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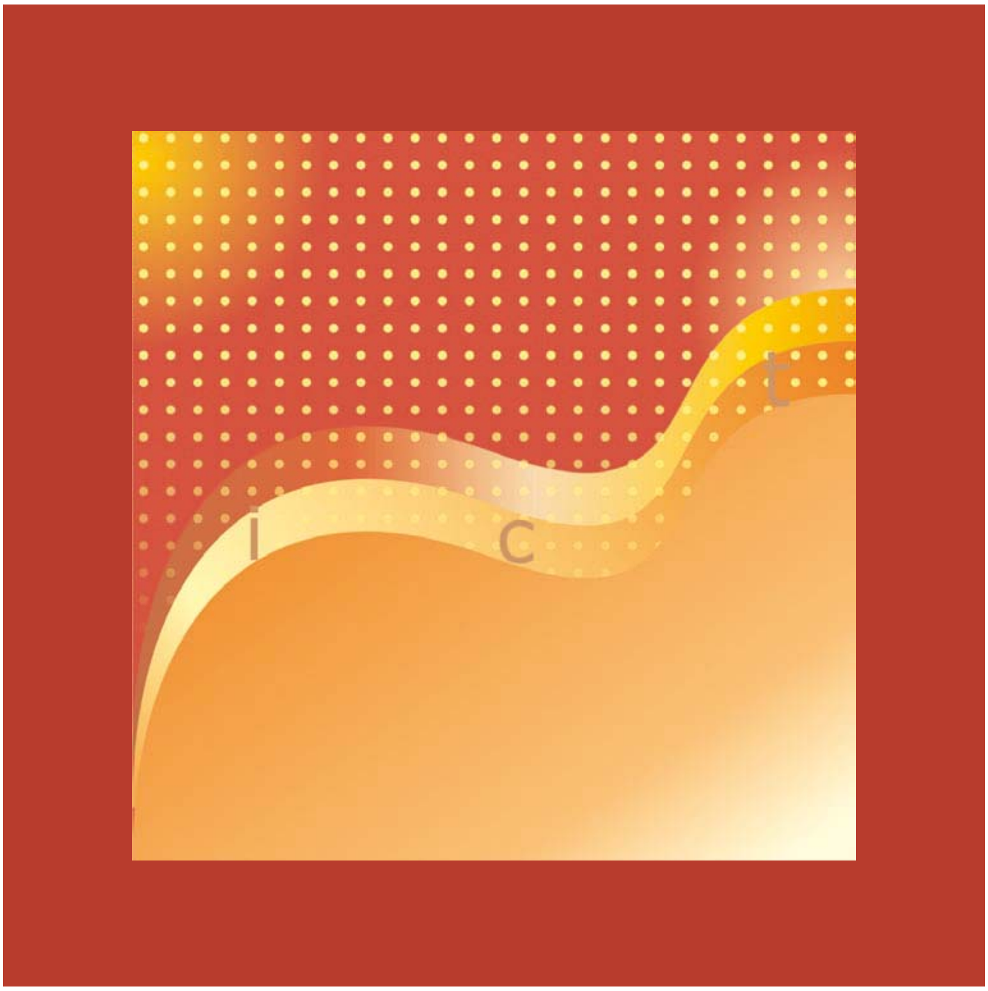
Science and technology for development: the new paradigm of ICT

Prepared by the UNCTAD secretariat



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Introduction

SCIENCE AND TECHNOLOGY FOR DEVELOPMENT: THE NEW PARADIGM OF ICT

It is now well established that the capacity to generate, assimilate, disseminate and effectively use knowledge to enhance economic development is crucial for sustainable growth and development, since knowledge forms the basis of technology innovations. In the context of a global economy driven by technological innovations, it is important for developing countries to lay proper foundations for building their capacity to acquire and create knowledge and technology in order to take advantage of the opportunities offered by globalization and, at the same time, to address emerging global challenges.

In the last part of the 20th century, the world economy witnessed an enormous increase in the generation of knowledge, resulting from the growth of research budgets and the availability of powerful research tools created by the rapid development of ICTs. This process was supported by global opportunities for accessing and disseminating knowledge, following the opening of borders to international trade and movements of persons and significant progress in transportation and communication technologies. Consequently, knowledge has become more important economically, in terms of investment in and production of knowledge-based goods and services. The adoption of new technologies and the improvement in human capital through knowledge have enhanced economic performance and increased factor productivity in many countries. At the same time, the fast pace at which new technologies are being developed, but also become obsolete, has profoundly changed the process of knowledge creation and acquisition, with sustained efforts being required for continuous upgrading of knowledge and virtually lifelong learning.

The challenge is therefore to harness knowledge for development by providing an enabling environment for the production of ideas and innovations, as well as for their dissemination and use by different actors, directly or indirectly involved in the production process. The creation and the use of knowledge to generate innovations – to improve or upgrade existing technologies or to introduce new technologies and business processes – depend on a number of prerequisites. The existence of supporting policies and institutions, such as government regulations and measures to encourage the creation and application of knowledge, financial institutions including venture capital, and institutions for standard- and norm-setting, is of the utmost importance in this regard. And so is the availability of qualified human resources and local training and research institutes – schools that train technicians and research institutes that are sources of technological innovations, as well as specialized institutes that prepare qualified businesspersons and policymakers. Also, efforts are needed at the international level to share knowledge and transfer technology for the benefit of less advanced countries.

Recognizing the power of knowledge, the IER 2007/2008 analyses the contribution of ICT to growth and development in the broader context of science and technology by considering ICT as one particular type of technology and applying the same economic analysis as in the case of technology for development. This analysis highlights the role of human capital, externalities and spillovers (notably through learning) and appropriate policies and institutions in the creation of innovations, which support the competitiveness of enterprises and of the economy in general. It also highlights the importance of open access to knowledge and hence the importance of diffusion of knowledge and technology, especially in the case of developing countries.

ICT is a general-purpose technology and as such has a pervasive impact on the economy. It introduces a new paradigm to the configuration of economic activities, changing in a radical way the approach to technology for development, because of the importance of spillover effects of ICT economic applications.

- First, the use and economic applications of ICT, more than the production of ICT, can make a powerful contribution to economic development. The economic impact of ICT could be more important, in terms of externalities and spillovers through its use and applications in different sectors of the economy, than its direct contribution to GDP as a production sector.

- Second, one of the most important externalities is a new mode of organization of production and consumption, which results in cost-saving transactions and faster and better communication between economic agents.

- Third, the rapid pace of innovation in the ICT sector itself has considerably reduced the costs of access to ICTs. This has allowed a democratization of ICT use, to be spread to poorer people in support of their livelihoods, and it has also facilitated the adoption of ICT in poverty reduction programmes.

- Fourth, ICT has generated new services in the forms of e-commerce, e-finance, e-government, and so forth. These new services can contribute to greater economic efficiency. However, other challenges may arise concerning questions of trust and security in the transactions that these new e-services generate.

