UNPACKING THE NEXUS IN ICT ADAPTATION, KNOWLEDGE MANAGEMENT AND INNOVATION FOR ECONOMIC DEVELOPMENT IN NIGERIA: THE LIBRARIAN PERSPECTIVE

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Abstract

This article focuses on the link between ICT adaptation, knowledge sharing and innovation for economic development. It argues that information management has taken a new dimension as a result of application of ICT in library activities and associated adjustments in the social institution. It implies that librarians use innovative systems approach to enhance knowledge sharing in order to promote economic development in Nigeria. The paper advocates various innovative approach that could attribute economic growth to continuous improvement in knowledge based and institutional arrangement for development while noting the creation, evolution, exchange and application of new ideas into marketable goods and services for the advancement of the society. The paper further reveals some challenges associated with economic development as poor policy implementation processes, poor funding of the libraries and poor human resources developments amongst others. In conclusion, this paper presents the way forward to the training of information professionals, adequate funding of the library and provision of ICT facilities etc.

Information remains the major pivot to economic development and achievement of development agenda worldwide, while ICT has been identified as key driver of growth and development in the 21st century, World Bank (2008). There seems to be a consensus in literature (World Bank 2008, and 2009, Akpan-Atata 2013) that enhanced knowledge management and innovation increases productivity and income thereby enhancing economic development. The approach here emphasizes innovation as using universities, research institutes and other institutions of higher learning to increase scientific, technological capabilities, and enhancing entrepreneurship by creating and expanding business and industries by effectively using intellectual, human, financial and social capital bases of these institutions. This can only become a reality when the libraries attached to the institutions are functional. In other words libraries should provide adequate and up –to-date information to meet the economics' growing demands for adaptation of new skill that could support the continued expansion of knowledge and development. The context of development as defined by this paper is one that enhances change, increased productivity and poverty reduction. The approach here highlights how these variables interact with one another to create new production combination by upgrading new current production activities in developing countries like Nigeria, which will necessarily involves integration of new knowledge into existing technologies. After all, effective and sustainable information development policies are those targeted at productivity activities and geared towards stabilising the economy.

As noted by Natarajan (2012) successful knowledge innovation and management will depend upon the value, behaviour and institutional system which gains competitive advantages and sustained development of libraries through innovation. The three underline themes that are fundamental to the new approaches needed to create prosperity in the economy therefore include:

- Knowledge as expandable source of economic wealth, by recognition of the enhancement intellectual assets.

- Successful innovation which depends on converting knowledge flows into goods and services.
- Collaboration which replaces the competition win/loss paradigm which is prevalent in world economic relations today with (win/win) benefits based on pooling competencies, knowledge, know-how and skills.

An Assessment of connection among these variables would help to formulate appropriate policies for exiting the underdevelopment trap and promoting sustainable development in Nigeria. It would also highlight the demonstrative capability for the library professionals in the new information society.

Therefore establishing the nexus that this paper has undertaken is consistent with the objectives of identifying the development domains of the most desirable policy outcomes for better targeting of intervention and priority setting for sustainable development in Nigeria.

ICT Revolution and Economic Development

ICT is multidimensional in nature. The economics and dynamics of networks are complex and only partially understood; development is also a complicated process. Analysing the interaction between the two is therefore very difficult. It is primarily for this reason that the debate over poverty reduction and the broad and systematic use of ICT in development policy and programs has until quite recently been polarized between sceptics and enthusiasts. Given the need to focus on basic development needs and priorities such as food, clean water, education, and disease eradication, some third world Countries like Nigeria view ICT as a luxury. While others in the developed world view it as almost a panacea for development problems. With the shift from anecdotal to empirical evidence of its full development impact, a more balanced perspective has emerged, in which ICT is no longer seen as an end in itself but rather as a critical enabler in the development process. There is already a strong correlation between ICT and the development delivery of services to the masses. According to World Bank (2008), in recent years ICT and the network revolution has forced a radical transformation of both developed and developing economies. New network economics and dynamics have combined multiple “positive feedback mechanisms” and “network effects” with disruptive and discontinuous change. This change encompasses rapidly decreasing technology costs with volume and innovation; vastly increased system development costs, risks, and timescales; new competitive market forces; heightened user expectations; uncertain industry restructuring and financial market behaviour; and standardization that is often non-proprietary, World Bank (2008). In addition, additional network benefits, such as electronic commerce, have appeared.

ICT Growth Rates

According to I.T.U (2003) estimates, access to telephone networks in developing countries tripled in the 10 years between 1993 and 2002, rising from 11.6 subscribers per 100 inhabitants to 36.4. By the end of 2002 there were more mobile cellular subscribers than fixed telephone lines in the world. Growth has been particularly strong in Africa, where an increasing number of countries now have more mobile phones than fixed telephones. With Nigerian taken the lead followed by South Africa and Egypt. Growth in personal computers and the Internet has been equally impressive. By the end of 2002 there were an estimated 615 million computers in the world, up from only 120 million in 1990. In 1990 just 27 economies had direct connection to the Internet; by the end of 2002, almost every country in the world was connected, and some 600 million people worldwide were using the Internet. Growth has been most rapid in developing countries, where 34 per cent of users resided in 2002, up from only 3 per cent in 1992 (ITU 2003). ICT has obvious benefits for economic growth, including pro-poor growth. It is as a generic technology and development enabler rather than a stand-alone production sector that it will most affect the economic development by creating new social and economic opportunities, promoting greater participation in development policies and processes, and increasing the efficiency, accountability, and delivery of public services.

Applying ICT to Specific Economic Goals

It has been observe that ICT and technology "push" projects are generally ill suited to fulfilling the requirements of the economic development. In third world countries, World Bank (2008) Nevertheless "Pulling" ICT into development projects where appropriate and relevant at an early stage—often with a mix of traditional and new media—to achieve greater efficiency and service delivery will have greater impact on poverty reduction. The success of the shift from push to pull will depend on fully integrating ICT into national development plans at an early stage and prioritizing ICT in sectors in which the potential benefits are greatest.

Research has shown that the greatest Goal benefits have accrued to countries that have adopted and implemented bottom-up and holistic e-strategies that are aligned with overall national development strategies. These countries have brought ICT to bear on all of the diverse components of national development agendas, such as governance and institution building; infrastructure and access; and health, education, and capacity building; local content development. They have created enabling policy and regulatory environments that stimulate competition, entrepreneurship, commerce, investment, job creation, and growth. Their success suggests that when a set of interrelated conditions is pursued simultaneously, the interplay among them becomes catalytic, creating a development or Goal dynamic (UNDP. (2001), (World Bank 2003). However, Consensus is building in the development community on the need for Nigeria and other African countries to focus attention on ICT interventions that match local needs and conditions and concentrate efforts in four principal areas (World Bank 2003) of:

- Stimulating macroeconomic growth, through the contribution of the ICT sector to the economy and the effect of investment in ICT on economic growth and job creation.
- Increasing the market access, efficiency, and competitiveness of the poor through micro level and people-oriented interventions (using village payphones, for example, and knowledge centres that improve agricultural practices through access to information on crop selection, irrigation, fertilizers, and fishing and livestock conditions).
- Increasing interactivity, making ICT continuously available, reducing its cost and global reach, and making social inclusion of poor and disadvantaged groups more feasible.
- Facilitating political empowerment, with improved planning in the development process through inclusive, informed priority setting, increasing accountability, and good governance. It is in these areas that paper shall address.

Eradicating Poverty and Hunger: the multidimensional nature of poverty has complex causes. In Nigeria like other third world countries, apart from lack of material wealth and possessions, poor people are often deprived of basic nutritional, educational, and healthcare needs. In addition, they are denied access to knowledge and information, a primary source of economic opportunity and political empowerment, rendering them vulnerable and prey to social exclusion. ICT can be used as both an accelerating and driving force as well as an outcome of human development. Promoting opportunities for the poor is an essential element of poverty reduction.

