science and technology, integrate Africa into the global market, and transform the economies for fierce competition in a world fueled by information and driven by knowledge. In a context of declining knowledge infrastructure, brain drain, limited support to R&D, outdated and irrelevant curricula, and limited direct links between science and industry, Africa stands little chance at making it in the new economy, unless deliberate and bold initiatives are implemented to reinvigorate higher education, science, and technology and innovations in Africa [Kaberuka 2007].

As part of its transformation into a "knowledge bank," the ADB is creating a division of higher education, science and technology, and vocational and technical training. This is the first time in the ADB's 40-year history that it has had such a division.

To further strengthen higher education, science, and technology, and to develop the needed human capacity to support growth in the regional member countries, the ADB would develop a Higher Education, Science, and Technology strategy to guide its interventions, galvanize the scientific community, and mobilize partners.[1] The strategy, which was formally approved in July 2007, is based on the following three strategic pillars:

- **Supporting the National and Regional Centers of Excellence.** Through this pillar, the ADB will upgrade existing national and

1 The African Development Bank Strategy for Higher Education, Science, and Technology is available at http://www.afdb.org/pls/portal/url/ITEM/37BA4431200596B1E040C00A0C3D289C.

regional centers of excellence to provide quality tertiary-level training. The objective will be to improve the conditions for conducting scientific and technological research and innovations. The ADB will also support the establishment of networks of higher education, science, and technology institutions to enhance collaboration and create economies of scale.
- **Building Infrastructure for Higher Education, Science, and Technology.** Through this pillar, the Bank will support the building, upgrading, and rehabilitation of select higher education institutions. It will also provide resources for laboratories.
- **Linking Higher Education, Science, Technology, and the Productive Sector.** Through this pillar, the ADB will work with other partners to design and implement strategic interventions for sustaining economic and social growth. For example, linking higher education to the extractive or tourism industries would be essential for the skills directly or indirectly linked to the needs of those industries.

Where leadership exists, the ADB will direct its efforts at supporting and building the institutions (including regional centers of excellence) that are critical for Africa to be a key player in the global economy.

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"Most LAC [Latin America and the Caribbean] countries are acknowledging the importance of promoting investment in STI activities and human capital to foster sustainable growth. . . . Their efforts, however, still do not measure up to those of their main competitors across the world to compete in today's knowledge economy."

—Ciro de Falco, executive vice president, Inter-American Development Bank

Ciro de Falco, executive vice president, Inter-American Development Bank (IDB), discussed the performance of Latin America and the Caribbean (LAC) with respect to STI and what the IDB is doing to strengthen this STI capacity.

After many years of benign neglect, most LAC countries are acknowledging the role of STI in fostering sustainable growth. Their efforts, however, still do not measure up relative to those of their main competitors. For example,

- LAC countries are notable underperformers in knowledge investment. Korea's investments in R&D are more than double those of the entire LAC region.

- R&D in LAC is overwhelmingly funded and performed by the public sector. The private sector, which is the main source of innovation in dynamic regions and economies, invests little in R&D. In addition, there are weak linkages between the private sector, on the one hand, and public research institutes, on the other.
- The supply of high-skilled personnel, and more specifically of scientists and engineers, remains limited.
- In many of the lesser-developed countries the basic technological infrastructure, including ICT, a key enabler to knowledge-based economy, is lacking; and capital markets are ill adapted to the financing of innovation.

There are, undoubtedly, bright spots in the region. Many countries are beginning to implement STI capacity building programs. ICT investments are increasing rapidly. Access to technological information and technology transfer mechanisms are improving. Best or better practices from disseminating and diffusing technology are spreading. Programs to add value to natural resources—while at the same time tackling energy and climate change problems—are emerging, which can be seen by the case of the Brazilian ethanol program.

Historically, the IDB played a pioneering role in developing Latin America's STI capacity. Cumulative funding for the S&T sector was more than $2 billion between 1962 and 2006, and more than $4 billion if related support to higher education and agricultural research is included. These efforts have contributed to training thousands of scientists, creating or expanding centers of excellence in more than 120 universities, and establishing numerous national science and technology institutions.