- Fifth, ICT is skills-demanding, and the importance of education and training to build a knowledge economy in which ICT represents an indispensable tool continues to grow.

- Finally, ICT has given rise to new models for sharing knowledge and collective production of ideas and innovations, which often bypass the incentive system provided by intellectual property rights. These "open access" models, whether in activities such as open source software, open innovations or common knowledge associations, can be an efficient channel for rapid diffusion of knowledge to less advanced countries and deserve greater attention.

This chapter will analyse the factors underpinning the contribution to economic development of science and technology and ICTs. It will then introduce the subsequent chapters of the Report which, in the light of this analysis, will examine in detail the different aspects of a strategy to harness ICTs for development.

A. Science and technology in development

1. Role of technology in growth and development

Science and technology are at the heart of economic growth and development. Different schools of growth theory, whether of the neoclassical or endogenous types, have all recognized the essential role of technological progress and its corollary, knowledge, in sustaining the growth process and increasing the level of per capita income. What are the factors which promote technological progress? What should be the policy and institutional arrangements which are most propitious for the creation of knowledge and innovations, leading to constant technological progress? Since knowledge is non-rivalrous,[1] its diffusion should be rapid. However, the process of technology diffusion and transfer, which is one of the most important issues for the economic development of developing countries, is not straightforward. Identifying the factors which encourage or hinder technology diffusion is the first step in helping developing countries secure access to, absorb or transform, and use technologies developed by technology leaders.

Understanding the mechanics of economic growth has always been the single most important objective of economists, from Adam Smith to Thomas Malthus, Karl Marx, and the more modern neoclassical economists and "endogenous growth" economists. The evolution of economic thought has led to a universal acceptance of the role of technology and knowledge as an engine of growth.[2] While capital and labour are necessary inputs, the production of goods and services is driven by technology, which is the technical process, method or knowledge associated with an appropriate combination of inputs to produce and enhance the quality of goods or services. Technology has a direct impact on the productivity of firms, but has also an impact at the macro level, insofar as some platform technologies provide the means for better organization of work and better communications among people. Economic growth cannot be sustained by capital accumulation alone, as the contribution of capital, without technological progress, will be subject to diminishing returns.

The two schools, neoclassical and endogenous, differ in the analysis of the duration of the economic impact of technology. The neoclassical approach takes the view that technological progress has only a transitory effect on the rate of growth, but a lasting effect on the level of per capita income, which will move to a higher new steady state level. The endogenous growth theory (or at least some versions of it) implies a permanent effect on the long-term rate of growth. Under the neoclassical approach, the economic development of countries at different levels of development will converge towards the same steady state level (the catch-up phenomenon), given conditions of perfect competition and free flow of technology between countries, while under the endogenous growth approach, structural characteristics implying different endogenous technological capabilities result in a persistent divergence of growth paths, which require government intervention to address structural problems, going beyond the simple recipe of increasing savings and investment rates.

Behind technology is the accumulation of science and knowledge which leads to innovations and their applications to new technologies.[3] The endogenous growth school has highlighted the importance of human capital, research and development for technology production. It has also studied the policy implications of knowledge externalities and spillovers (Romer, 1990, 1994). In order to harness knowledge for technological progress, growth and development, there should be good institutions to coordinate the activities of different actors (from researchers to entrepreneurs and including intermediaries and consumers), and to legislate for, and support (through provision of finance and infrastructure), the creation of knowledge and technology, their diffusion and access to them by the public. Many authors (e.g. North, 1990; Mokyr, 2002) maintain that the interaction between institutions and knowledge is central to economic progress.[4]

For poorer countries, the most important challenge is the mobilization of resources to build up institutions and industries and build capacity to absorb and use imported technology, as well as to create local innovations.[5] The question of technology diffusion and transfer from lead technology producers to less advanced countries is of crucial importance for developing countries in general.

Measuring the economic impact of technology

What is technology? Technology is broadly defined as the way in which inputs to the production process are transformed into outputs (goods and services), and is basically knowledge. Technological progress can take the form of *product innovation,* which increases the quality of output or *process innovation,* which in turn improves efficiency in the production of output. Technology can be embodied in capital goods (and is thus directly measurable) or in human capital (and captured as tacit knowledge or know-how which can or cannot be codified). It is thus, in practical terms, very difficult to measure technology.[6] This is why technology is not entered as an independent input in empirical studies on sources of economic growth: ideas and knowledge are not quantifiable magnitudes.

Instead, it is assumed by economists that technology increases the productivity of the production function or its factor inputs, and that the economic impact of technology can be therefore measured by changes in productivity. The productivity effect of technology can be "Hicks-neutral" (i.e. it has an equal impact on factors of production and is exogenous to the production function), in which case it is captured by the concept of total factor productivity[7] (TFP) (also known as multifactor productivity), or technology increases the productivity of capital (capital-augmenting technology) or labour (labour-augmenting technology).

At the macro level, the concept of TFP has been used to measure the contribution of technology to economic growth. It should be noted, however, that TFP might capture other factors, including policy and institutional changes, variations in capacity utilization or other inefficiencies or efficiencies not due to technology. Nevertheless, a number of empirical studies have used TFP to analyse income gaps or long-term growth. For example, Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) found that a large part of the differences in per capita income between rich and poor countries is explained by differences in TFP. Other studies estimated the contribution of TFP growth, as compared with the growth of capital and labour (or sometimes human capital), to the growth of GDP. In the case of East Asian countries, a number of studies, including Young (1994, 1995), Kim and Lau (1994) and Collins and Bosworth (1996), using the TFP approach, found that TFP explained a small part of the growth of East Asian countries (covering the period 1960–1990) and that the role of capital accumulation was preponderant in the strong growth experience of those countries. Those findings led to the conclusion that growth in East Asian countries was not led by technological progress, but by high rates of capital accumulation. This was a surprising conclusion, given the well-known fact that economies such as the Republic of Korea, Taiwan Province of China, Singapore, Malaysia and Thailand have sustained their economic growth by rapidly moving up on the technological ladder. Government policies in those economies have always attached importance to the development of knowledge and human capital, to the absorption of foreign technology and to the production of indigenous technology. There are thus obvious shortcomings in the TFP approach based on the neoclassical aggregate production function, and many authors have questioned the applicability of the assumptions of that model to the analysis of real economic life (see Felipe, 1997; Nelson and Pack, 1997). It has been pointed out that the spectacular growth achievements of the East Asian economies are closely associated with the entrepreneurship, innovation and learning that occurred in those economies before they were able to master the new technologies imported from industrialized countries. Thus, technology matters and high investment rates are not the only explanation, the more so since the contributions from capital accumulation and technological progress to growth can be closely interdependent: technological progress increases capital and labour productivity, thus encouraging capital-deepening in the production process, which in turn allows the introduction of more innovations (for example, in the case of investment in ICT). Thus, the impact of technology on economic growth should not be assessed by using only the concept of TFP, since technology impact, through capital-deepening, on the productivity of capital and labour is equally important.