Improving Primary Education*: According to World Bank report m*ore than 370 million of the world's 1.3 billion school-age children (28 per cent) are not in school. Most live in Sub-Saharan Africa, South Asia, and parts of Latin America, the Caribbean, and the Middle East. Nigeria takes a great chunk because of insurgency and economic hardship. The problem of poor schooling and lack of schooling is unlikely to improve without major interventions. The basic building blocks of a good education system—Libraries, teachers, infrastructure, curriculum and content, teaching and learning tools, and administration— are missing in many developing countries Including Nigeria ICT adaptation can help overcome many of these deficits in an efficient way (Hepp and others 2004). For instance ICT-based distance training can overcome the shortage of well-trained teachers by accelerating their training. Ineffective distribution of content can be tackled through ICT-based delivery of content. Administration can be streamlined through basic ICT applications. Although pilot projects in the Researching ICT for Education in Africa Program (ICT4E) have shown the potential of ICT in schools, it is essential to move beyond these pilots and create comprehensive, demand-driven, coordinated “end-to-end” systems. Creating such systems will require bringing together coalitions of stakeholders in each state or zone (region) to plan and implement national or regional e-schools initiatives. These initiatives will require technical, financial, and other support from global players, especially donors and relevant private sector companies. E.g. The Global Schools and Communities Initiative (GeSCI), founded by the United Nations and the governments of Canada, Ireland, Sweden, and Switzerland, will aim to catalyse and support national and regional e-school initiatives that bring together local actors under the leadership of the local ministries of education and ICT. GeSCI can help countries like Nigeria plan and connect to global partners who can provide expertise or financial support. Currently working in Bolivia, Ghana, Namibia, and Andhra Pradesh in India, GeSCI emphasizes the fact that ICT in schools has impact far beyond the classroom, yielding enormous benefits to local communities in the form of employment, adult education, health, business services, communication, and e-government.

Other Levels of Education

Although the above focus on primary education, the role of ICT at other educational levels is also important (de Ferrranti and others 2003), a good example of the use of ICTs to promote tertiary learning is the African Virtual University, created in 1997 as pilot project of the World Bank. *In Nigeria and many other* developing countries, universities suffer from unclear mandates and limited funds. They lack the flexibility to meet basic needs (often dealt with by public research centres in “mission mode”) or promote competitiveness (dealt with by the private sector or government training institutes).1 Universities often lack the resources and the demand from a sound productive economic sector that is eager to benefit from the knowledge these universities and their students could create. They suffer from a “loneliness syndrome.” Reversing this syndrome is one of the challenges for development, one that cannot be fulfilled by pushing universities to change while everything else remains the same. With more than 136 federal, state and private Universities, a better approach is to channel energies within the university environment to carry out a combined research, teaching, and application mandate, with different types of universities taking on different challenges and government and industries engaging in effective interaction with them. This path is not without dangers. One potential problem is that the pendulum could swing too far, so that universities become outposts for government or private sector service functions or engage only in applied research. Incentives need to be calibrated so that as universities continue to produce knowledge, they also seek to transfer that knowledge to useful applications where appropriate, Yusuf (2006) Informed science, technology, and innovation policy needs to account for the fact that universities need to continue to have local relevance while fulfilling broader mandates of education and knowledge acquisition and diffusion, Akparobore (2013).

ICT and Lifelong Learning

In lifelong learning the ICT provides opportunities for acquiring the four major objects of learning outlined by UNESCO (Delors eat al 1999). These are learning to know, learning to do, learning to live together and learn to be. Learning to know deals with the acquisition of broad knowledge relevant to several areas of human endeavour and the opportunity to work in-depth on a small number of subjects. Learning to do refers to knowledge and skills acquired not only on occupational skills but always the competence to deal with many situations. Learning to live together entails developing and understanding other people and appreciation of interdependence of human beings and finally learning to be related to the development on one’s personality and being able to ask with even greater autonomy, judgement and personal responsibilities. (Delors 1999). ICT provides for all these through online courses, materials and through them users knowledge, skills and competences are updated.

Working Toward Gender Equality*:* ICT can be used to influence public opinion on gender equality, increase economic opportunity, improve women’s education and conditions for women as educators, and enhance women’s ability to know their rights and participate in decision making. ICT promotes gender equality by providing online opportunities that are not always available in the off-line world. The Internet allows women to interact with men from remote locations, without face-to-face contact. ICT helps female entrepreneurs reduce transactions costs, increase market coverage, and expand across borders. The Self-Employed Women's Association (SEWA) of India use mobile village phones, the Internet, satellites, and television to promote the artisan handicrafts of the 5,000 women who belong to the network and to provide them with access to market information. Primary responsibility for childcare, cooking, and other household tasks have impeded women's ability to attend school. In some countries social customs make it difficult for women to participate in activities that involve mixing with men. In most developing countries, female school enrolment declines after childbearing age. ICT can help overcome these problems, through distance learning. Women's enrolment for ICT–based teacher training has outnumbered that of men in many countries.

Promoting Health. ICT has already had an enormous impact on althaea in developing countries. It has enabled healthcare workers to conduct remote consultation and diagnosis, access medical information, and coordinate research activities more effectively in the past two decades than in the history of medicine. ICT is an essential component in providing remote health care services, storing and disseminating healthcare information, conducting research, and training and networking health workers. Through both traditional (radio, television, video, CD) and new (wireless, Internet) media, ICT also provides an effective and cost-effective channel for disseminating information on healthcare and disease prevention to the masses. The role of ICT in achieving health-related Goals is indispensable. ICT is an invaluable tool for both healthcare workers and the international development community in reducing child mortality improving maternal health and combating HIV/AIDS, malaria, and other diseases Childhood diseases prevented 9 per cent of the world's children from living to see their third birthday. Healthcare workers can use ICT to establish databases to track vaccination programs, coordinate shipments of antibiotics, and inform communities of medical services that can prevent child mortality. Maternal death is the leading cause of death for women of reproductive age in the developing world. ICT can critically reduce the incidence of maternal death numbers by facilitating access to information and healthcare services. In the fight against HIV/AIDS, ICT can strengthen disease monitoring and management, drug distribution systems, disease monitoring and management, drug distribution, training of caregivers, patient education and monitoring, and support networks for people living with HIV/AIDS and the people who care for them. The potential to enhance the response to HIV/AIDS has not yet been fully leveraged in the country's most affected by the crisis. Many of these countries lack the infrastructure and the human capacity (weakened by the toll taken by brain drain and HIV/AIDS) required implementing comprehensive ICT strategies that could improve prevention, treatment, and policy support. The potential of ICT as a cross-cutting tool across the Goals that can add value in addressing the pandemic has not been widely recognized. Several initiatives to use ICT to prevent and treat HIV/AIDS are currently under way. These initiatives range from networks aimed at enhancing access to knowledge on HIV/AIDS treatments to the use of geographic information systems to map the spread of the disease in relation to socioeconomic variables and treatment (Committee on the Geographic Foundation for Agenda 21 2002). In some cases, clinical information infrastructure systems and simple mechanisms have been used to address the logistics of distribution and monitor the use of essential drugs. Virtual forums and lists have facilitated the discussion of access and treatment, enhanced advocacy, and raised awareness. Evaluations of effectiveness and the identification of good practices and mechanisms to scale up interventions and systems have not yet been conducted. The HIV/AIDS response needs to be cross-sectoral to address the pandemic's multiple dimensions. A more widespread coordination and strategic deployment of ICT that create new synergies and enhance overall response effectiveness are overdue.