But the results are still not sufficient to meet Latin America's development challenges. Therefore, over the next three years the IDB intends to focus on the following:

- Mainstreaming STI issues in its country strategy documents
- Strengthening institution building and technological infrastructure
- Developing human resources
- Supporting R&D and innovation in strategic sectors and technologies
- Promoting innovation in the private sector
- Fostering regional cooperation in STI

With respect to the human resources, human resource support programs must focus on both the supply and demand side of the equation.

This means that IDB programs should foster the production of a skilled workforce at postsecondary technical levels and increase the supply of science and engineering graduates, notably through the financing or cofinancing of student loans. But the IDB also expects to support the demand side through incentive systems that increase the capacity of firms to recruit highly skilled personnel, provide fellowships or traineeships that facilitate the mobility of science and engineering graduates in the private sector, as well as offer lifelong training programs. The IDB also aims to place renewed importance on providing financial support and policy advice in the field of higher education, particularly in the areas of science, engineering, and technical training, with emphasis on curricula design and accreditation.

Developing capacity for sustainable growth cannot be accomplished without a solid base of technological infrastructure. Many countries of the region still lack some of the basic infrastructure and services that are crucial for establishing and disseminating standards and ensuring quality control (metrology laboratories). Services specialized in the provision of technological information or transfer are also very often underdeveloped. IP regimes and patent offices frequently need to be better attuned to the needs of would-be innovators both in terms of the protection they offer and access to new knowledge. By international standards, many countries of the region are still lagging with respect to public and private investment in ICT. Although the IDB is committed to fostering such investment, more efforts will be made to support this type of infrastructure and equipment, because there is widespread evidence of its contribution to knowledge diffusion, skills improvements, and productivity gains.

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Ambassador Munir Akram, permanent representative of Pakistan to the United Nations and chairman of the Group of 77, noted that the developmental promise of S&T remains unfulfilled for many poor countries. The rich are getting richer, and the poor, poorer. Instead of bridging the gap, technology has often become a greater divider. Creating links between knowledge generation and development is one of the greatest challenges facing the developing countries and their development partners.

Effective policies and strategies for building STI capacity in developing countries are vital for poverty alleviation, balanced socioeconomic growth, and equitable integration into the global knowledge-based economy. A country cannot compete in the global economy without the

"The renewed commitment of the international community, especially financial institutions, is essential to support national efforts of developing countries for capacity-building. Bilateral and multilateral donors must increase their official development assistance for science and technology initiatives and programs in the developing countries."

—Ambassador Munir Akram, permanent representative of Pakistan to the United Nations and chairman of the Group of 77

capacity to acquire, develop, and apply science and technology. Thus, there is a strong case for the international community to develop a concrete plan of action to promote the application of science and technology to realize the MDGs and other internationally agreed-on development goals. Such a plan should consist of clear national and international actions.

At the national level, developing countries should adopt strategies for technological learning. These strategies should involve continuous interaction between government, industry, academia, and civil society. STI should be mainstreamed into national development strategies.

It is clear that no one size fits all. However, looking at the experiences, successes, and failures, it is clear that some essential points need to be undertaken at the national level by developing countries:

- *Improve the infrastructure for technological development*. This could include the establishment of business and technology incubators, export processing zones, and production networks.
- *Structure their investment and trade policies in ways designed to acquire technological capabilities*. In this context, incentives for FDI could place a premium on technology transfer and diffusion.
- *Strengthen education institutions and R&D organizations and their effective linkages with industry.* This activity would be vital.
- *Make a concerted effort to preserve the traditions of their people as well as indigenous and local traditional knowledge, practices, and technology*.

At the international level, several actions can be taken to advance the contribution of S&T to development:

- *First, the renewed commitment of the international community, especially financial institutions, is essential to support developing country efforts at STI capacity building.*