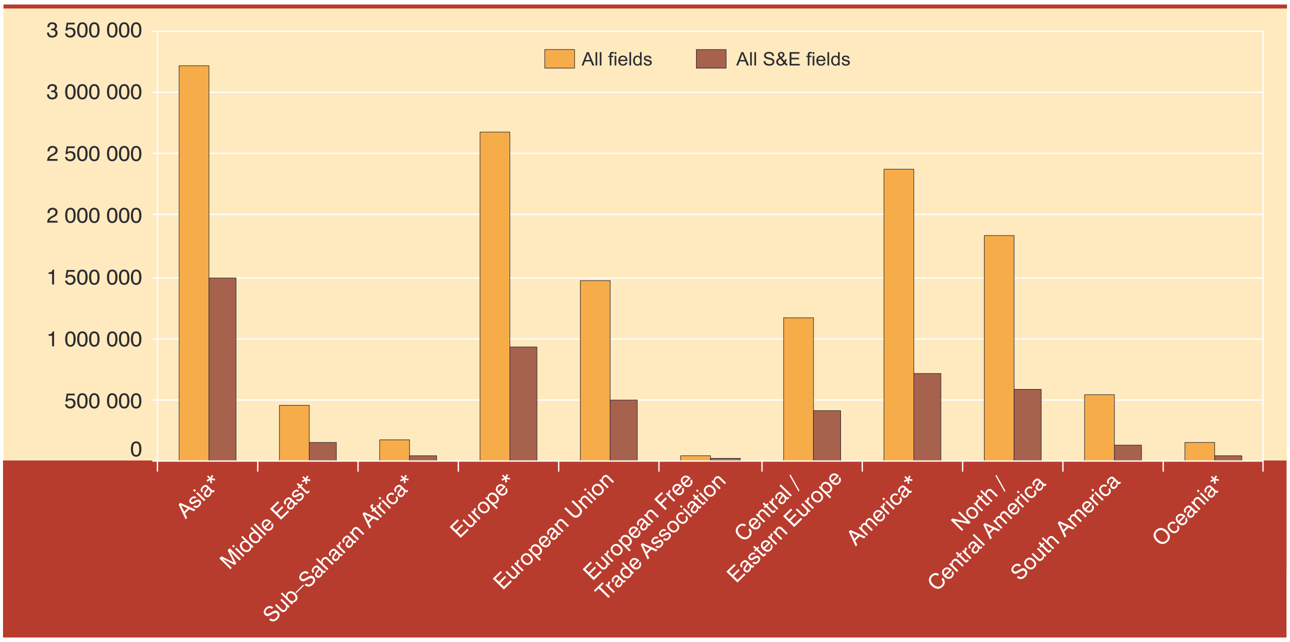
The concept of TFP is also used at the industry and firm levels to determine the factors which increase the TFP of the economy as a whole or of industrial firms in different sectors. For reasons of data availability, most studies have been done in the context of industrialized countries. The role of ICT in particular in increasing TFP has been extensively studied (see chapter 3 of this Report). Other studies found that research and development (both public and private), as well as technology spillover effects, contribute to increasing TFP in the manufacturing and services sector.[8]

2. Technology and institutions

In analysing the history of industrial revolutions in Europe and the United States, as well as the "Asian Miracle", scholars have identified the crucial role of institutions and policies in supporting the production and diffusion of ideas and knowledge, which are the foundations of technological progress. What should be the appropriate policy and institutional environment to encourage the production, diffusion and use of scientific and technological knowledge for the benefit of the economy as a whole? It is often said that

Chart i.1

Science and engineering in first university degrees, by selected region, 2002 (or more recent year)



Note: * Includes only locations for which relatively recent data are available.

Source: Data complied by the National Science Foundation from the OECD Education database, and UNESCO, Institute for Statistics.

without entrepreneurs, venture capital and schools that train the technicians who can build and maintain new technologies, innovations will not yield economically significant results.

Human capital and research and development are crucial to the development of ideas and their applications to technological innovations. In that respect, countries should attach the utmost importance to the quality of the national education system and research institutions, aiming at building up an "army" of good researchers. Recent statistics show that there is still a wide gap between developed and developing countries with regard to research and development, although the newly industrializing countries in East Asia are narrowing it.

As can be seen from chart i.1, the proportion of university graduates in the field of science and engineering in the total number of university graduates is the highest in Asia, followed by Europe and North America. In other regions, this proportion is negligible.

Table i.1 shows statistics concerning the number of researchers and the amount of gross expenditure on R&D (GERD). It appears from that table that the developed countries have a very high concentration of researchers (3,272.7 per million inhabitants and 70.8 per cent of the total number of researchers in the world), while developing countries have much lower magnitudes (314.3 researchers per million inhabitants and 29.2 per cent of the total number of researchers). Likewise, the percentage in GDP of gross expenditure on R&D (GERD/GDP) is 2.3 per cent for developed countries, which is more than double the level of 1.0 per cent for developing countries. Among the developing countries, however, the newly industrializing countries of Asia are above the developing country average, showing a concentration of 777.2 researchers per million inhabitants, and GERD/GDP equivalent to 2.3 per cent of GDP.

The institutional framework should also ensure a good flow of knowledge between scientific research and technological applications (in both directions), as well as a good flow of information among researchers and users, at the national and international levels. This framework has become known as the "national innovation system", which can be defined as a complex network of agents, policies and innovations supporting technical progress in an economy.[9] Within that framework, and in the context of developed countries where more information is available, the increasing frequency of collaborative research and public–private partnerships is to be noted. Industry clusters and technology parks are also interesting models of organizations that allow a good flow of information, complementarities and spillover between different firms along the value chain and in different sectors (production, business services, financial services, transportation etc.). Likewise, domestic and foreign networks reinforce each other through international research cooperation or strategic alliances for R&D.

Governments play a crucial role, because knowledge creation cannot rely on market mechanisms alone. Policies to support knowledge creation (such as tax subsidies, intellectual property protection, government funding and government procurement) as well as knowledge diffusion (establishment of libraries, communication networks, access cost subsidies, etc.) are examples of government measures in that area. A clear legal and regulatory framework in many areas, touching upon the interactions and transactions among different actors, is also necessary. The approach to intellectual property rights needs to strike a balance between incentives for creativity and society's interest in maximizing the dissemination of knowledge and information.

Lastly, the question of financing of innovation and technology is of equal importance. Developing countries may explore the applicability of the venture capital market model of developed countries. Development assistance from multilateral and bilateral agencies needs to attach more importance to the science and technology development. Taxes and subsidies can also play a role.

3. Knowledge diffusion and technology transfer

The market for knowledge[10] is often characterized by imperfections, whereby social and private returns derived from knowledge can differ widely. In the area of knowledge creation, this "market failure" may lead to private underinvestment in knowledge: this is why Governments have taken measures to provide incentives for individual agents to create knowledge through intellectual property rights, tax rebates and subsidies,[11] and full or partial funding of research. In particular, intellectual property protection through the establishment of patents, trademarks, copyrights or trade secrets confers the right to appropriate the income derived from the application of proprietary research in order to recover the high fixed cost of research or to enjoy monopoly rights for a certain period.