Improving Environmental Management. Akpan-Atata (2013 proposes integrating the principles of sustainable development into country policies and reversing the loss of environmental resources, halving the proportion of people without access to safe drinking water, and achieving significant improvement in the lives of slum dwellers. Managing and protecting the environment improves human health conditions, sustains agriculture and other primary production sectors, and reduces the risks of natural disasters. The effects of ICT on sustaining the environment are multidimensional. ICT facilitates greater participation by the population in activities to protect the environment through networking and information exchange. It provides researchers with critical tools for observing, simulating, and analyzing environmental processes. It promotes environmentally friendly work habits, by reducing paper consumption and facilitating telecommuting; raises awareness of the environment, through knowledge sharing; facilitates environmental monitoring and associated resource management and risk mitigation; enables greater environmental sustainability in other industrial, commercial and agricultural sectors; and improves communication and implementation of policies. ICT plays a key role in environmental management in activities ranging from optimizing clean production methods to decision making. Spatial information is information related to a particular geographic location or area. It allows analysts to view the distribution of income across a country as a grid in order to target areas for action, understand demographic trends, and monitor progress. Spatial information collected by satellite or airborne remote sensing can be used to understand the capability of the land to support economic activity and water use efficiency. This information can help ensure that natural resources are used efficiently and sustainably. New technologies are being developed that provide more accurate and timely estimation of risk. Spatial information about fire, rainfall, wind, and salinity may help countries identify and estimate risk more accurately.

Innovation

1. Information organizations of all kinds (such as Librarians publishers, subscribtion agents, and information and advice services) have change significantly in recent years accordingly these changes has involved high levels of innovation. Some of the innovation are driven directly by the opportunities provided by the opportunities provided by new technological innovation from other organisations, coupled most changes in consumer expectation and behaviour (e.g access to full text of journals through Google's as a search engine). Others are facilitated by information technologic but driven policy and market place change (e.g self-issue of books institutional repositories). Other innovations are particularly affected by technological platform but represent for example innovation in community involvement such as new services for disadvantage groups and the organization of biblotraphy reading groups.

Despite there being a hive of activities and regular reporting on achievement in the popular and professional press (the outcome of innovation process, there has been little discussion of innovation and its processes in the information management professionals or academic literature.

An innovation strategy would for example contribute to the selection, coordination and planning of innovation at all levels in the organization. It would also promote a focus on innovative creative an entrepreneurial organizational culture, to facilitate all stages of innovation process. Major shift in the role of libraries, or importantly, the public perception of the rationale for libraries will require some since quick and swift footed large scale innovation.

Europa 2009 raises awareness of the importance of creativity and innovation for personal, social and economic development, to dissemination good processes to stimulate education and research and to promote policy debate on related issues. However, despite this growing acknowledgement of the importance of innovation, there is evidence that many organizations have a distance to travel in understanding and manage innovation and organisation.

Damanpour, Summaries the situation these:

Organisation innovates because of pressure from the actual environment, such as competition, deregulation, isomorphism resource scarcity. And customer demand, or because of an internal organisation choice, such as gaining distinctive competencies reaching a higher level of aspiration and increasing extend and quality of services. Either way of adoption of innovation is intended to ensure adaptive behaviour, changing the organization to maintain or improving it performance.

Innovation and Economic Advancement

Economic historians suggest that the prime explanation for the success of today's advanced industrial countries lies in their history of innovation along different dimensions: institutions, technology, trade, organization, and the application of natural resources (Rosenberg and Birdzell 1986; Mokyr 2002).

These factors also explain the economic transformation of developing countries that have recently industrialized. Scientific and technological innovations come about through a process of institutional and organizational creation and modification. Defining characteristics of the West have been the institutionalization of private enterprise, continuous reductions in the cost of production, the introduction of new products, and the exploitation of opportunities provided by trade and natural resources. These achievements are a tribute to the private sector and the state's ability to recognize new opportunities and the ways in which to exploit them. Economic growth and innovation since the path breaking work of Solow (1956, 1957), economists have recognized the critical importance of innovation and capital accumulation for growth. Empirical evidence and the modern theory of economic growth provide strong support for the thesis that long-term economic growth requires not only capital but also an understanding of innovation (Clark and Juma 1992). As the Millennium Project's *Investing in Development: A Practical Plan to Achieve the Millennium Development Goals* (UN Millennium Project 2005) shows, countries that are not on track to meet the Goals lack sufficient levels of physical, human, social, and other forms of capital. An important element of any Goal strategy must therefore be to raise the stock of these different forms of capital. (These interventions are described in more detail in *Investing in Development* and the reports of other Millennium Project task forces.)

Focusing only on accumulating capital will not be sufficient to ensure long-term growth rates that can reduce poverty and help achieve the other Goals, however—as the case of Latin America, where income and capital levels are relatively high and growth rates persistently low, suggests. Innovation and technology are also needed to transform countries from reliance on the exploitation of natural resources to technological innovation as the basis for development. Finland has transformed its economy from one dependent on natural resources to one at the top of the list of most indices of global competitiveness. This transformation began in the 1980s, with efforts aimed at aligning governance structures with long-term technological goals. Finland's success reflects its ability to combine science and technology policies aimed at promoting research with industrial policies geared toward manufacturing and export into a comprehensive innovation policy (Lemola 2002). The focus on Nokia as a national symbol conceals innovations in other sectors of the economy such as wood processing, opto-electronics, and biotechnology. Finland focused on reforming its policies in education, research, innovation, and support for entrepreneurship. While the private sector is acknowledged as the locus of competitiveness, a wide range of public sector bodies play key roles. For example, the Ministry of Education and the Ministry of Trade and Industry are critical components in the Finnish innovation system. In 2003 the Ministry of Education controlled some 42 per cent of the public research budget, while the Ministry of Trade and Industry accounted for nearly 35 per cent. Other ministries also fund research. The Ministry of Education oversees 20 regular universities, 29 universities of applied science, and the Academy of Finland. The Academy is the most important planning and basic research funding agency in basic research. The Ministry of Trade and Industry formulates innovation policy, supports private sector R&D, and oversees the country's Technology Development Agency (Tekes). Tekes is the main planning and funding organ for applied technology research and private sector R&D. It allocates nearly 30 per cent of the country's public research funding. The Technical Research Centre (VTT), part of the Ministry of Trade and Industry, conducts contract research in partnership with the private sector (Berwert and others 2004). The main policy body is the Science and Technology Policy Council, founded in 1987 to succeed the Science Policy Council, established in 1963. The Council brings together key science and technology players to develop visions and reach consensus on specific actions. Its members include the Prime Minister, who chairs the council; the Minister of Trade and Industry and the Minister of Education, who serve as vice-chairs; the Minister of Finance; and leading actors in the fields of science and technology. The council reports to Parliament. Other components of the Finnish innovation system include Sitra, an independent public foundation that explores new technological directions. Supervised by Parliament, it operates in the fields of venture capital, research, education, and innovation. Complementary institutions deal with investment, employment, and inventions that are part of the Finnish ecology of innovation. These institutions have benefited from the realignment of institutions with technological innovation goals. Advances in economic theory, notably the development of endogenous growth models (Lucas 1988;