- *Second, a global campaign should be initiated for human resource training focused on the challenges of achieving the MDGs.* The industrial countries and advanced institutions can provide scholarships to developing countries. Similarly, world-class centers of excellence in areas relevant to agriculture and industry should be established in the developing countries through external cooperation. Similarly, high-quality "virtual universities" and virtual means of research could be created to spread knowledge, innovation, and technological application.
- *Third, international rule-making and standard-setting activities should respond to the concerns of developing countries and not discriminate against them*. To this end, the developing countries should be enabled to participate fully in standard-setting bodies. The application of new standards should take into account their impact on the developing countries.
- *Fourth, the agreement on Trade Related Aspects of Intellectual Property (TRIPS), and other IP laws, should be reviewed and, where necessary, revised to enhance their contribution to development*. This should be pursued both in the World Intellectual Property Organization (WIPO) and the World Trade Organization (WTO). This process can be informed by the experience with HIV/AIDS medicines.
- *Fifth, a more direct endeavor should be made to utilize global scientific and R&D capabilities for development*. The research and developmental needs and priorities of developing countries and possible niche opportunities for specific countries and regions should be identified. Modalities could be explored to secure funding for such research needs. For example, a Global Research and Development Fund could be created to guarantee minimum returns to private and nonprofit enterprises and institutions in industrial and developing countries to undertake research in areas and issues of interest to the developing countries—for example, tropical diseases, agriculture, and so on.
- *Sixth, an international organization should be entrusted to compile a list of credible S&T institutions and programs in the developing countries*, in the public and private sectors, to which financial support could be committed by development partners.
- *Seventh, appropriate institutional mechanisms should be devised to exchange best practices and experiences both in terms of success and failures in advancing the acquisition and use of science and technology*, at both the North-South and South-South levels.

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Walter Erdelen, assistant director-general for natural sciences, United Nations Educational, Scientific, and Cultural Organizations (UNESCO), spoke on behalf of Director-General Koïchiro Matsuura.

UNESCO supports the statement highlighted in several of the Forum's background documents that "STI capacity building is an absolute necessity for poor countries." Following are two recent examples of encouraging commitments to STI:

- The Eighth African Union Summit of Heads of State and Government, which focused on scientific research, technology, and innovation for Africa's socioeconomic development, led to a commitment to increase investments in science to at least 1 percent of GDP by 2010.
- The Caribbean Community (CARICOM) meeting held in May 2006 recognized STI as the driver of the global economy and approved the Tobago Plan of Action for Harnessing Science and Technology for Caribbean development.

These examples show that there is now a strong political will at the highest levels to use science as an instrument for development. With this in mind, UNESCO Director-General Koïchiro Matsuura, in his message on the occasion of the World Science Day for Peace and Development in November 2006, stated the following:

> No nation that wants to achieve social and economic progress can afford to be without independent capacity in science and technology. Over the past two decades, inadequate human and institutional capacity in science has been identified as one of the recurring factors preventing developing countries from reaching national and international goals [Matsuura 2006].

A key question posed by the Forum background paper asked, "What capacities must be built?" In answering this question, (i) we need to be more focused and targeted in the discussion about capacity building in STI, and (ii) we need new concepts and new approaches to capacity building itself.

The following provocative points explain these concerns. First, capacity building does not take place in an ideal world. Many countries are in conflict situations, and if we look into the African continent, many countries are in postconflict situations. What does the theme of this very meeting, building STI capacity for sustainable growth and poverty reduction, mean in such a context? UNESCO has recently taken on this challenge in creating IPSO (the Israeli-Palestinian Science Organization).

Similar challenges are faced in the context of disasters. Developing countries are increasingly facing disasters at unprecedented rates with strong impacts on communities. S&T capacity must also be adapted to the context of both unique education systems and culture systems. UNESCO, for example, is discussing what adaptation to climate change means in terms of different cultural contexts.

From experience, UNESCO sees the need to assist developing countries in building capacities for the reform and governance of national science, engineering, technology, and innovation (SETI) systems. This assistance will complement the capacities being developed, with assistance of the development banks, for the reform and governance of the economic systems. Through the reform of the governance of SETI systems, UNESCO wishes to ensure a well-functioning linkage between national SETI systems and economic systems.

The case of Nigeria is one example of UNESCO's current ongoing work. With funds provided by the Nigerian government and the UNESCO/Japan Funds-in-Trust for the Capacity Building of Human Resources, UNESCO is assisting the "Reform and Revitalization of the Nigerian Science, Engineering, Technology, and Innovation (SETI) System." The project has resulted in the training of 450 Nigerian officials on the concept of an NIS; another 120 officials on S&T budgeting; the creation of the Nigerian Forum on Science, Technology, and Parliament; the design of institutional mechanisms for coordinating SETI activities in Nigeria, including a high-level science governance council to be chaired by the president of Nigeria; and the development of guidelines for self-evaluation by SETI institutions, science-based ministries, and the federal Ministry of Finance.