Table i.1

Researchers worldwide, 2002

	Researchers (thousands)	Researchers worldwide (%)	Researchers per million inhabitant	GERD / GDP (%)
World	**5 521.4**	**100.0**	**894.0**	**1.7**
Developed countries	3 911.1	70.8	3 272.7	2.3
Developing countries	1 607.2	29.1	314.3	1.0
LDCs	3.1	0.1	4.5	0.1
Americas	**1 506.9**	**27.3**	**1 773.4**	**2.2**
North America	1 368.5	24.8	4 279.5	2.7
Latin America and the Caribbean	138.4	2.5	261.2	0.6
Europe	**1 843.4**	**33.4**	**2 318.8**	**1.7**
European Union	1 106.5	20.0	2 438.9	1.8
Comm. of Ind. States in Europe	616.6	11.2	2 979.1	1.2
Central, Eastern and other Europe	120.4	2.2	895.9	1.1
Africa	**60.9**	**1.1**	**73.2**	**0.3**
Sub-Saharan countries	30.9	0.6	48.0	0.3
Arab States (Africa)	30.0	0.5	159.4	0.2
Asia	**2 034.0**	**36.8**	**554.6**	**1.5**
Comm. of ind. States in Asia	83.9	1.5	1 155.0	0.4
Newly indus. Asia	291.1	5.3	777.2	2.3
China	810.5	14.7	633.0	1.2
India	117.5	2.1	112.1	0.7
Japan	646.5	11.7	5 084.9	3.1
Israel	9.2	0.2	1 395.2	4.9
Arab States (Asia)	9.7	0.2	93.5	0.1
Other Asia	65.5	1.2	100.2	0.1
Oceania	**76.2**	**1.4**	**2 396.5**	**1.4**

Source: Adapted from UNESCO.[12]

It has been noted that the past 20 years have witnessed four major trends in knowledge.[13] First, there has been an enormous increase in the creation of knowledge, resulting from the growth of research budgets and the availability of powerful scientific research tools. Second, knowledge has become more important economically. It represents an increasingly important product or service, as in marketed information; an increasing share of competitive investment, in the information economy; and an increasing share of physical products. Third, the increasing openness of borders to products and people and the development of transportation and communication (particularly digital information technologies) have created new global opportunities for accessing and disseminating knowledge. Fourth, knowledge is increasingly privatized and commercialized, and the use of intellectual property rights to protect knowledge has restricted access to information and technologies. Furthermore, the international governance of knowledge has moved towards tighter and more harmonized IPRs at the international level, with a view to minimizing the free-rider problem. That has been achieved through the WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the "TRIPS-plus" provisions of regional and bilateral trade agreements negotiated by the European Union and the United States, and a number of new treaties negotiated under the auspices of the World Intellectual Property Organization (WIPO).

In the area of knowledge diffusion and technology transfer, externalities and spillovers can yield enormous benefits for the economy as a whole, and for the rest of world in the presence of technology flows among countries. In some instances knowledge can be considered a public good (non-rivalrous and non-excludable). Many inventions were built on earlier inventions ("standing on the shoulders of giants"), and the benefits of technological progress are not limited to one firm or one sector, because of complementarities in the application and generation of knowledge, and are thus extended to the economy as a whole. The benefits of externalities and spillovers may not be fully reaped because of high access costs or other obstacles. In the case of cross-border flows of knowledge, high access costs and barriers resulting from a harmonization and tightening of IPR standards at the international level may be harmful for poorer countries with limited human and capital capacity.[14] While market failures may be important, measures to address them have not been clearly identified, especially with regard to the transfer of technology from developed to less developed countries.

Market-based mechanisms for technology transfer through trade, foreign direct investment or licensing have always been used by developing countries to acquire new technologies. Many of the newly industrializing countries in East Asia have relied on those mechanisms to develop and move their productive technological capacity from OEM (original equipment manufacture) to ODM (own-design manufacture), and finally to OBM (own-brand manufacture).[15] However, with the restrictions in the international IPR regimes (especially after the adoption of the TRIPS Agreement in the WTO), costs for access to foreign technology are increasing, and many learning by-doing-methods, for example reverse engineering, may not be possible any more. Foreign enterprises in high-technology sectors may prefer to establish their own subsidiaries or to acquire local firms in order to restrict the transfer of technology. Other mechanisms for technology transfer involve arm's length arrangements in the form of inter-firm strategic alliances for R&D, public–private partnership projects (for example, between public research institutes in developing countries and foreign firms, mostly subsidiaries of transnational corporations), labour migration (skilled inputs of expatriates), and so forth. In the case of low-income countries, those mechanisms are used less because of weak local capacities.

An international debate has been engaged with regard to finding the right balance between production and dissemination of knowledge. Finding an optimal international IPR regime is a complex problem: in addition to a careful evaluation of externalities and spillovers from both the producer and user perspectives, account should be taken of the differential development and social needs of developing countries. One of the most visible results of that debate was the decision taken by the WTO in Doha to interpret TRIPS in a way that recognizes the urgent public health needs of poor countries. However, worldwide, IPR regimes in developed countries have become more restrictive.[16]

Many approaches have been suggested in order to encourage more effective transfer of technology to developing countries.[17] These can be grouped under a few main headings, and deserve more attention and research at the policymaking level:

- Improving flexibilities in intellectual property rights, in terms of calibration of standards and norms for countries at varying levels of development. For example, it has been suggested that patent holders from developed countries could decide to apply a multi-price strategy in order to reduce access costs for low-income countries. The lower price could be maintained through price control or compulsory licensing. Another flexibility is the distinction between basic research and commercially applied research. The former, including related databases, may be accessible free of charge. It should be noted that open-access basic scientific research and commercial research have traditionally operated in a complementary fashion. Increasing transaction and access costs in scientific research can be harmful to dynamic industrial competition, as scientific spillovers to potential commercial technology innovations risk being minimized. Flexibility could also be applied in the form of exemptions or exceptions for acute public health, environmental and social needs of poor countries. The TRIPS Agreement also provides scope for flexibilities (in terms of limitations, exceptions or extensions) that can be exploited by the least developed countries.

- Open access regimes. These are arrangements whereby researchers deliberately forgo the pecuniary benefits attached to the proprietary protection of their inventions and collectively contribute to improvement of the research product (see box i.1). In some areas involving extensive cumulative innovation, such as computer software,[18] biotechnology or other public domains of common knowledge, those arrangements may be the most efficient forms for advancing knowledge. The key feature of open access models is that either the knowledge is put in the public domain or its use is free of restrictions, as specified in the terms and conditions of licences, and open access projects may arise where traditional intellectual property incentives are weak.[19]

- International partnerships for generating and sharing information. Many global initiatives have been launched, with the financial support of the public and private sectors, to enhance global research and information capabilities, so as to overcome crucial problems in the areas of rural development, environment and health in the poorest developing countries. International partnerships could be reinforced in those areas, as well as in other areas, in order to allow more effective participation by poor countries in sharing the benefits of common knowledge.