Romer 1990; Aghion and Howitt 1992), lend strong support to this report's focus on the need for institutions and policies to promote science, technology, and innovation. The models and their empirical applications show that innovation and adoption of technologies is endogenous and driven largely by the combination of investments in science, technology, and innovation and adequate policy frameworks. The rise of science and technology, particularly the institutionalization of the scientific method in the seventeenth century, created a forum for experimentation, the exchange of findings, and advancement and refinement of method. Experimentation and uncertainty were encouraged through the support of risk-taking and the rewarding of discovery. Eventually, transformation of organizational types took place in the private sector as well as in new public institutions that could weather economic uncertainty over time. Incentives for investment followed. This environment produced a diversity of products, services, organizations, and institutions suited to different conditions. But dependence on local market niches has been complemented by the emergence of global markets. In today's increasingly global environment, developed countries and their corporations tap the world's natural resources, have access to the best and brightest human resources from around the globe, manufacture in the most cost-effective locations, and sell their products throughout the world. The most recent successes lie in the
newly industrial economies of East Asia. High growth rates were certainly a necessary part of the story, but they were buttressed by diverse and adaptable institutions that oversaw new production regimes, export orientation, and compacts between state and private enterprise (Hobday 1995). Choices made by governments and the rapid adaptation to changed economic circumstance allowed producers to reap signify ant rewards while requiring them to demonstrate a certain commitment to national goals. Legitimacy for governments in this region was derived in part by higher economic growth rates. Economic development became a vehicle for buttressing democracy—both the Republic of Korea and Taiwan (China) elected and are now governed by presidents from parties that were once in the opposition. Technological divergence across countries the productivity of and return on investments in science, technology, and innovation is likely to be lower in developing countries than in developed countries.

Knowledge Sharing

The recent redefinition of HIV/AIDS by the United States as a security crisis is one example of this broadened view of security in the twentyfirst century. Most international disputes and conflicts have revolved around access to land, commodities, and natural resources. These economic factors continue to play a role today. But increasingly, the world will be made up of societies in which economic value will be derived from knowledge, especially scientific and technical knowledge. Unlike traditional sources of wealth, knowledge is not scarce and can therefore grow at exponential rates. Knowledge-based societies will not develop without conflicts of their own, but warfare based on mercantilism or land grabs will take different forms. One of the major new forces emerging today is global civil society, which promises to become even more important a force. Many of the nongovernmental organizations (NGOs) and NGO networks that make up this global civil society derive their capacity from their use of advanced ICTs; many have a keen interest in seeing science and technology serve peaceful democratic purposes and create open societies. One of the key challenges ahead is to better integrate NGOs into policymaking mechanisms and forums at the local and international levels, forums that have been traditionally dominated by state and corporate actors. Technology in today's global setting Countries' achievements in creating and diffusing technologies and building human skills to master new innovations can be gauged in three areas: technology creation (measured by patent and royalty receipts), the diffusion of new technologies (measured by Internet use and exports of medium- and high-tech goods) and old technologies (such as telephony and electricity), and human skills (measured by mean years of schooling and the gross tertiary science enrollment ratio). A host of success stories has been analyzed and widely advertised, but the global rules governing market exchange and intellectual property rights have changed, causing developing countries today to face constraints (as well as opportunities) that their predecessors did not

Infrastructure and Technological Learning Processes

Infrastructure contributes to technological development by providing opportunities for technological learning associated with the acquisition of technology (Putranto, Stewart, and Moore 2003). Because of the fundamental role of infrastructure in the economy, the learning process in infrastructure development is a crucial element of a country's overall technological learning process (box 5.2). This dynamic aspect of infrastructure is often overlooked in the development and infrastructure literature. Every stage of an infrastructure project, from planning and design through construction and operation, involves the application of a wide range of technologies and institutional and management arrangements. Because infrastructure facilities and services are complex physical, organizational, and institutional systems, deep understanding and adequate capabilities are required on the part of engineers, managers, government officials, and others involved in these projects. Infrastructure plays another crucial role in science, technology, and innovation efforts in developing countries: it is one of the most important factors in attracting foreign direct investment, in addition to being itself an investment target whose future economic sustainability is expected to stabilize (Ramamurti and Doh 2004). Infrastructure is one of the key factors that multinational corporations consider in determining the location, scope, and scale of their investments. Foreign direct investment in infrastructure increased substantially in the 1990s, for several reasons, including favorable foreign direct investment policies, the reduced risk of expropriation in developing countries, and the development of innovative financing strategies, such as nonrecourse project financing and securitization. Increased foreign participation in infrastructure projects, particularly in the form of foreign direct investment, means that there are now more opportunities for developing countries to use infrastructure development as part of their technological and institutional learning process. Governments need to design and implement the rules and regulations that govern private networks that are no longer under public control. They also have the option of building up the infrastructure that replaces private networks. Given that the global economy relies increasingly on information and knowledge flows, governments are faced with strategic options that could have significant implications for their science, technology, and innovation policies.

Innovation in Energy: the Sustainability Challenge

The linkages between infrastructure development and technological innovation are illustrated by global trends to adapt to changing energy needs and new environmental standards. The emergence of alternative energy technologies and the challenges they pose to conventional sources illustrate the degree to which improvements in energy technologies have become central to long-term energy security and environmental management (Holdren and others 1999). After the 1970s fuel crisis, the Brazilian government initiated a large program to encourage the design and manufacture of ethanol-only cars, as well as to cultivate sugarcane and refine it into ethanol as a way to reduce country's dependence on imported oil. By the end of the 1980s, ethanol engines powered almost 80 per cent of cars produced in Brazil. The industry faced occasional shortages of ethanol fuel, however, and during the 1990s the price advantage of ethanol declined as gasoline prices fell. As a consequence, by 2002 ethanolonly cars represented a mere 3.5 per cent of new car sales in Brazil. Some auto-parts producers came up with the idea of building flex-fuel engines as a way out of the difficulties faced by ethanol vehicles (box 5.3). Some multinational auto-parts producers that located their world research centers. Particularly in the form of foreign direct investment, means that there are now more opportunities for developing countries to use infrastructure development as part of their technological and institutional learning process. Governments need to design and implement the rules and regulations that govern private networks that are no longer under public control. They also have the option of building up the infrastructure that replaces private networks. Given that the global economy relies increasingly on information and knowledge flows, governments are faced with strategic options that could have significant implications for their science, technology, and innovation policies. The linkages between infrastructure development and technological innovation are illustrated by global trends to adapt to changing energy needs and new environmental standards. The emergence of alternative energy technologies and the challenges they pose to conventional sources illustrate the degree to which improvements in energy technologies have become central to long-term energy security and environmental management (Holdren and others 1999). After the