In essence, this is an overhaul of the whole system of STI in a particular member state. The project, which has already led to expressions of interest from other countries in Africa and elsewhere, could become a model to build the governance capacities of national STI systems.

How can UNESCO work with its member states, the World Bank, regional development banks, and other organizations to develop the necessary national STI capacities? Its first role could be in fostering interagency cooperation for building the capacities of governments to formulate STI policies. This cooperation would help to ensure that STI policies are harmonized with trade, investment, and industrial policies.

This will improve the current situation in which individual agencies work independently and are often approached by the same client countries.

UNESCO also is willing to cooperate with the World Bank and other partners in the elaboration of science investment programs at the national level. The "One UN approach" resulting from ongoing reform of the United Nations makes this a realistic proposal, especially within the United Nations Development Assistance Framework (UNDAF). In the Nigerian example, all UN agencies in Nigeria have designated focal points for the STI reform project, and they will be working jointly to provide input to the second phase of Nigeria's National Economic Empowerment Development Strategy (NEEDS II).

UNESCO's director-general will give great attention to the recommendations emanating from the Forum, and UNESCO is willing to cooperate in implementing the resulting initiatives.

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Kobsak Chutikul, special advisor to the secretary-general of the United Nations Conference on Trade and Development (UNCTAD), spoke on behalf of UNCTAD Secretary-General Supachai Panitchpakdi and thanked the World Bank for the opportunity accorded to UNCTAD to partner with the World Bank in the preparation of a very important and timely event.

"It is not the lack of science or technological innovation, but rather the lack of national capacity to harness its potential that hinders countries from fully leveraging this vehicle for socio-economic progress and development. In many developing countries' development strategies, the science and technology component has been marginalized."

—Kobsak Chutikul, special advisor to the secretary general, UNCTAD

STI has seldom been as crucial to development as it is today. S&T can be a powerful tool in combating poverty through its contribution to sustained economic growth, enhanced market efficiency, and creation of employment opportunities. The application of S&T in agriculture has the potential to increase food production through better soil management, efficient irrigation, and high-yield crops with enhanced food value. S&T may also play a pivotal role in meeting health-related MDGs: drugs, vaccines, diagnostic systems, improved access to medical information, and monitoring systems for drug quality are indispensable in the fight against infant and maternal mortality, malaria, HIV/AIDS, and other diseases.

The importance of S&T is increasingly recognized at the intergovernmental level. This can be seen, for example, in the outcome of the 2005 World Summit and the World Summit on the Information Society (WSIS). Heads of state committed themselves to a number of measures to address the special needs of developing countries in science- and technology-related areas. They also committed themselves to promoting and facilitating access to technologies and to assisting developing countries in their efforts to promote and develop national S&T strategies.

However, the socioeconomic benefits of modern S&T have yet to reach across all countries and people. It is not the lack of science or technological innovation, but rather the lack of national capacity to harness its potential that hinders countries from fully leveraging this vehicle for socioeconomic progress and development. In many developing countries' development strategies, the S&T component has been marginalized.

UNCTAD's reports stress the fundamental importance of building a solid national S&T base to enable the generation, use, and diffusion of scientific and technological knowledge (UNCTAD 2007). UNCTAD's research further suggests that active and long-term government intervention is needed to accomplish four objectives: (i) to better tailor education to the needs of industry; (ii) to encourage collaboration between public and private R&D; (iii) to establish appropriate infrastructure, including science parks and incubators; and (iv) to make strategic use of IP systems. In short, S&T must be mainstreamed into countries' development efforts.

In UNCTAD's own work, S&T has always figured prominently. As the lead entity for science and technology within the United Nations, UNCTAD has contributed significantly to the conceptualization of technology issues, such as the legal environment for technology transfer and the various channels for acquisition, the terms and conditions of the technology transfer process, the technological capacity building process, and best practices for obtaining access to technology.

