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**Enhancing the enabling environment at all levels to strengthen productive capacity, trade and investment: mobilizing resources and harnessing knowledge for development**

# Harnessing knowledge and technology for development

**Note by the UNCTAD secretariat**

## I. Introduction

1. UNCTAD XII will be convened in Accra under the broad theme of "Addressing the opportunities and challenges of globalization for development". Sub-theme 3 of the Conference will consider issues pertaining to the strengthening of productive capacity, trade and investment, notably through resource mobilization and the harnessing of knowledge for development. The round table on "harnessing knowledge and technology for development", which will be organized on 24 April 2008 in the context of UNCTAD XII, will debate policies and initiatives at the national and international levels. The purpose of this note is to identify some issues for discussion at the round table. It is based on earlier work done within UNCTAD and elsewhere, and on the exchanges of views that were conducted during the pre-conference event organized on 6 December 2007 in preparation for UNCTAD XII on the topic of "science, technology, innovation and ICTs (information and communication technologies) for development".

## II. The role of science and technology in development

2. 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. Knowledge forms the basis of technological progress and innovations which are long-term drivers of economic growth. They are also key driving forces which shape the fast-changing global economic landscape.

3. In the last part of the twentieth 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 and 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.

4. 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 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 (a) government regulations and measures to encourage the creation and application of knowledge; (b) financial institutions, including venture capital; and (c) institutions for standard- and norm-setting – is of the utmost importance in this regard. 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.

5. Behind technology is the accumulation of science and knowledge which leads to innovations and their applications to new technologies. In order to harness knowledge for technological progress, growth and development, there should be good institutions to (a) coordinate the activities of different actors, from researchers to entrepreneurs, including intermediaries and consumers; and (b) legislate for and support (through provision of finance and infrastructure) the creation of knowledge and technology, their diffusion and access by the public.

6. 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. 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 good flows 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 research and development.

7. 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.

8. 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 science and technology development. Taxes and subsidies can also play a role.

# III. The role of ICT in the economy

9. Developments in the field of knowledge, technology and innovation and their impact on the global economy cannot be fully understood without considering the critical role played by new information and communications technology.

10. 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 and steam) or transport innovations (railways and motor vehicles). As a GPT, the impact of ICT on the economy of a country is pervasive.

11. ICT is above 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, and constantly upgraded to respond to changing needs). ICT applications allow not only a significant increase in 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.

12. There are many features which characterize the new ICT paradigm:

(a) ICTs have significant spillover effects on the productivity of the economy as a whole. Greater use of ICTs creates "intangible assets" (in the form of, for example, organizational or managerial improvements) which contribute to increasing the overall efficiency of all sectors of production. ICT can also be instrumental in generating complementary innovations, which boost the productivity in industries/services using ICT.

(b) Wireless and distanceless communications allow more flexibility and networking in the organization of work. 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. For developing countries, those innovations have provided new opportunities for insertion in the global value chains and for diversifying production activities and exports.

(c) The rapid pace of innovation in the ICT sector has contributed to the decline in access costs. This opens up opportunities for poorer people to use ICTs for income-earning activities, as well as for upgrading their own knowledge.

(d) The services sector has been particularly affected by information technology. New services such as e-commerce, e-finance, e-government, and so forth have been created and have contributed to greater economic efficiency. However, other challenges may arise concerning questions of trust and security in the transactions that these new e-services generate.

(e) ICT increases the returns to higher education and the benefits for lifelong learning. Education and training are ever more important in building a knowledge economy in which ICT represents an indispensable tool.

(f) 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.

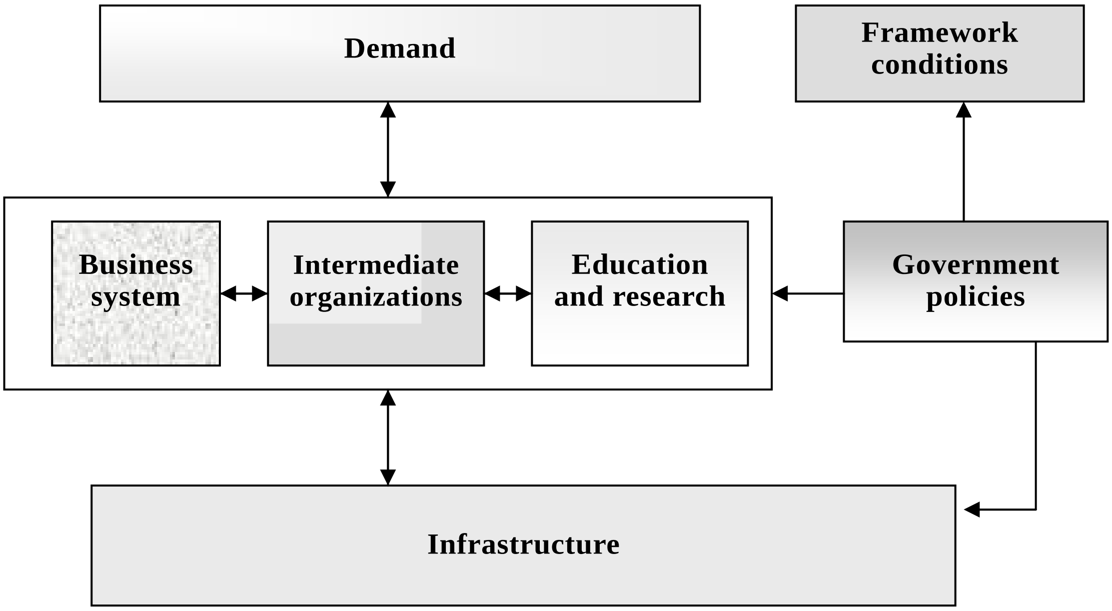
## IV. Strengthening national innovation systems