1970s fuel crisis, the Brazilian government initiated a large program to encourage the design and manufacture of ethanol-only cars, as well as to cultivate sugarcane and refine it into ethanol as a way to reduce country’s dependence on imported oil. By the end of the 1980s, ethanol engines powered almost 80 per cent of cars produced in Brazil. The industry faced occasional shortages of ethanol fuel, however, and during the 1990s the price advantage of ethanol declined as gasoline prices fell. As a consequence, by 2002 ethanol only cars represented a mere 3.5 per cent of new car sales in Brazil. Some auto-parts producers came up with the idea of building flex-fuel engines as a way out of the difficulties faced by ethanol vehicles (box 5.3). Some multinational auto-parts producers that located their world research centers in Brazil on related technologies built on Brazil’s technological capabilities in ethanol engines to develop flex-fuel technologies. Flex-fuel technologies can give customers and nations the flexibility to respond to volatile changes of fuel prices. These technologies also reduce urban pollution and the production of greenhouse gases. Flex-fuel engines also increase agricultural employment and income generation in developing countries. Research facilities as infrastructure Defining infrastructure to include technological innovation requires rethinking the strategic importance of research facilities (Nightingale 2004). Indeed, infrastructure projects can serve as research facilities themselves while maintaining strong links with other research institutions (Conceição and others 2003). The management of geothermal energy facilities, for example, require continuous in situ research as well linkages with external research facilities. But much of the research associated with infrastructure projects in developing countries is usually implicit. Support to strategic technology development should be considered part of the national infrastructure, in the same category as energy, transportation
networks, and water and sanitation. A number of developing countries, such as South Africa, are starting to work toward creating networked research facilities that are accessed in a managed way. Other countries have consolidated research entities to create single research institutions designed to maximize synergies in human resources. The best-known research facility of this kind is the Industrial Technology Research Institute (ITRI) in Taiwan (China). ITRI was created in 1973 by the Ministry of Economic Affairs as a nonprofit R&D organization focused on applied research and technical service. Its original aim was to address the technological needs of Taiwan’s industrial development. By 2003 it had more than 6,000 people in 11 laboratories. It acts as a locus of technical support to industry and an unofficial arm of the government’s industrial policies. ITRI operations have become global. ITRI’s main task has been identifying the latest technology available globally, adapting it to local needs, and then diffusing it into Taiwan’s industrial sector. Most of the major semiconductor foundries in Taiwan (China) have their roots in the Institute. ITRI also undertakes contract research for the private sector, provides technical training, carries out long-term research projects for the state, and provides incubation facilities to help entrepreneurs establish high-tech firms. Planning for infrastructure development An essential aspect of economic planning in developing countries is fostering the development and maintenance of infrastructure in a way that is appropriate to local conditions and consistent with ecological and other principles. Planning for infrastructure development should be placed on par with other planning processes. Infrastructure serves as a strategic foundation for the application of technology to development. As an essential element of a country’s long-term development efforts, it should include direct links to human resource development, enterprise creation, and R&D. Developing countries need to prioritize infrastructure investment according to the degree of needs and the potential impact of particular investments on the economy and the society as a whole. Doing so does not mean that they should focus only on basic infrastructure, however, and forgo investment in infrastructure that is of strategic importance. To the contrary, developing countries need to upgrade strategically important infrastructure in order to tap into the opportunities that may arise from rapid technological change and the increasingly integrated global economy. Developing countries also need to enhance their own ability to develop, operate, and maintain infrastructure services. Foreign construction and engineering firms will continue to be the main sources of technological, organizational, and institutional knowledge for infrastructure development. But governments in developing countries should devise policies to encourage technology transfer and build local capabilities in infrastructure projects (box 5.4). Research and development activities for the development, operation, and maintenance of infrastructure should also be promoted, and

linkages should be established with both domestic and overseas research networks. Infrastructure services may be provided through combinations of public and private enterprises, while taking into account the needs of the poor.

Challenges

Science and Technology

Investment in science, technology, and innovation education has been one of the most critical sources of economic transformation in the newly industrial countries. Such investment should be part of a larger framework to build capacities worldwide. The one common element of the East Asian success stories is the high level of commitment to education and economic integration within the countries. This strategy was a precursor to what have come to be known as *knowledge societies* (World Bank 2002). The commitment of the Republic of Korea to higher education suggests that spectacular results can be achieved in a few decades. These experiences are not limited to this region. The impact of education on local economies is also being recorded in less developed countries. Policy approaches to education, however, continue to generate considerable controversy in international development circles. Primary and secondary school education in science The growth of higher education needs to be accompanied by an increase in opportunities for graduates to apply what they learn. Developing countries need to devote resources to allowing more young people to obtain higher education, paying special attention to the barriers that appear at the secondary school level. To increase job opportunities for graduates, they need to give incentives to private enterprises, particularly small and medium-size firms, to hire young university graduates, a strategy that helps create a virtuous circle of technological upgrading.

It is becoming evident that science education should be strengthened at the earliest level in educational systems. This will require greater emphasis on science education in primary schools (box 6.1). The importance of introducing science education in early childhood is illustrated by the failure in many parts of the world, especially in Africa, to understand the scientific basis of disease. This failure not only makes it difficult to implement public health programs, it has been a major factor in the spread of infectious diseases, especially HIV/ AIDS. Providing an early foundation in science education is therefore critical to human development. Although the education Goal is limited to achieving universal primary education, science, technology, and innovation education at the secondary and tertiary levels are critical to creating an innovative society.

Developing countries should be encouraged to adopt curricula that ensure that all students completing secondary school in any field will have been exposed to at least one area of science. They should also be encouraged to invest in science education at the secondary and tertiary levels in order to increase the number of scientists, engineers, and technologists. Changes are also needed at the high school level. High school curricula need to be modified to prepare students for the materials introduced at universities. Teaching methods should also be changed to reflect the spirit of scientific inquiry by encouraging independent projects, inviting experts to speak as guest lectures, and taking students on field trips. Higher education in science, technology, and innovation Higher education is increasingly being recognized as a critical aspect of the development process, especially with the growing awareness of the role of science, technology, and innovation in economic renewal. While primary and secondary education have been at the focus of donor-community attention for decades, higher education has been viewed as essential to development only in more recent years. Today's economic circumstances make higher education a more compelling need in developing countries than it has ever been. Key factors in this change include increased demand for higher education due to improved access to schooling, pressing local and national concerns that require advanced knowledge to address, and a global economy that favours participants with high-technological expertise. Universities have immense potential to promote technological development. But most universities in developing countries are ill equipped to meet the challenge. Outdated curricula, undermotivated faculty, poor management, and a continuous struggle for funds have undermined the capacity of universities to play their roles as engines of community or regional development.