To assist developing countries in their efforts to build sound national systems of innovation, UNCTAD carries out Science, Technology, and Innovation Policy reviews (STIPs). The main objective of these reviews is to help developing countries and countries with economies in transition to evaluate the effectiveness of national S&T policies and their impact on wealth creation, industrial competitiveness, and quality of life. The focus of STIPs is to help governments, especially those in Africa, formulate and implement S&T policies that address their development challenges. UNCTAD has already completed three reviews (Colombia, Jamaica, and Iran) and is currently undertaking one for Angola. It has begun planning reviews for Ghana and Mauritania. The World Bank and other interested development partners such as UNESCO and the ADB are invited to join in this endeavor.

UNCTAD holds a strong belief in the importance of S&T for development and is committed to strengthening activities in the S&T field. Hopefully, the meeting marks the beginning of closer collaboration between UNCTAD and the World Bank in the area of S&T. In partnership, UNCTAD hopes to help move forward concrete ideas for bringing S&T to the forefront of the global development agenda and translating political commitment into concrete action.

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"Scientific advances pioneered at research centers in the developing world can become important innovations through international collaborations."

—Gordon Conway, chief scientific advisor, DFID

Gordon Conway, chief scientific advisor, DFID, noted that DFID expects to provide $20 billion of annual development assistance by 2013, with $375 million devoted to STI by 2010. DFID is in the process of preparing a science and innovation strategy that will outline its plans to help developing countries build their STI capacities. DFID hopes to work with other aid agencies in this endeavor, including the International Development Research Center in Canada (IDRC), the Scandinavian aid agencies, and the World Bank.

Conway's main message was that STI capacity building programs must strive to integrate developing-country scientists into global scientific research networks. This integration would enable these scientists to work on local problems while, at the same time, tap into the international knowledge networks that may be working on related or similar pieces of the puzzle. In today's global economy, multinational scientific collaboration is a critical ingredient for research, development, and innovation. For example, the New Rice for Africa (NERICA) project was started at the African Rice Center.[2] But cooperation with Chinese researchers on tissue cultures

2 For more on the NERICA project, see http://www.warda.org/warda/uplandnerica.asp.

led to the cultivation of new rice varieties. Similarly, the research for insecticide-treated bed nets was conducted at the Medical Research Council laboratories in the Gambia.[3] But the manufacture of the impregnated bed nets was the result of cooperation with Japanese, Saudi Arabian, and Chinese engineers and firms.

The challenge, then, is for the scientific and technological institutions in developing countries to become embedded in these global networks of innovation. STI capacity building programs should be designed with this objective in mind. This is the critical challenge for both donor agencies, such as DFID, that support STI capacity building and for the scientists, engineers, and innovators working in developing countries.

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Paul Dufour, senior advisor, International Affairs, Office of the National Science Advisor, Canada, asked how scientifically and technologically advanced nations like Canada can mobilize a portion of their science and research assets to solving developing country problems. Under the leadership of former Prime Minister Paul Martin and Arthur Carty, Canada's national science advisor, Canada has been trying to do just that.

"The need for the donors and development institutions to coordinate their STI capacity building efforts is a key challenge going forward."
—Paul Dufour, senior advisor, International Affairs, Office of the National Science Advisor, Canada

As a first step, the previous Canadian government challenged all stakeholders to mobilize their knowledge assets to meet the challenges of the developing world and pledged to devote at least 5 percent of its national R&D spending in addressing this challenge. Other aspects of the effort, as discussed at the Global Forum by Bonnie Patterson,[4] include encouraging Canadian research networks to focus on global health issues and endowing scientific research chairs in developing country universities.

3 For more on the Medical Research Council's pioneering work on insecticide-treated mosquito nets, see http://www.mrc.ac.uk/YourHealth/StoriesDiscovery/MosquitoNets/index.htm.

4 Bonnie Patterson is president of Trent University and chair of the Association of Universities and Colleges of Canada.

This STI capacity building effort should not be seen as the responsibility of aid agencies alone. All institutions that constitute Canada's knowledge assets—including universities, research institutions, private firms, and so on—should and must participate. Every OECD country should participate in this effort. A Carnegie Group of G-8 S&T ministers and advisors is searching for ways to apply the G-8's STI capabilities toward helping the African Union meet the targets outlined in the NEPAD Science and Technology Consolidated Plan of Action.[5] STI and development will be on the agenda for both the German and Japanese G-8 chairmanships.