- Global support for building capacity in developing countries, especially the least developed countries, to enhance human capital, infrastructure and institutions in order to develop their scientific and technical knowledge. There is a strong case for donors to increase "knowledge aid" and aid for science and technology.[20]

B. ICT as a general-purpose technology

The ICT revolution has been compared to earlier industrial revolutions in modern economic history, and ICT has been classified as a general-purpose technology (GPT) to the same extent as power delivery systems (electricity, steam) or transport innovations (railways and motor vehicles). The widespread use of ICT in economic and social spheres has shaped what is usually called as the "New Economy". What is the "new paradigm" that ICTs have brought to the economic landscape, and what are the broad policy implications that can be drawn from this new trend? An analysis based on the proliferating literature on ICT as a GPT and its economic impact provides some answers.

1. New paradigm

The role of technology in growth and development as reviewed in the earlier section is crucial. When it comes to the GPT, this role is pervasive, as GPT interacts with any single sector of the economy and opens up and facilitates the emergence of new opportunities, entailing innovational complementarities in downstream sectors. According to Lipsey, Bekar and Carlaw (in Helpman, 1988), GPTs are technologies that have four characteristics:

1. Wide scope for improvement and elaboration;
2. Applicability across a broad range of uses;
3. Potential for use in a wide variety of products and processes;
4. Strong complementarities with existing and potential new technologies.

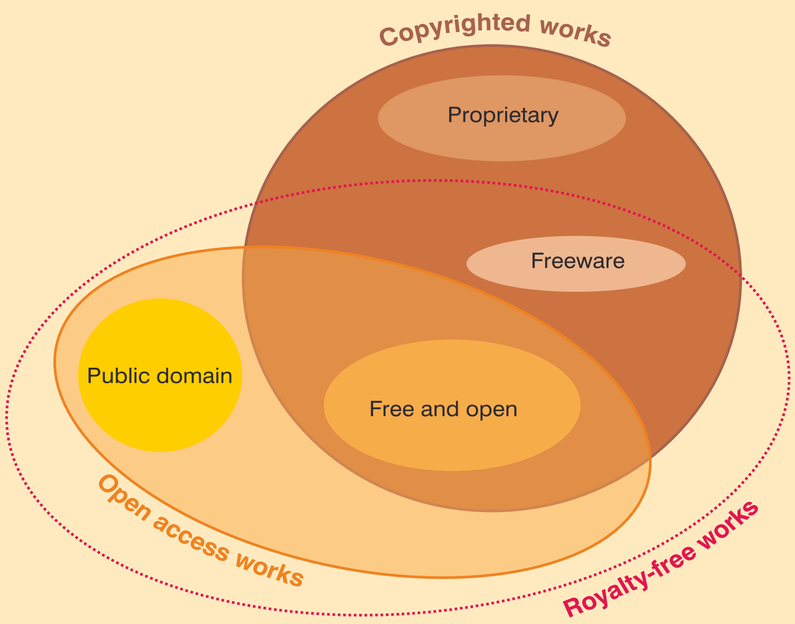
All those characteristics contribute to a substantial increase in the productivity of capital and labour for the economy as a whole. As reported by David and Wright (1999), GPTs are variously characterized in terms of inter-industry linkages, R&D investments, economies of scale, better coordination, spillover and so forth. But GPT phenomena can also generate alternating phases of slow and rapid productivity: the slowdown phase may be attributed to the diversion of resources into knowledge investment during the gestation of new GPT. Reference is made to the famous "Solow paradox" concerning the lack of impact of ICT investment on productivity in the United States in the 1970s and early 1980s. Another general conclusion is that GPT diffusion may be strongly conditioned by the supply of complementary productive inputs, especially high by skilled labour.

As a GPT with the characteristics mentioned above, ICT, as much as electrical power, has a profound and

Box i.1

Copyright and open access to knowledge

A copyright is a statutory (i.e. designated and imposed by law) time-bound monopoly right that is assigned to the creator of a copyrightable work at the time of the creation of that work. A copyright is tradable; it can be sold, leased or rented. Copyrighted works do not have to be registered with an authority, but if there is an intent to sell, lease or rent, registration secures the confidence of contracting parties in such a transaction. After a copyright expires, the work falls into the public domain. The chart below describes the interaction of several types of copyright and access, while the table organizes these concepts into a grid.



Is it: / The content is:	Subject to copyright law?	Open access?	Royalty-free?
Proprietary	Yes	No	No
Freeware	Yes	No	Yes
Free and open	Yes	Yes	Yes
Public domain	No	Yes	Yes

If a work does not carry an explicitly stated copyright licence, or carries only a "*copyright-date-owner*" designation, the default copyright is ***proprietary copyright***. A proprietary licence may also be explicitly stated. The owners of such works have exclusive rights to use them and to authorize use by others. "Use" is defined as any reproduction (copying), public performance (e.g. theatrical or musical works), recording of the work (e.g. a composer's song or a writer's screenplay is recorded and distributed as a song or film on a CD or DVD), broadcasting (radio, cable or satellite), or translation of the work into other languages or its adaptation (e.g. a novel into a screenplay).

Works under a ***freeware copyright*** have the same restrictions as proprietary works except that the owner will explicitly grant a royalty-free licence for non-commercial use of the work as it is without allowing subsequent copying, broadcasting or adaptation.

The terms and conditions of a ***free and open copyright*** (FOC) are expressed explicitly in an accompanying FOC licence that promotes content and knowledge sharing without letting them fall into the public domain. An FOC licence will prevent or discourage the copying and redistribution of the work under a proprietary copyright licence, but will oblige or encourage users to copy, modify and redistribute the work or derivative works under a FOC licence. FOC licenses for software are developed or accredited by the Free Software Foundation (FSF) and the Open Source Initiative; the most common licence is the FSF "GNU General Public License". Free and Open licences for text works, music and audiovisual expressions are developed and maintained by the Creative Commons project. The FSF "GNU Free Document License" is also in use.

Box i.1 (continued)

The ***public domain*** consists of works whose copyright owners have explicitly and publicly relinquished any copyrights they may have had on those works. Works whose copyright duration has expired, as a result of which the terms and conditions of the copyright no longer apply, also fall into the public domain. Works in the ***public domain*** can be freely copied, altered and used in derivative works without any obligation for any of its prior copyright owners. However, derivative works based on ***public domain*** content can be distributed under restrictive proprietary copyright – something that FOC generally avoids.

Open access designates all works that are free of restrictions on use, sharing, modification and incorporation, entirely or in part, into derivative works, and include works under FOC and the public domain. ***Royalty-free*** works are those that either generally or under certain conditions (e.g. non-commercial use) do not require users to pay a royalty for the right to access the content or knowledge. These include open access works and works under a freeware proprietary copyright.