Vocational and polytechnic institutes in developing countries are very important. Technologists, technicians, and craftspeople are the bedrock on which small and medium-size enterprises are founded, especially in operations and maintenance. Many developing countries have made the mistake of neglecting the training of technicians and technologists. During the 1970s many engineering graduates left India to seek employment abroad. Others were underemployed as draftsmen. This underutilization of highly trained human resources took place at a time when India suffered from a critical shortage of skilled craftspeople, such as pattern makers and instrument technicians. This experience highlights both the importance of training technicians and technologists and the need to foster internal demand for engineers. Science and engineering courses continue to be unattractive to women even though the role of women in economic development is being recognized (box 6.2). Equipping women with the necessary scientific knowledge and technical skills needed for full employment is a critical aspect of the ability of developing countries to participate in the global economy. Developing countries are starting to explore ways to expand higher education opportunities for women. This could be a critical starting point for receiving support to higher education from developing international development agencies, such as the World Bank. The need for training and capability building of technicians and technologists in developing countries has become even more acute with the advent of computer-aided design and drafting in engineering and construction industries. The proliferation of sophisticated computer-controlled machineries and instruments for manufacturing has also increased demand for technicians and technologists. These people are also needed in healthcare and banking. Developing countries should invest in and promote institutions that provide recognition and continuing professional development of technologists and technicians, institutions such as the Institution of Incorporated Engineers and the Institution of Technician Engineers in the United Kingdom. Scientists and engineers in the global economy The scientific, technological, and engineering community and the associated institutions (universities, technical institutes, professional associations) are among the most critical resources for economic transformation. They deserve special policy attention. A disturbing global trend is the decline in enrollment in engineering courses in universities and institutions of higher learning, especially in developed countries, where some engineering departments have closed. To meet the shortage of engineers and scientists, developed countries recruit from developing countries. Ironically, developing countries are putting their scarce resources into education and training that benefits the developed world. Developing countries' ability to absorb scientists and engineers is limited due to their early stage of development. But highly educated human resources can attract foreign firms interested in investing in science, technology, and innovation in the developing country. Expatriates have helped establish small and medium-size enterprises by investing in their country of origin, often using technology acquired abroad, and they are involved in establishing joint enterprises between their home countries and adopted countries.1 Public policy and a dynamic business community facilitate these processes. Nevertheless, "brain drain" remains one of the most hotly debated international issues. The home country's loss of skills—and educational investment— needs to be set against the experience gained abroad by scientists and professionals, which may be available for use upon their return if adequate measures toward that end are implemented (see chapter 8 for further discussion on the diaspora). The international mobility of skilled people is one of the key mechanisms for the transition of technological capability across countries. To use this mechanism effectively, countries need to design institutions that enable them to use the skills of their nationals wherever they live. Such institutional arrangements need to rely on a commitment to international cooperation and partnerships. A new Colombo Plan for Sub-Saharan Africa Since 1951 donor countries have offered scholarships and fellowships to developing countries in the Asia Pacific region under the Colombo Plan for Cooperative Economic Development in Asia and the Pacific. During its first three decades, the Colombo Plan played an important role in supporting the development of technological and scientific expertise in Indonesia, the Philippines, Malaysia, Singapore, and Thailand. The Colombo Plan also contributed significantly to the stable administrative transition from colonial rule in Southeast Asia. It had an important impact on donor countries, especially Australia, where the presence of Colombo Plan students from Asia triggered a flow of students from Southeast Asia. The Colombo Plan Scholarship and Fellowship Program is a collection of bilateral programs between donor and recipient countries that is largely devoid of multilateral bureaucracy and politics. As a result, program implementation is very focused on the needs of the recipient and the capabilities of the donor. Arrangements like the Colombo Plan can effectively support low-income countries that lack sufficient institutions of higher learning in rapidly building technological and scientific expertise. Donor countries should establish a second Colombo Plan for Sub-Saharan Africa. The program could build on the existing expertise and structures of the first Colombo Plan. Such an arrangement would permit the rapid scaling up of investments in professional manpower across Sub-Saharan Africa. The beneficiaries of such a plan could help lay the foundations for stronger institutions of higher education across the continent as part of the emergence of systems of innovation (Muchie, Gammeltoft, and Lundvall 2003). Toward that end, provisions could be made in the scholarships and fellowships that ensure that recipients return to their home countries after completing their studies abroad. Having knowledgeable people is not enough, however. If investments in science and technology are inadequate, scientists and engineers will have few opportunities to apply what they have learned. The acquisition of knowledge and opportunities to apply it creatively are two inseparable parts of the learning process. Learning is an endless process. Lifelong learning is based on being able to participate in activities in which explicit and tacit knowledge is shared, exchanged, and created. Learning societies can be defined as places where a sizable proportion of the population and of the social and economic organizations permanently perform knowledge-demanding activities in which many actors need to, and are able to, systematically upgrade their individual and collective skills, as well as their awareness of scientific and technological changes. In other words, learning societies are "interactive learning spaces" (Arocena and Sutz 2003). Fostering the development of and strengthening interactive leaning spaces can be seen as a fundamental developmental task. If it is achieved, the use of new knowledge in a socially valuable way will follow, as will better possibilities to face the challenges posed by scientific and technological changes. In this respect, international development agencies and their African counterparts could launch a new Colombo Plan with a focus on the sciences. Such a program could also be launched as a partnership between African and Asian countries that have previously benefited from the Colombo Plan and are willing to their share experiences. New roles for universities and technical institutes A new view that places universities at

the center for the development process is starting to emerge. This concept is also being applied at other levels of learning, such as colleges, research and technical institutes, and polytechnic schools. Universities and research institutes (including polytechnics) are now deeply integrated into the productive sector as well as society at large. Universities are starting to be viewed as a valuable resource for business and industry; universities can undertake entrepreneurial activities with the objective of improving regional or national economic and social performance.2 Others are charged with explicit reconstruction mandates (box 6.3). In facilitating the development of business and industrial firms, universities can contribute to economic revival and high-tech growth in their surrounding regions. There are many ways in which a university can get integrated into the productive sector and into society at large. It can conduct R&D for industry; it can create its own spin-off firms; it can be involved in capital formation projects, such as technology parks and business incubator facilities; it can introduce entrepreneurial training into its curricula and encourage students to take research from the university to firms. It can also ensure that students become acquainted with problems faced by firms—through internships, for example. Universities should also ensure that students also study the relationships between science, technology, innovation, and development, so that they are sensitive to societal needs. This approach is based on the strong interdependence of academia, industry, and government.3 Industry in the developed world has benefited from the activities of research universities, particularly from their state-of-the-art laboratories, which conduct cutting-edge research for them. Universities benefit from the research funds provided by industry. Many universities in developing countries serve merely as degree- or certificate-awarding institutions, providing the necessary documentation for thousands of young people to apply for jobs. Marginalized in the development process, these universities seek only to churn out graduates. Universities need to be re-envisioned as potentially powerful partners in the development process. This adjustment can be implemented in a top-down manner by changing existing norms and procedures. It can be done for all academic departments of the university or certain select ones deemed to be of more importance with regard to national development goals. Imposing new standards on only certain departments would imply widely different standards for students and faculty and would likely require a separate administrative setup for the departments with higher standards. Moreover, the university's location would have to be appropriate for the selected disciplines. A benefit of this approach would be working with an established institution. Such an institution already has libraries, staff, and very likely some links with other research institutes. Technical institutes are created to serve industry. By nature they are disposed to work with firms. Without neglecting their essential and primary roles in capability building for technologists and technicians, some of these institutes could be upgraded to university status. New universities may also be created; particularly if a new field of knowledge in which existing universities have inadequate capability has been made a national priority or if student demand has outstripped university capacity. These universities could be entirely new institutes or expansions of industry based training institutes. For universities to be able to contribute to science and technology–based regional development, appropriate supporting institutions will be necessary. These include both enabling policies and organizations that can increase the pathways of interaction between academia, government, and industry. Specific measures include tax breaks, venture capital funding, low-interest loans, changes in intellectual property rights, higher returns on inventions, heavy investment in ICT, business incubation, and technology parks and centers within or near universities. Partnerships with other institutions, at the national or regional level, could be of great benefit. Many developing country academics are benefiting from institutional partnerships with universities and R&D institutes abroad. Research partnerships across academic, industry, and government institutions help reduce knowledge gaps, especially in small and medium-size enterprises, which often lack adequate R&D facilities. Reshaping universities to perform development functions will include modifying their curricula, changing schemes of service, modifying pedagogy, shifting the location of universities, and creating a wider institutional ecology that includes other parts of the development process. To help universities adopt a key development role, national development plans will need to incorporate new links between universities, industry, and government (box 6.4). This is likely to affect the entire national innovation system, including firms, R&D institutes, and government organizations. Developing countries will not be able to exploit the might of new technologies unless they become seriously involved in high-technology fields. For this reason, university curricula are vitally important. The science, technology, and innovation curricula in many developing country universities are outdated or lack a cross-disciplinary approach. In certain departments, the research emphasis needs to be shifted toward issues of local and national relevance. University faculties in many developing countries are poorly rewarded and thus undermotivated. Faculty are not always conversant with the latest developments in their fields. Their teaching methods tend to be old-fashioned, with little use of audio-visual equipment during lectures or of advanced apparatus during laboratory sessions, for example. Some of these problems are caused by inadequate funds. Faculty need to be aware of developments at the frontiers of their research. Research ability will need to be considered when assessing applications for graduate study. Incentives such as scholarships and low-interest loans should be made available for the most promising students. Universities that are expected to boost technology-based industry need to be located near high-tech firm clusters and research institutes, most likely in urban areas. If firm formation is expected to take off after the university is established, the university needs to be located in an area that is conducive to further development.

Universities and technical institutes that are expected to play an important role with regard to community development are likely to be more effective in rural areas. Institutions that are involved in research that is very site specific will need to locate themselves, or some of their laboratories, accordingly. (Universities interested in marine research, for example, should be located near the coast.) Universities throughout the world are undergoing reform and seeking new models to address challenges of sustainable development (box 6.5). Latin American, African, and Asian countries are exploring new approaches that can guide the creation of new universities and reform existing ones. The search is focusing on identifying appropriate curricula and pedagogy and integrating these institutions into the communities in which they are located. The new models emphasize educating graduates who serve as agents of socioeconomic change rather than mere holders of degree certificates. Broadly speaking, there are three possible categories of action: reforming existing universities, upgrading existing institutes, or starting new universities.