The discussion of S&T education in development should go beyond tertiary and higher education. OECD countries are increasingly worried about declining interest in science and math at the earliest stages of education. Math and science in basic education are becoming emphasized in developing countries. This issue requires considerably more attention by the donors than it currently receives, which raises the possibility of a new "grand challenge" to mobilize initiatives of education around science and engineering.

Changing paradigms in international S&T partnering will have important impacts on how STI affects the development process. These changes include the following:

- New global rules affecting the movement of people, knowledge, and technology
- The emergence of enabling or transformative technologies and their impacts
- A growing multidisciplinarity of research and distributed knowledge networks
- A reassessment of strategies of STI funding and governance mechanisms
- The vital role of global partnerships and regional knowledge networks for development
- The growing importance of the society-science interface being registered globally

5 The NEPAD Science and Technology Consolidated Plan of Action is available at http://www.nepadst.org/doclibrary/pdfs/ast_plan_of_action.pdf.

Successful STI capacity building in developing countries, and especially the LDCs, will require coordinated efforts from the development agencies. Despite all the bilateral and multilateral initiatives under way, a coordinated strategy from the donors has yet to emerge. This need for the donors and development institutions to coordinate their STI capacity building efforts is a key challenge going forward.

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References

Arnold, Erik, Martin Bell, John Bessant, and Peter Brimble. 2000. "Enhancing Policy and Institutional Support for Industrial Technology Development in Thailand: The Overall Policy Framework and the Development of the Industrial Innovation System." World Bank, Washington, DC.

Bell, Martin. 2003. "Knowledge Resources, Innovation Capabilities and Sustained Competitiveness in Thailand: Transforming the Policy Process, Report Prepared for the National Science and Technology Development Agency of Thailand." Funded by the World Bank via IDF Grant No. TF050237, January. World Bank, Washington, DC.

Blomstrom, Magnus, and Ari Kokko. 2007. "From Natural Resources to High-Tech Production: The Evolution of Industrial Competitiveness in Sweden and Finland." In *Natural Resources: Neither Curse nor Destiny*, eds. Daniel Lederman and William Maloney, 213–46. Washington, DC: World Bank.

Brimble, Peter, and Richard F. Doner. 2007. "University-Industry Linkages and Economic Development: The Case of Thailand." *World Development* 35 (6): 1021–36.

Chandra, Vandana, ed. 2006. *Technology, Adaptation, and Exports: How Some Countries Got It Right*. Washington, DC: World Bank.

Chandra, Vandana, and Shashi Kolavalli. 2006. "Technology, Adaptation, and Exports: How Some Developing Countries Got It Right." In *Technology, Adaptation, and Exports: How Some Developing Countries Got It Right*, ed. Vandana Chandra, 32. Washington, DC: World Bank.

Council of the Indian Academy of Sciences. 2004. *Science Careers for Indian Women*. Available at http://www.ias.ac.in/womeninscience/INSA_1-17.pdf.

Dahlman, Carl J., and Jean-Eric Aubert. 2001. *China and the Knowledge Economy: Seizing the 21st Century*. World Bank Institute Development Studies. Washington, DC: World Bank.

Docquiera, Frederic, and Abdeslam Marfouk. 1999–2000. "Measuring the International Mobility of Skilled Workers (1990–2000)." Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=625258.

English, Phil, Steve Jaffee, and Julius Okello. 2006. "Exporting Out of Africa: The Kenya Horticulture Success Story." In *Attacking Africa's Poverty: Experience from the Ground*, eds. Louise Fox and Robert Liebenthal, 117–47. Washington, DC: World Bank.

Fairbanks, Michael, and Stace Lindsay. 1997. *Plowing the Sea: Nurturing the Hidden Sources of Growth in the Developing World*. Boston: Harvard Business School Press.

Gender Advisory Board. 2006. *Gender, Science, and Technology for Sustainable Development: Looking Ahead to the Next 10 Years.* Available at http://gab.wigsat.org/GAB_Report_Paris2006.pdf.

Gomory, Ralph E., and William J. Baumol. 2000. *Global Trade and Conflicting National Interests*. Cambridge: The MIT Press.

Hoekman, Bernard M., and Beata K. Smarzynska Javorcik, eds. 2006. *Global Integration and Technology Transfer.* Washington, DC: Palgrave Macmillan and World Bank.