Source: UNCTAD.

widespread impact on the structural transformation of all sectors of the economy as well as on society as a whole. It also has a widespread impact on the consumption side, since it is also a consumption product. The ICT revolution is often associated with the advent of the "New Economy". By the 1990s, the United States had grown at a surprisingly rapid pace, with record employment, low inflation, and acceleration of productivity growth. This was accompanied by significant investment in, and diffusion and widespread application of, ICTs. The term "New Economy" was first adopted in the context of the United States, but was then applied to the rest of the world when economies were characterized by dynamic growth led by adoption of new ICTs, and accompanied by significant changes in the organization of work which are different from those of the "old economy".

What is the new paradigm that ICTs have introduced? ICT is first of all a powerful technology for information processing, from both the quantitative point of view (astronomical size of data that can be stored and processed) and the qualitative point of view (adapted to a great variety of uses, rapid and wireless connections, distanceless, constantly upgraded to respond to changing needs). Moreover, ICTs are diverse instruments (computers, phones, other audio-visual instruments) that can be used by customers with different degrees of skills.

ICT applications allow not only a significant increase in productivity (total factor productivity, labour productivity, capital productivity), but also a reconfiguration of work organization, within the firm, among firms, among all market participants (consumers and producers), and between the Government and the rest of the economy. The innovations that accompany ICT applications are numerous and will most likely multiply in the future because of the "wide scope for improvement and elaboration" of ICTs. The following is an enumeration (which is not exhaustive) of the implications related to the new paradigm introduced by the ICT revolution.

- First, ICTs have significant *spillover* effects on the productivity of the economy as a whole. They contribute to economic growth[21] in three ways:

– As ICT production: contribution of the ICT product sector to GDP (chapter 2 will review latest developments in the ICT sector);

– As capital input: ICT equipment is used for the production of other industries and services as a capital good;

– As a special capital input: ICTs produce benefits that go beyond those accruing to the ICT sector or the investment in ICT as capital input in other sectors. Those benefits are derived from externalities or spillovers which benefit indirectly all market participants, thus, contributing, to overall productivity and aggregate income growth.

In sum, ICTs contribute directly to GDP growth as a production sector in themselves: the rapid technological progress in the production of ICT goods and services contributes to more rapid growth of TFP in the ICT-producing sector. Second, investment in ICT as a capital input contributes to overall capital- deepening in other sectors, thus helping to increase labour productivity. Third, greater use of ICTs creates "intangible assets" (in the form, for example, of organizational or managerial improvements), which contribute to increasing the overall efficiency of all sectors of production, thus increasing the TFP. ICT can be instrumental in generating complementary innovations, which boost the productivity in industries/services using ICT. Several econometric studies[22] in the context of industrialized countries have shown the importance of ICT's spillover effect on GDP. If the externalities or spillover effects are substantial, there is a large discrepancy between social and private returns, which may warrant the introduction of measures to encourage wider diffusion of ICT use by all market participants.

- Second, wireless and distanceless communications allow more *flexibility* and *networking* in the organization of work. It was reported that ICT use in developed countries is associated with changes in organizational practices, including the transition from mass production to flexible manufacturing technologies, faster and more direct interactions with suppliers and customers, decentralized decision- making, greater ease of coordination, and enhanced communication within the firm.[23] This has given rise to cost-saving management techniques such as just-in-time inventory control, fragmentation and internationalization of the production chain, and outsourcing of services and certain production tasks, to name but a few. For developing countries, those innovations have provided new opportunities for insertion in the global value chains and for diversifying production activities and exports. At the same time, ICTs facilitate the creation of networks, which enhance teamwork and increase the exchange of information among people belonging to the same professional associations and the same communities. It can be said that ICT networking facilities were at the origin of open source systems (UNCTAD, 2003). The tremendous increase in information flows and the availability of ICT tools to analyse that information have encouraged, and accelerated the pace of, business innovations, which in turn enhance the productivity and competitiveness of firms (see chapter 3 of this Report).

- Third, the rapid pace of innovation in the ICT sector has contributed to the decline in the costs of access to ICTs. This opens up opportunities for poorer people to use ICTs for income-earning activities as well as for upgrading their own knowledge. Chapter 6 will review the role of mobile telephony in the digital empowerment and inclusion of poor people in Africa. Recognizing the useful role of ICT in poverty reduction strategies, many Governments of developed and developing countries have developed policies for "e-inclusion". The approach to "e-inclusion" should not be limited to the problem of access, but should include the concept of supporting livelihoods through ICT. Chapter 7 will analyse that concept in the light of the experiences of telecentres for the poor.

- Fourth, the services sector has been particularly affected by information technology. The last decade has seen the creation of many forms of business (B2B or B2C), which rely on electronic communications for business transactions and organization of work, with names such as e-commerce, e-finance, e-banking, and e-insurance. Governments, through e-government, have also increasingly relied on ICT to organize their services and to deal with the public. Chapter 5 will review the implications of e-banking and e-payments for developing countries and economies in transition.

- Fifth, ICTs affect employment and wages for low- and high-skilled workers. They influence the evolution of the composition of the labour force: the unskilled workers are the main losers in sectors where investment in technology and greater productivity are high, and this phenomenon seems to be manifesting itself in both developed countries and developing countries (UNCTAD, 2006). Computer-based networks are changing the way people work and the way they are paid, in the sense that the rewards for multi-tasking are increasing and employers seem to prefer employees with broad-based education and conceptual and problem-solving skills. Skills can also be acquired on the job through on site-training. The returns to higher education are rising and the benefits for lifelong learning are increasingly being recognized.

2. Some policy implications of ICT for development

The ICT revolution is spreading to the developing world and brings with it the promise of a major technology leapfrog, which will contribute to rapid modernization of the economies of developing countries. In order to reap the opportunities offered by ICT, countries may find it necessary to identify a set of policies to encourage the creation, diffusion and use of knowledge, which should form the basis of a sustained growth strategy. The ICT contribution to building knowledge capital should be taken fully into account in designing innovation policies (see chapter 4). Innovation patterns are country- and industry-specific, and countries at different levels of development will have different approaches according to their capacities and priorities. Taking for granted a general enabling policy framework for investment and enterprise development, specific innovation policies should aim at promoting national knowledge systems to support the competitiveness of national economies. The building blocks of such an innovation policy framework can include the following:

- Enhancing human capital, by upgrading the education system in line with the needs of the economy, and by encouraging well-targeted R&D programmes;
- Providing adequate infrastructure for supporting the creation, diffusion and exchange of knowledge: finance (banking, venture capital), ICTs and business services (including institutions dealing with standards and norms);
- Encouraging partnerships (between public and private sectors, among firms, between domestic and foreign partners, regional initiatives etc.);
- Facilitating networking through the creation of clusters and technology parks;
- Special programmes to support start-ups (for example, business incubators);
- Regulations which provide clear and transparent rules for conducting business (intellectual property protection, Internetgovernance, ICT policies, labour policies, etc.);
- Promoting an "inclusive" policy of technology diffusion in order to encourage low-skill innovations in support of the livelihoods of the poor;
- Other government contributions, such as the launching of large R&D projects, tax rebates or subsidies for R&D activities by the private sector, a special government-sponsored technology fund, and so forth.