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

14. The broad policy and institutional framework supporting science, technology and innovation (STI), is built on models which vary between countries and which have evolved over time. Broadly speaking, STI frameworks have evolved from "linear" models to "circular" models.

15. Linear models imply that there is one way of causal relation from initial impulse to final outcome, which is innovation. The initial impulse can be either of a "supply-push" nature – that is, it originates from government initiatives to set up institutions and policies to encourage research and development – or of a "demand-pull" nature, where the initial impulse comes from the demands and needs existing in the markets. Linear models imply simplistic policy approaches. The push models imply supply-side policies, e.g. investment in training, research and development, and national and national ICT infrastructures, while pull models imply demand-side policies, e.g. market stimulation, user training and establishing uniform standards. In practice, national policies have often been volatile mixtures of technology push and demand pull models reflected in swings of emphasis between interventionist and laissez-faire policies.

16. More recently, the STI framework adopts "circular" models, built on the concept of "national systems of innovation", which are the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies. The broad components of this system are represented in the diagram below:




17. In such a system, innovation depends on the existence of a variety of agents and institutions (much greater in scope than technology providers and technology users), and the effectiveness of innovation depends on the interactions between these agencies and institutions. The ability and propensity of an enterprise to innovate depends not only on its access to knowledge from research institutes or technology services centres, but also on many other factors, including: (a) access to finance; (b) access to human resources; (c) adequate basic physical infrastructure; (d) firm-level capabilities; (e) inter-firm linkages and collaboration; (f) general business services; (g) demand conditions; and (h) the framework conditions. The framework conditions include financial environment, taxation and incentives, propensity for innovation and entrepreneurship, trust and mobility. Taking for granted general enabling framework conditions for investment and enterprise development, specific government innovation policies should aim at promoting national knowledge systems to support the competitiveness of national economies. Such policies can include the following:

(a) Enhancing human capital, by upgrading the education system in line with the needs of the economy, and by encouraging well-targeted research and development programmes;

(b) Providing adequate infrastructure for supporting the creation, diffusion and exchange of knowledge, such as finance (banking and venture capital), ICTs and business services (including institutions dealing with standards and norms);

(c) Encouraging partnerships (between public and private sectors, among firms, between domestic and foreign partners, regional initiatives etc.);

(d) Facilitating networking through the creation of clusters and technology parks;

(e) Special programmes to support start-ups (for example, business incubators);

(f) Regulations which provide clear and transparent rules for conducting business (intellectual property protection, Internet governance, ICT policies, labour policies, etc.);

(g) Promoting an "inclusive" policy of technology diffusion in order to encourage low-skill innovations in support of the livelihoods of the poor (for example, cheap laptop computers using solar energy and innovations to improve productivity in poor rural areas); and

(h) Other government contributions, such as the launching of large research and development projects, tax rebates or subsidies for research and development activities by the private sector, a special government-sponsored technology fund, and so forth.

18. Within 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 that formulate ICT policy as an integral part of science, technology and innovation policies.

19. 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.

## V. Investing in science and technology education and training infrastructure

20. Education, especially science education, is important not only for increasing general science and technology literacy, but also for enabling developing countries to build up a critical mass of scientists, researchers and engineers. However, in many countries, there is a deficit of engineers and scientists. Recent years have also witnessed a worrying trend that the percentage of university enrolment in science, mathematics and engineering has been decreasing. Concerted efforts are urgently needed to reverse this trend and encourage science education at all levels.

21. In many developing countries, the problem is further exacerbated by the problems of "brain-drain." By some estimates,[1] up to one third of research and development professionals from the developing world reside and work in Organization for Economic Cooperation and Development (OECD) countries. Academic and research institutions in many developing countries have not expanded sufficiently to absorb graduates in science and technology. The conditions of work are poor in comparison to those in developed nations. Professional opportunities are fewer due to poor physical infrastructure, lack of financial resources and the absence of the critical mass of researchers required to create active research communities.