InterAcademy Council. 2004. *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology.* Available at http://www.interacademycouncil.net/?id=9988.

International Council for Science. 2002. "ICSU Series on Science for Sustainable Development No. 5: Science Education and Capacity Building for Sustainable Development." Available at http://www.icsu.org/Gestion/img/ ICSU_DOC_DOWNLOAD/66_DD_FILE_Vol5.pdf.

Jaffee, Steven. 2005. "Delivering and Taking the Heat: Indian Spices and Evolving Product and Process Standards." Agriculture and Rural Development Working Paper No. 19: Cost of Compliance with SPS Standards. World Bank, Washington, DC.

Jaffee, Steven, and Spencer Henson. 2004. "Standards and Agro-Food Exports from Developing Countries." World Bank Policy Research Working Paper No. 3348. World Bank, Washington, DC.

Juma, Calestous. 2007a. "Food Security, Agriculture, and Economic Growth: Opportunities for Cooperation between The United States and Sub-Saharan Africa." Testimony to the House Committee on Foreign Affairs, Subcommittee on Africa and Global Health, United States House of Representatives, July 18.

———. 2007b. "The New Culture of Innovation: Africa in the Age of Technological Opportunities." Keynote Paper presented at the 8th Summit of the African Union, Addis Ababa, Ethiopia, January 29–31.

Katz, Jorge. 2006. "Salmon Farming in Chile." In *Technology, Adaptation, and Exports: How Some Developing Countries Got It Right*, ed. Vandana Chandra, 193–223. Washington, DC: World Bank.

Keesing, Donald B. 1967. "Outward-Looking Policies and Economic Development." *The Economic Journal* 77 (306): 303–20.

Kim, Linsu. 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning.* Boston: Harvard Business School Press.

———. 2003. "The Dynamics of Technology Development: Lessons from the Korea Experience." World Bank Institute Working Papers, World Bank, Washington, DC and the Policy and Human Resources Development Trust Fund of the Government of Japan.

Lall, Sanjaya, and Shujiro Urata, eds. 2003. *Competitiveness, FDI, and Technological Activity in East Asia*. Cheltenham, UK: Edward Elgar.

Lederman, Daniel, and William F. Maloney, eds. 2007. *Natural Resources: Neither Curse Nor Destiny.* Washington, DC: World Bank.

Liu, Xielin, and Steven White. 2001. "Comparing Innovation Systems: A Framework and Application to China's Transitional Context." *Research Policy* 30 (7): 1091–114.

Mason, Andrew D., and Elizabeth M. King. 2001. "Engendering Development—Through Gender Equality in Rights, Resources, and Voice." World Bank Report No. 21776. World Bank, Washington, DC.

Mathews, John A. 2002. "Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-up Strategies." *Asia Pacific Journal of Management* 19 (4): 467–88.

———. 2007. "Latecomer Strategies for Catching Up: Linkage, Leverage, and Learning." *World Bank Development Outreach* 9 (1): 24–27.

Murenzi, Romain. 2006. "Physics Has a Key Role in Development." *SciDev.Net*, January 16. Available at http://www.scidev.net/Opinions/index.cfm?fuseaction=readOpinions&itemid=458&language=1.

National Research Council. 2006. *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*. Washington, DC: National Academies Press.

Rasiah, Rajah, ed. 2004. *Foreign Firms, Technological Capabilities, and Economic Performance: Evidence from Africa, Asia, and Latin America*. Cheltenham, UK: Edward Elgar.

Rodrik, Daniel, and Arvind Subramanian. 2003. "The Primacy of Institutions and What This Does and Does Not Mean." *Finance and Development* 40 (2): 31–34.

Sachs, Jeffrey D., and Andrew M. Warner. 1997. *Natural Resource Abundance and Economic Growth*. Cambridge: Harvard University.

Sala-i-Martin, X., and K. Schwab, eds. 2006. *Global Competitiveness Report 2006–07*. The World Economic Forum. Basingstoke, UK: Palgrave MacMillan.

Science Initiative Group at the Institute for Advanced Study. 2007. "Proposal for a Regional Initiative in Science and Education (RISE), Phase II." Available at http://www.msi-sig.org/rise.html.