In all cases, supportive policies and regulations will need to be made and links created between universities, industry, and government. For universities and technical institutes to adopt their new role as development partners, a new set of management procedures will be required. The recommended changes—in many cases requiring drastic revisions in student and faculty selection procedures, new incentives and transparency mechanisms, and revised curricula and teaching methods—are likely to cause upheaval and resentment in various circles of the university. These organizational transformations must be effected, taking into account of the different systems of governance of universities, which differ across countries. In some cases strong management can be recommended to ensure that the new schemes are put and remain in place. In other cases this recommendation makes no sense. In Latin America public universities are autonomous bodies ruled by processes in which faculty and students go through democratic procedures to elect rectors, vice-chancellors, and deans. Systemic tuning is needed to help the three actors—universities, government and industry—interact in a productive and respectful manner.

Universities and technical institutes will very likely work closely with industry as well as government in the pursuit of national objectives. Therefore, it is important that the university have mechanisms in place through which it can retain its autonomy. Forging partnerships with nongovernmental organizations Science, technology, and innovation education can be enriched through partnerships with NGOs. The case of the Foundation for the Application and Teaching of the Sciences (FUNDAEC) in Colombia illustrates the importance of creating such partnerships (G. Correa, FUNDAEC, personal communication, 2004). The organization was created 30 years ago in the Valle del Cauca region of Colombia by a small group of physicists, mathematicians, agronomists, and professors in the social sciences who saw the need to extend highquality education beyond the walls of the traditional university. The founders developed a common perspective that the right of the masses to have access to information and to fully participate in the generation and application of knowledge are fundamental to social and economic development. This fundamental principle led to the creation of the University for Integral Development. The university has brought together a large number of organizations from across the world, working together to learn about how to involve populations in the processes of knowledge generation in pursuit of greater wellbeing (C. Honeyman, FUNDAEC, personal communication, 2004). FUNDAEC has pursued a variety of lines of action toward this central goal, including systematic investigations with rural families in the area of agricultural and livestock production, helping to form cooperative community groups, developing appropriate agro-industrial technologies, developing the capacities of rural youth, and working with rural economies and small-scale businesses. As FUNDAEC has engaged in each of these areas, it has codified what it has learned in a series of educational materials written for secondary school and university levels. Some of these materials are available through FUNDAEC's University Center for Rural Well-Being, reaching more than 550 undergraduate and graduate students since its foundation. A further 75 interactive texts make up the curricular material for the Tutorial Learning System (*Sistema de Aprendizaje Tutorial* or SAT), an innovative secondary-school education and community development program. Some 70,000 students in Colombia have graduated from this program and another 30,000 are currently enrolled. The program has also been implemented on a small in several other countries in Latin America. SAT was originally created to contribute to the process of development within a defined microregion near the city of Cali. Over the past few decades, however, as the reputation of the program has grown, it has become recognized as a formal secondary school system. More than 40 NGOs now offer its educational materials within an expanding number of regions, with FUNDAEC continuing to provide training and curricular development. Often funded directly by local and municipal governments, the SAT program exemplifies a successful collaboration between the public and private sectors, carried out in pursuit of a common goal. Carrying forward FUNDAEC's central principle, SAT students are involved from the very beginning of their studies in the processes of generating knowledge, as they carry out investigations in their own communities and develop projects and initiatives to meet the particular needs they identify. In its willingness to engage with others in such a far-reaching and ongoing process of learning, FUNDAEC provides an important example of the ways in which educational innovations can succeed in involving populations that have, for too long, been excluded from worldwide processes of knowledge generation and application. Conclusion It is more important than ever for developing countries to move ahead in scientific and technological development at an advanced level. Doing so will enable them to build local capacity that can help solve the many science and engineering– related problems they face. It will also position them to take an active part in the global knowledge economy. Universities are vastly underutilized and potentially powerful vehicles for development in developing countries, particularly with respect to science and technology. If both universities and industry are encouraged to work actively together, universities will be able to assume new roles that could accelerate local and national development. Rendering these institutions more effective as key development partners will require changes at several levels of university administration. It will also require deep changes in enterprises, private as well as public, so that they can become strong demanders of the universities' capabilities, helping transform these capabilities into capacities. Government will need to act as a careful facilitator of interactions between these two actors. If this is achieved, the "loneliness syndrome" that for so long affected universities in developing countries will be redressed, allowing them to contribute to economic growth and social development.

Conclusion and Recommendations

The process of technological innovation has become intricately linked to the globalization of the world economic system. The shift from largely domestic activities to more complex international relationships demands a fresh look at policies that integrate science, technology, and innovation into economic strategies. Despite the increasing globalization of technology, the involvement of developing countries in producing new technologies and innovations is almost negligible. The production of technological knowledge is concentrated in industrial countries. There are major differences in the generation of knowledge not only between developed and developing countries but also among developing countries. The challenge facing the global community is to create conditions that will enable developing countries to make full use of the global fund of knowledge to address development challenges. Enhancing the capacity to use available technologies much of the international debate over technology has focused on new technologies and ignored the global context in which such inventions are applied. Globalization of technology falls into three categories: the international exploitation of nationally produced technology, the global generation of innovation, and global technological collaborations (Archibugi and Pietrobelli 2003). The first category, international exploitation, includes innovators' attempts to gain economic advantages by exploiting their technological assets in foreign markets. Multinational corporations, as the agent of this type of technological globalization, often maintain their national identity, even when their technologies are
sold in more than one country. They exploit their technological assets in overseas markets by selling their innovative products, selling their technological knowledge (through licenses and patents), and establishing local production facilities (through foreign direct investment). The second category, global generation¸ refers to the production of technologies by single proprietors (largely multinational corporations) on a global scale. Multinational corporations use international but intrafirm networks of R&D laboratories and technical centers and one of three main approaches. In the center-for-global approach, the core strategic resources—top management, planning, and technological expertise—are located at a company's headquarters. In the local-for-local approach, the firm's subsidiaries develop their own technological knowledge and know-how to serve local demand and preferences. The interactions among subsidiaries are limited in terms of the development of technological innovations. In the local-for-global approach, multinational corporations conduct their R&D activities in multiple locations. The third category, global technological collaborations, has grown in importance in recent years. Technological collaborations occur when two companies establish joint ventures or formally agree to develop technical knowledge and products, while maintaining their respective ownership. Many partnerships are between firms located in different countries, thus contributing to technological globalization. ICT has created a new way of viewing how different industrial, agricultural, and service elements link together in ways that

distinguish more than just the economic contribution of these different growth segments. These technologies challenge us to find new ways in which human efforts can enhance institutional life and sustain technological learning in developing economies so that gains in one area can be automatically translated and multiplied as gains in learning in another. ICT can be applied to meeting the Goals in at least three areas. First, ICT plays a critical role in governance at various levels. Because of the fundamental link between technological learning and the ways societies and their industrial transformations evolve, it is important to situate technological innovation and the application of ICT at the center of governance discussions. Second, ICT can have a direct impact on efforts to improve people's quality of life through better information flows and communications. Third, ICT can enhance economic growth and income by raising productivity, which can in turn improve governance and the quality of life. The benefits of the new technologies are the result not only of an increase in connectivity or broader access to ICT facilities per se. They accrue from the facilitation of new types of development solutions and economic opportunities that ICT deployment makes possible. When strategically deployed and integrated into the design of development interventions, ICT can stretch development resources farther by facilitating the development of cost-effective and scalable solutions. Networking technology can be deployed to enable developing countries to benefit from new economic opportunities emerging from the reorganization of production and services taking place in the networked global economy. ICT will become one of the main enablers in the pursuit of poverty alleviation and wealth creation in developed and developing countries alike. At the same time, as a facilitator of knowledge networking and distributed processing of information, ICT can be used to foster increased sharing of knowledge. A distorted academic reward system is preventing researchers in developing countries from enhancing their nations' scientific and technological capabilities.