22. Developing countries should consider providing special working conditions for their best science and technology talent, especially young graduates, as a mechanism to enhance future leadership for science and technology. Close ties with expatriates can also generate research talent for their countries of origin through collaborative projects. These links often provide sources of new technologies through investment in

[1] UNDP Commission on Private Sector and Development Report (2004). *Unleashing Entrepreneurship: Making Business Work for the Poor*. http://www.undp.org/cpsd/report/index.html. On the problem of brain drain from LDCs, see UNCTAD (2007). *The Least Developed Countries Report 2007.*

the home countries. Some countries, such as India and Pakistan, have benefited from expatriate scientists or those who have returned from abroad.

23. Even when science and technology professionals remain in their home countries, their attention is often diverted away from research of local relevance. This is because work on scientific problems that are of interest to the international community stands a better chance of receiving academic recognition and opportunities for collaborative research from well-funded institutions. This creates a situation where the scarce resources in developing countries are diverted to benefit developed countries.

24. In order to address this problem, a review of the academic reward system, particularly within developing countries, is necessary. Innovative compensation and reward structures should be created to promote research directed to addressing national and regional development challenges. Educational institutions need to provide students not only with an understanding of fundamental principles and technological trends, but also applied skills and industry-specific technological knowledge. Coursework on entrepreneurship and business management should also be introduced, thereby preparing students for the rigours of managing innovative enterprises, as well as facilitating a culture of entrepreneurship.

25. Linkages between universities and industry in the conduct of research and development have become quite pronounced in the developed world, providing benefits to both parties, derived from well-specified projects undertaken in a joint collaborative effort. Industry obtains access to state-of-the-art university laboratories, talented research scientists, as well as a pool of potential recruits. Universities receive industry’s financial support – necessary to conduct their work and expand their resources – and also receive feedback from industry to adapt research to the needs of the economy. Notwithstanding these mutual benefits, attention should also be given to the need for universities to preserve their independence in research and development activities, which should not be uniquely driven by commercial objectives. In contrast with their developed counterparts, many universities in developing countries lack such mutually beneficial linkages with industry.

26. The improvement of higher education will not be fully effective at stimulating innovation unless it is also accompanied by an expansion of opportunities for graduates to apply their skills and talents. With a significant amount of research and development activity occurring in the private sector, business enterprises serve as a primary source of demand for science and technology specialists.

27. By providing employment opportunities and career paths for scientists and technologists, enterprises encourage students to enrol in scientific and technological fields. As more students graduate with relevant skills and motivation, this growing pool of human capital will, in turn, attract more enterprises to the region, thus creating a virtuous, self-reinforcing circle of technological capacity development and research and development activity.

28. Government incentives can be provided to private enterprises, particularly small and medium-size enterprises (SMEs), to hire university graduates. Incentives could include tax breaks or financial aid to support internships or offset the initial cost of hiring and training new employees. Enterprises could also be encouraged to employ students as interns or part-time researchers, laying the foundation for later employment.

29. For universities to be able to fully contribute to science and technology-based regional development, appropriate support mechanisms are necessary, including implementing tax incentives for research and industry–university collaboration, and making capital available through venture financing or affordable loans. Governments can encourage university–industry research and development linkages by establishing

formal institutional relationships. Research networks or consortia can provide opportunities for cross-sectoral information-sharing and collaboration without requiring a major investment by individual parties.

30. Technology offices, technology parks and incubators have proven to be effective conduits to pool scarce resources – i.e. research and development, education and finance – needed to stimulate research commercialization and subsequent enterprise growth. Other similar mechanisms have also been used. For example, Taiwan Province of China has successfully used research and development consortia to foster cooperation between laboratories in the government-funded Industrial Technology Research Institute and local enterprises. This joint effort has resulted in technology transfer and innovative processes and products.

# VI. Bridging the technological gap and digital divide

31. Technological progress (outcome of technology) can take the form of product innovation, which increases the quality of output, or process innovation, which increases 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, practically difficult to measure the level of technology of a country.

32. Attempts to measure technology gaps between countries use some specific indicators related to technology embodied in capital goods or linked with human capital (such as patents, scientific publications and licenses). Measures using such indicators as electric power consumption, telephone mainlines, Internet penetration, broadband installation, road density, rail density, machinery and technical equipment, patents, scientific publications, number of researchers, scientific graduates and engineers, etc. all indicate that the technological gap between rich and poor countries remains important[2] and the sizes of the gaps are correlated with income levels. Except for a very small number of emerging industrializing countries, developing countries in general do not have the capacities to generate innovations at the technological frontier. While the production of technological knowledge takes place mainly in the developed world, most developing countries lag behind in the generation and adoption of technology and innovation.