Shukla, Rajesh. 2005. *India Science Report: Science Education, Human Resources, and Public Attitudes towards Science and Technology, 2005*. National Council of Applied Economic Research. Available at http://www.insaindia.org/India%20Science%20report-Main.pdf.

Silberglitt, Richard, Philip S. Antón, David R. Howell, and Anny Wong. 2006. *The Global Technology Revolution 2020, In-Depth Analyses*. RAND Corporation. Available at http://www.rand.org/pubs/technical_reports/TR303/.

Smillie, Ian. 2000. *Mastering the Machine Revisited: Poverty, Aid, and Technology*. Bourton-on-Dunsmore, UK: ITDG Publishing.

Soboyejo, Wole. 2007. "Science and Technology Education in African Development." *World Bank Development Outreach*. 9 (1): 14–16. Available at http://www1.worldbank.org/devoutreach/january07.

Spar, Debora. 1998. "Attracting High Technology Investment: Intel's Costa Rican Plant." Occasional Paper 11, Foreign Investment Advisory Service of International Finance Corporation and World Bank, Washington, DC.

Szanton, David L., and Sarah Manyika. 2002. *PhD Programs in African Universities: Current Status and Future Prospects*. Berkeley: University of California.

UNCTAD (United Nations Conference on Trade and Development). 2006. "The Least Developed Countries Report, 2006: Developing Productive Capacities." Available at http://www.unctad.org/Templates/Page.asp?intItemID=3073&lang=1.

———. 2007. "The Least Developed Countries Report, 2007: Knowledge, Technological Learning, and Innovation for Development." Available at http://www.unctad.org/Templates/WebFlyer.asp?intItemID=4314&lang=1.

Universal Declaration of Human Rights. 1948. G.A. res. 217A (III), U.N. Doc A/810 at 71 (1948).

United Nations. 1997. *Report of the Economic and Social Council for 1997*. No. A/52/3, September 18. New York: United Nations.

Wagner, Caroline S. 2006. "International Collaboration in Science and Technology: Promises and Pitfalls." In *Science and Technology Policy for Development, Dialogues at the Interface,* eds. Louk Box and Rutger Engelhard. London: Anthem Press.

Watkins, Alfred, and Anubha Verma. 2008. *Building Science, Technology, and Innovation Capacity in Rwanda*. Washington, DC: World Bank.

Watson, Robert, Michael Crawford, and Sara Farley. 2003. "Strategic Approaches to Science and Technology in Development." World Bank Policy Research Working Paper 3026. World Bank, Washington, DC. Available at http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2003/05/23/000094946_03051404103334/Rendered/PDF/multi0page.pdf.

Wernli, Claudio. 2007. "First-Rate Science and Modernization of the National Research System in Chile." *World Bank Development Outreach*. January. Available at http://www1.worldbank.org/devoutreach/january07.

Whitaker, Meri, and Shashi Kolavalli. 2006. "Floriculture in Kenya." In *Technology, Adaptation, and Exports: How Some Developing Countries Got It Right*, ed. Vandana Chandra, 335–67. Washington, DC: World Bank.

Winder, Dylan. 2005. "Research and the Fight against Poverty." *Research Global* no. 9 (February). Association of Commonwealth Universities. Available at http://www.acu.ac.uk/resman/pdf/issue_9.pdf.

World Bank. 2002. "How Korean Firms Use Knowledge." World Bank, Washington, DC.

———. 2003. "Implementation Completion Report, Technology Development Project, June 9, 2003." World Bank, Washington, DC. Available at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2003/06/16/000090341_20030616145153/Rendered/PDF/254931CN1Tech0Dev01ICR.pdf.

———. 2004. "Reducing Growth, Sustaining Growth: Scaling up Poverty Reduction. Case Study Summaries." World Bank, Washington, DC. A Global Learning Process and Conference in Shanghai, May 25–27.

———. 2005. "Economic Growth in the 1990s: Learning from a Decade of Reform." World Bank, Washington, DC. Available at http://www1.worldbank.org/prem/lessons1990s.

———. 2006. "Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems." World Bank, Washington, DC. Available at http://siteresources.worldbank.org/INTARD/Resources/Enhancing_Ag_Innovation.pdf.

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