Academics are rewarded for working on problems of interest to international science, not local problems. Researchers who work on important problems for their country or region risk not being able to publish their findings in mainstream journals or not being invited into intellectual circles of international standing. Changing this system could encourage researchers to work on development problems (box 8.1). One way of creating incentives to work on development needs is to rethink and "endogenize" the academic reward system. A faster way to create incentives is to organize calls for research proposals directed to solve developmental problems, particularly those affecting the poor (box 8.2). This does not mean that scholars should concentrate exclusively on applied research: often a mixture of basic and applied knowledge is necessary to solve the complex issues that affect poor people. Another significant problem in developing countries is the absence of demand for value-added and more sophisticated technological activity. One of these technological activities is R&D as it relates to enterprises' collective learning functions—that is, their organizational path to assimilating and innovating new technologies. If this important function is left unattended, enterprises will remain dependent on imported technologies, which are expensive and not adapted for local conditions. If demand for future high-level technological activity is not transmitted to enterprises through appropriate policies, countries run the risk of importing equipment without the complementary
generation of domestic innovations. One element of successful interventions in East Asia has been precisely this type of demand-side boost to create incentives for enterprises to invest in R&D and raise levels of R&D spending significantly. Yet another problem for developing countries is the isolation of their research institutes and laboratories. Commercialization of R&D faces problems of scaling up from laboratory findings to industrial output. There is no easy solution to this problem, except to create opportunities for R&D laboratories in the public domain to work with private industry. In Taiwan (China) R&D consortia are formed to foster cooperation between various laboratories in the government-funded Industrial Technology Research Institute (ITRI) and local small and medium-size enterprises to transfer technologies and develop innovative processes and products (Madsen and Chug 2003) (box 8.3). Industry associations such as the Taiwan Electrical and Electronics Manufacturers' Association (TEEMA) were involved in identifying enterprises to join R&D consortia and in performing administrative work for the consortia that were established. These R&D consortia are formed to overcome the size limitations of small and medium-size enterprises and develop the kind of economies of scale for innovation that are

usually enjoyed only by larger firms. Consortium members research and develop products, process technologies, and even technical standards. Through public-private collaboration of joint R&D, some developing countries have been able to enter a product market right at the beginning of the high-growth stage. Their innovation strategy changed from one of "catching up" to one of being a "fast follower," able to stay at the leading edge of technology and remain responsive to shifting market trends. Even the "fast-follower innovation strategy" is ineffective as a strategy to upgrade technologically in the face of the changing nature of more dynamic industries, which are essentially an integration of selected industrial sectors. A good example is the ICT industry, which integrates information technology, consumer electronics, and the telecommunications sectors. To overcome such a problem, the government of Taiwan (China) helped local firms form new product consortia and alliances to ensure that Taiwanese manufacturers were not left out in the initial stages of developing novel products or new architectural standards considered to have the potential to become popular.

The Structure of Scientific Advisory Bodies

The structure of advising may follow a number of models, including the corporate non-profit model, the independent advisory model, and the embedded advisory model. In each case, certain elements increase effectiveness. First, the advising function should have some statutory, legislative, or jurisdictional mandate to provide advice to the highest levels of government. This protects the advisor from being unduly influenced by political pressures, and it provides credibility and regularity to interactions between the advising and the decision making roles of government. The advisor should have a trusted and regular link to those making decisions at the highest levels. This trusted link should have some privilege attached to it, so that the science advisor can offer frank advice without fear of being penalized by interest groups. However, the science advisor needs to strike a delicate balance between advice given in confidence to policymakers and some accountability to the public sector, lest the science advisor be seen as a "mouthpiece" for those in power and lose the ability to interact with the science, technology, and innovation community and the public at large. Second, the structure should have its own operating budget and a budget to fund policy research. This helps the advising structure create an institutional memory of how decisions are made effectively and how they can be improved in the future. It also helps coordinate decision making across government agencies and with outside groups. Third, the science advisor should have access to good scientific or technical information, from within the government; from the science, technology, and innovation community; from national academies; or from international networks. This network of advice should be readily available, so that when decisions need to be made, technical advice is immediately at hand. Finally, the advisory processes should have some accountability to the public and some method of obtaining public opinion. This may involve some outreach, through tools such as foresight exercises or regular interaction with legislative bodies. The science advisor should work with those in power to establish a national vision, one that encompasses specific missions and targets for the sustainable use and enhancement of national capabilities. These types of mission statements exist in many countries. They offer guidelines that can be used by countries seeking to implement this type of strategic planning. The establishment and maintenance of science, technology, and innovation advisory institutions in developing countries is an essential component of development planning. These activities are considered expensive, and their cost-effectiveness is often questioned. Several countries have found ways to both increase their effectiveness and reduce their costs. Malaysia, for example, has used members of national academies as volunteers.

Cross-country Experience with National Science Advisors

Advising structures differ across countries, depending on their governance structures. The taxonomy of advising bodies and the circumstances under which they are established are also complex. Some committees are ad hoc and flexible, others are more permanent. In many countries, including the United Kingdom and the United States, a single person serves as chief scientific advisor to the head of state and chairs a panel of prominent scientists advising the executive branch. In the United States input into the executive's decision making is limited to an intimate circle of task forces and councils. In contrast, government ministries and departments in many countries are offered more opportunity for participation. In France, for example, responsibility for much of the advising process has been tasked to issue-specific agencies. In France and the United Kingdom, issue-specific agencies have responsibility for implementing legislation. Some Swedish policy-oriented agencies also implement government policies, relying on researchers to provide scientific expertise for their decisions. Sectoral agencies also rely on a mix of sources for advice. In Sweden sectoral agencies rely on internal experts that often overlap with executive science advisors. In France, Italy, and the United Kingdom, sectoral ministries and departments rely on a variety of committees for their information. Policymakers in the United Kingdom are informed by a variety of sources, including the Royal Society, the Royal Academy of Engineering, the Council for Science and Technology, the Office of Science and Technology, the prime minister's science advisors, individual departmental science advisors, a Parliamentary Committee on Science and Technology, and an Association for the Advancement of Science. In both Germany and the United Kingdom, ministries have their own permanent science, technology, and innovation committees. In contrast, in Italy emerging problems are handled by ad hoc issues-based committees. In the Newly Independent States, sources of science, technology, and innovation advice to sectoral agencies have included national scientific, technical, and engineering academies; autonomous research councils and organizations; NGOs; and agencies of other governments. Looking at the different science advisory mechanisms for legislatures, in the United States every Congressional office and committee has staff experts. In the United Kingdom science advisors provide expert oversight only for the executive branch. The China People's Political Consultative Conference (CPPCC) functions as an in-house advisory group of policy experts who serve the National People's Congress (NPC) and State Council, China's two primary legislative bodies. It is fully funded by the Chinese central government. Funding issues are at the heart of debates over how to establish advice mechanisms. The robustness of China's science advisory mechanisms and their span across organizations seems due in large part to the funding they receive from the government. Government support and how it shapes (or does not shape) the nature of a science advisory institution, institutional procedures, and institutional capacity are recurring themes for budding science, technology, and innovation advisory groups in developing countries.