Against this broad policy framework to encourage innovations, the particular role of ICT as an enabler of innovations should be recognized and encouraged. Given the strong links between ICT use by enterprises, competitiveness and innovation, there is a need for better integration of policies to promote ICT use by enterprises within general innovation policies. One way to achieve that integration is to systematically coordinate policies from different ministries and at different levels. Many of the developed countries have entrusted overall policymaking for innovation and e-business to the same organizations, which formulate ICT policy as an integral part of science, technology and innovation policies.

It should be stressed that ICTs enable more rapid dissemination and better coordination of knowledge, thus encouraging open access to sources of innovation. An innovation policy framework that fully takes into consideration the changes generated by ICT must give prominence to open approaches to innovation, which present significant advantages for developing countries. Chapter 4 will set out in some detail the policies needed in that respect.

ICT policy should also address the question of *digital divide* (in comparison with the rest of the world, but also the internal digital divide faced by the underprivileged strata of the population). The basic dimensions of the digital divide include issues of access (connectivity, costs), skills (digital literacy) and content (localization of content). ICT policies have been extensively reviewed in earlier IERs, especially the IER 2006.

The digital divide between rich and poor countries remains significant (chapter 1). ICTs are evolving rapidly, and at the same time, costs are declining and many kinds of software have become available through the free and open source software networks. Although some new ICT applications (Wi-Fi, Semantic Web, to name just two) and continuing falls in access costs will allow developing countries to leapfrog on the technology trail, a number of challenges remain to be tackled in order to close the digital divide. The first is to invest in the development of human capital capable of rapidly absorbing and effectively using the new technologies. The second is to regulate e-commerce and provide protection and security to users under cyberlaws (chapter 8 will address the question of harmonising cyber legislation in ASEAN). The third is the financing of infrastructure, taking into account the costs of adjustment of displaced technologies. In all three areas, development partners can make a significant contribution.

C. Harnessing ICT for development

Against this backdrop of introductory analysis of the role of science and technology, and ICTs in development, the IER 2007/2008 examines in detail different aspects mentioned earlier concerning the role of ICT.

Chapter 1 reviews the recent trends in the diffusion of ICT in developing countries. Except for countries in East Asia, developing countries in general remain far behind developed countries in the adoption of ICTs and their use by enterprises. Statistical information is presented to illustrate the recent trends in ICT access and use by individuals, households and enterprises worldwide.

Chapter 2 reviews recent developments in the ICT sector worldwide. It is noted that production, trade and investment in the ICT sector will continue to increase, and the production sites will tend to shift from developed to developing countries. South–South trade in ICT goods exceeded South–North trade in 2004, and is expected to exceed North–North trade in 2007. This corresponds to the rapid catching-up by several developing countries in terms of ICT uptake and the development of their information economies. China and India are the world's largest exporters of ICT goods and services respectively. The expanding ICT industry and international service outsourcing offer a huge potential for developing countries. At the same time, competition will increase and countries wishing to attract FDI and BPO contracts will need to invest in education and telecommunication infrastructure, and to improve their investment climate.

Chapter 3 assesses the impact of ICTs on production efficiency. While in the case of developed countries the relationship between ICT and economic growth is well documented, there are very few studies in the case of developing countries. In general, the favourable impact of ICT on labour productivity is observed in both developed and developing countries. UNCTAD, in cooperation with the Government of Thailand, has undertaken an econometric study of the impact of ICT use on the labour productivity of Thai firms, and SMEs in particular. The results are very encouraging and demonstrate the favourable impact of computer use on the productivity of those firms.

Chapter 4 looks at ICT-driven innovation processes, and the policy framework encouraging innovations. Government policies aimed at supporting and facilitating long-term growth need to recognize and exploit the dynamic relationship between the use of ICT and innovation. A growing number of initiatives at all governmental levels now aim at supporting ICT-driven innovation. The links between innovation policies and policies to promote the use of ICT and e-business by enterprises are becoming stronger and in many countries they are now being placed within the same institutional framework and under the same overall political responsibility. There are, as mentioned earlier in the present chapter, a number of "institutional" matters to be addressed, such as the establishment of a development-friendly intellectual property regime and competition policies, the reinforcement of education and research systems, the creation of public knowledge structures, the development of IT infrastructures, the creation of a trust environment for ICT use, and well-functioning capital markets. Beyond those general issues, countries need to reinforce the complementarity between ICT and innovation policies. An important consideration for them is to put in place instruments to support ICT-enabled innovation among SMEs. This means that adequate outreach strategies need to be developed and that policies should be implemented with enough continuity and integration with sectoral approaches. These should facilitate the emergence of ICT-enabled alliances and networks for research and development. Equally important from the developing country perspective is the need to support open, user-centred innovation approaches: development-friendly intellectual property regimes are particularly useful in that regard.

Chapter 5 deals with the application of ICT in one service sector, namely financial services. The use of ICT in banking and payments is one of the main channels for innovation in the financial services industry, making it possible to drastically decrease the unit transaction costs of repetitive and high-volume operations and to automate the process of credit risk management. Given the relatively higher share of banking as a source of finance for development, the chapter stresses the importance of introducing modern e-banking and e-payment methods in developing and transition economies. In addition to traditional e-banking and e-payments operations, it reviews highly important issues such as access of SMEs and micro-enterprises to e-banking and e-payments facilities. Special attention in that respect is paid to the phenomenon of remittances as a major source of finance for enterprises and households, and the use ICT as a means of reducing the costs of delivering those small-scale private financial transfers.

Chapter 6 examines the experience of using mobile telephone to increase economic opportunities in Africa. While Internet access has become a reality for many businesses and public institutions, and for individuals with higher levels of education and income, for the vast majority of the low-income population, mobile telephony is likely to be their sole tool connecting them to the information society in the short to medium term. Mobile telephony can lead to economic growth in several ways. Investment in network infrastructure and related services creates direct and indirect employment opportunities. The use of mobile telephony in the conduct of business reduces the costs and increases the speed of transactions. Those effects will be more pronounced in economic activities that have a greater need for information or where added information enables increasing returns to scale. While methodologies and estimates will vary, current research indicates that mobile telephony has important economic effects for developing countries. The growing availability and the constant decrease in the price of mobile services are, in themselves a welfare gain.

In Africa, mobile phones have proved so successful that in many cases they have replaced fixed lines. As a result, mobile phone subscriptions since 2001 have quadrupled. However, improving rural penetration and achieving universal access remain a daunting task because of inherent difficulties caused by a lack of commercial distribution channels, insufficient education and poverty.