33. A small group of newly industrializing countries has successfully reduced the technological gap and has even surpassed industrialized countries. Their catching-up experiences demonstrate that coherent and carefully crafted technology policies can considerably strengthen competitiveness and promote entry into more complex and higher-level technology sectors. A number of key lessons can be drawn from these experiences:

(a) Domestic innovation cannot be achieved without access to international markets, technology transfer and learning. In turn, increased exports to international markets are the results of domestic technological capacities and innovations. Strategic investments in human resource development, education, infrastructure and openness to foreign technologies are critical.

(b) Simply opening to free trade and investment flows may not be sufficient to develop technology. Without Government's active support through efficient STI policies, countries at the low end of the technology ladder may find themselves stagnated in low-technology specialization, and may lose their competitiveness over time.

[2] See, for example, UNCTAD (2007). *The Least Developed Countries Report 2007*; World Bank (2008). *Global Economic Prospects 2008, Technology Diffusion in the Developing World*; UNCTAD (2008). Information Economy Report 2007–2008.

(c) Skills development, industrial specialization, enterprise learning and institutional change create cumulative, self-reinforcing processes that promote further learning. It is very difficult for countries trapped in a development pattern characterized by low technology, low-skill and low-learning specialization to change course without a concerted shift in a large number of interacting markets and institutions. Foreign technology transfer – either through trade, foreign direct investment or other channels such as international partnerships or contribution from expatriates – can play a useful role.

34. Given the pervasive role of ICT in the development of technological capacities of countries, special attention needs to be given to narrowing the digital divide between countries. The basic dimensions of the digital divide include issues of access (connectivity costs), skills (digital literacy) and content (localization of content).

35. ICTs are evolving rapidly and at the same time costs are declining, and many kinds of software have become available through free and open source software networks. Although some new ICT applications 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 cyber laws. 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.

# VII. International cooperation

36. Developing countries' development strategies have to address the most important challenge to create institutions and industries and reinforce skills to absorb and use imported technology, as well as to create their own technological innovations. While countries have the primary responsibility to build their science and technology foundations, given the large technological gaps noted earlier, the question of technology diffusion and transfer from lead technology producers to less advanced countries is also of crucial importance for developing countries to narrow these gaps.

37. Market-based mechanisms for technology transfer through trade, foreign direct investment or licensing have always been used by developing countries to acquire new technologies. However, with the restrictions in the intellectual property rights regimes, costs for access to foreign technology are increasing, and many learning-by-doing methods, for example reverse engineering, may not be possible any more. Other mechanisms for technology transfer involve arm's-length arrangements in the form of inter-firm strategic alliances for research and development, 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.

38. Many approaches have been suggested in order to encourage more effective transfer of knowledge and technology to developing countries, especially the low-income countries:[3]

(a) Improving flexibilities in intellectual property rights, in terms of calibration of standards and norms for countries at varying levels of development, for example through multi-price strategy. There is flexibility in the distinction between basic research and commercially-applied research, with the

[3] For more details, see UNCTAD (2008). *Information Economy Report 2007/2008, Science and Technology for Development and the new Paradigm of ICT.*

possibility that the former (including related databases) is accessible free of charge. Flexibility could also be applied in the form of exemptions or exceptions for acute public health, environmental and social needs of poor countries.

(b) Open access regimes could be emulated. 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 licenses. In some areas involving extensive cumulative innovation, such as computer software, biotechnology or other public domains of common knowledge, those arrangements may be the most efficient forms for advancing knowledge.

(c) International partnerships for generating and sharing innovations, involving both public and private sectors, and with effective participation by developing countries. For example, 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 poor countries.

(d) 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.

# VIII. Conclusion

39. This note has briefly reviewed the challenges and opportunities, as well as national and international measures, in relation with the critical development strategy of harnessing knowledge for development.

40. The high-level round-table panellists may consider this note as a background document to address the following questions:

(a) What are the national and international strategies for the development of sustainable knowledge and skills? How can international cooperation contribute to the transfer of technology and knowledge?

(b) How big is the knowledge and technology gap between developed and developing countries, and in what ways can new technologies (ICT) help to catch up? What policies and institutional framework can be implemented to enhance access to and use of ICT for productivity gains and social benefits?

(c) How can participation of developing countries in the international research partnerships and projects to address current and future global challenges be assured?

(d) What actions can be taken at the international level to reduce the knowledge gap – a technology fund, more focus on innovation and knowledge in bilateral and multilateral development cooperation programmes, a global network to share knowledge (for example, under United Nations auspices)? How can the private sector, and especially international companies, contribute to international initiatives to enhance science and technology in developing countries?