Chapter 7 analyses the experiences of telecentres in promoting the livelihoods of people living in poverty. Telecentres – namely, public facilities where people can access ICTs, communicate with others and develop digital skills – have become a key programme and policy instrument for supporting wider ICT access, thus broadening the social and economic benefits of ICT. Telecentres can support the livelihoods of people living in poverty by providing access to key information, supporting the development of technical and business skills, facilitating access to government services and financial resources, and supporting micro-entrepreneurs.

A number of policy recommendations are addressed to Governments in order to enhance the favourable impact of telecentres:

- Develop and promote relevant e-government content and services that support economic activities and livelihoods;
- Support the development of e-business skills;
- Provide strategic financial support for telecentre networks to provide value- added services and develop expertise in economic activities, as in the example of the telecentre in Nunavut (Canada).

Likewise, some recommendations are addressed to telecentre networks:

- Provide value-added services that have a direct impact on the livelihoods of the local community;
- Mainstream e-business skills training programmes;
- Enhance the understanding of the local context and strategies for supporting livelihoods;
- Support the economic activities of those in weaker positions by employing community infomediaries, as well as by providing targeted training and services; and
- Further engage with organizations that support economic activities, such as business associations or micro-credit institutions, in order to provide business- supporting services through the telecentres.

Chapter 8 examines the experience of the Association of Southeast Asian Nations (ASEAN) in the adoption of a regional harmonized e-commerce legal framework consistent across jurisdictions. The ASEAN region is the first region in the developing world to harmonize its e-commerce legal framework. By the end of 2008, all ASEAN member countries will have enacted consistent national e-commerce legislation. An increasing number of developing countries are adapting their legislation to e-commerce in order to remove barriers to online services and provide legal certainty to business and citizens. The impact of the introduction of legislation on the expansion of e-commerce activities is reported by countries to be positive, leading to increased ICT-related business opportunities and foreign direct investment, according to an UNCTAD survey on e-commerce legislation in developing countries carried out in 2007. The ASEAN project shows the importance of aligning domestic and international e-commerce laws to avoid overlaps and inconsistencies and create a smooth, consistent legal platform for businesses engaging in e-commerce at the regional level. Part of the success of the ASEAN E-Commerce Project is due to its focus on trade facilitation and global harmonization and international interoperability, rather than merely on regional harmonisation.

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Notes

1. Knowledge is non-rivalrous because its use by an individual will not prevent anyone else from using it. The typical example is a mathematical formula, which can be used by an unlimited number of people.

2. Many pioneering works, including by Kaldor and Schumpeter, highlighted the importance of technological progress and innovations for economic growth. More recently, two schools of analysis became prominent. The approach of the neoclassical school on economic growth was exemplified by the seminal work of Robert Solow and the endogenous growth approach was introduced by Paul Romer. Both schools recognized technological progress as the engine of growth, but the neoclassical school takes technology as an exogenous factor, while the endogenous school makes technology endogenously determined by economic activities, including research and development.

3. The chain from science and knowledge to innovations, and finally to technology, is not necessarily linear and runs in both directions: many technologies, especially the general-purpose technologies such as ICTs, contribute to the creation of knowledge and innovations, which in turn can lead to improvements in those technologies and others.

4. These authors point out that even though technology may be the engine of economic growth, institutions are the drivers of that engine. Institutions, formal or informal, matter more: "the trustworthiness of government, the functionality of the family as the basic unit, security and the rule of law, a reliable system of contract enforcement, and the attitudes of the elite in power toward individual initiative and innovation" (Mokyr, 2003).

5. The special case of the least developed countries is extensively analysed in UNCTAD (2007).

6. Comin, Hobijn and Rovito (2006) made a major effort to build a comprehensive database of technologies, which are classified as capital goods and new production techniques. They measure the diffusion of technology by measuring the use of capital goods or the share of output produced with the technique. Their data cover 115 technologies in over 150 countries during the last 200 years. Although very comprehensive, this database may not capture all the technological product or process innovations in every single sector.

7. Using an aggregate production function (most of the time, the Cobb–Douglas function), total factor productivity (TFP) is defined as the portion of growth in output which cannot be explained by the contribution of growth in inputs (capital and labour) and is thus attributed to the effect of technology. This is often measured as the residual after subtracting output growth from growth in inputs (multiplied by their respective shares in income), using a growth accounting method and assuming perfect competition in factor markets. It is often referred to as the "Solow residual".

8. A review of the role of scientific and technological knowledge in productivity at the firm level, in industrialized countries was undertaken for UNCTAD by Donald Siegel (Science and technology for development, mimeograph, 2007).

9. For more detailed analysis of the "national innovation system" and its applicability to developing countries, and especially to the LDCs, see UNCTAD (2007 chapter 3).

10. Reference is made here to commercial innovations leading to industrial technologies, while basic research is often funded by Governments in the context of university or other government-sponsored research programmes.

11. The WTO Agreement on Subsidies and Countervailing Measures prohibits subsidies contingent upon export performance or use of domestic goods, and classifies as actionable subsidies those that cause injury to the domestic industry of another Member or cause serious prejudice to the interests of another Member.

Subsidies for research activities conducted by firms or by higher education or research establishments on a contract basis with firms are not actionable (up to a limit of 75 per cent of the cost of industrial research or 50 per cent of the costs of pre-competitive development activity). The agreement does not apply to fundamental research activities conducted independently by higher education or research establishments.

12. http://www.unesco.org/science/psd/publications/wdsciencereptable2.pdf.

13. Barton (2006).

14. It has been argued that, in addition to the loss of benefits in terms of forgone externalities and spillovers, high access costs and barriers reduce policy space, insofar as poor countries cannot encourage uncompensated knowledge spillovers through weak IPR regimes and other technology-related policies, such as the performance requirements for technology transfer.

15. See Hobday (1995) for a detailed analysis of technological upgrading in East Asian countries.

16. The European Union has introduced more protection of databases, while the United States has expanded the scope of patentable research findings, including what otherwise would be considered discoveries of nature rather than inventions. Other developed countries have also increased protection of plant and animal varieties, genetic sequences and biotechnological research tools. See International Task Force on Global Public Goods (2006).

17. There have been many studies and proposals on this issue. The approaches suggested in this chapter are adapted from two main recent publications – UNCTAD (2007, chapter 3) and Maskus (2006).

18. On free and open source software, see UNCTAD (2003, chapter 4).

19. There are many instances where open access to new ideas and inventions/research is preferred: when open source projects are complementary to proprietary projects; when personal motivations are prevalent, such as intellectual challenge, education, blocking market dominance by others, or achieving common standards; when intellectual property incentives are weak, because of the small size of markets; or when intellectual property benefits are slight. Open access projects are often protected by a general public licence that obligates contributors to maintain open access and prevents improvers from taking ideas private through proprietary copyright licences. A good review of market conditions pertaining to open source can be found in Maurer and Scotchmer (2006).

20. UNCTAD (2007, chapter 5).

21. Paul Schreyer (2000).

22. See, for example, Basu and Fernald (2006) and Guerrieri and Padoan (2007).

23. Bresnahan, Brynjolfsoon and Hitt (2001).