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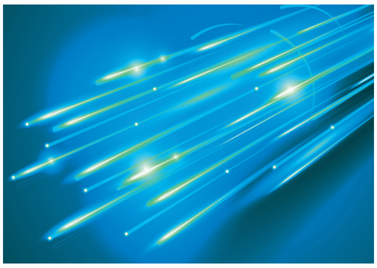
TRANSFER OF TECHNOLOGY AND KNOWLEDGE SHARING FOR DEVELOPMENT

Science, technology and innovation issues for developing countries

UNCTAD Current Studies on Science, Technology and Innovation. **N°8**

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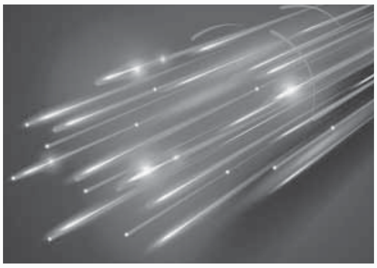

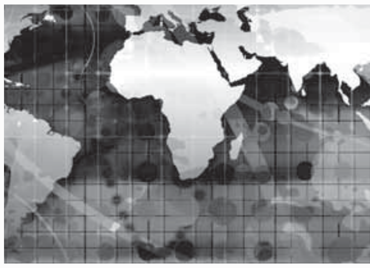

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Preface

In the outcome document of UNCTAD XIII, the Doha Mandate, member States noted that the development of a strong science, technology, and innovation (STI) capacity was the key to addressing many of the persistent and emerging trade and development challenges that developing countries face. Decisive and actionable STI policies needed to become a central feature of national development strategies.

Promoting and facilitating transfer of technology has long been an irreplaceable component of those policies. In this context, this report responds to the mandate given by member States in UNCTAD's Programme Narrative for the Biennium 2012–2013 for the secretariat to produce "Studies on science, technology and innovation including a comprehensive study to identify issues of developing countries on transfer of technology and knowledge-sharing for development". To complement its stronger analytical orientation the present report is being published simultaneously with another one that presents four case studies of practical experiences of transfer of technology in various developing regions of the world.

Developing country policies on technology transfer are necessarily complex and cross linked with a range of issues in the broader development agenda. Policy outcomes need to target increasing access to technology, including improving the abilities of firms and other users of technology to identify, acquire, adapt and use knowledge and technology. Underlying these outcomes are national policies that support improving domestic absorptive capacities and stimulate local innovation as well as international efforts to develop a supportive environment for technology transfer. However, it is important to bear in mind that the end purpose of these policies is not to achieve successful transfer of technology per se, but to support a process of innovation that creates value – most often economic value, but also social value – through the successful application of technology to productive activities or social endeavours. That is the reason why this report focuses not only on the effectiveness of various channels of transfer of technology but also on the policies that developing countries may implement to ensure that technology transfer contributes to more effective innovation in their economies.

Policymakers need to recognize that there is a virtuous circle whereby successful technology transfer and the resulting innovation leads to improved technological absorptive capacities, and hence more effective further transfer of technology. National or regional innovation systems are an important component in energizing this circle. Building national systems of innovation that enable both domestic innovative capabilities and absorptive capacity to effectively acquire technology from abroad is a long-term, complex effort that calls for policy persistence, coordination and integration. It also requires an appropriate international trade and investment environment, financial support and strong knowledge and technology links.

Acknowledgements

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Feedback on earlier drafts of the report was provided by Pedro Mendi (Navarra Center for International Development), Pedro Roffe (ICTSD), Bineswaree Bolaky (UNCTAD/ALDC), Ermias Biadgleng (UNCTAD/DITC), Torbjörn Fredriksson (UNCTAD/DTL), Michael Lim (UNCTAD/DTL), Jorge Niosi (University of Quebec at Montreal) and Marta Pérez Cusó (UNCTAD/DTL). Written comments were also provided by the World Intellectual Property Organization (WIPO).

The report was typeset by Dimo Calovski. Sophie Combette designed the cover.

Contents

Abbreviations

CDN	Clean Development Mechanism
FDI	foreign direct investment
FOSS	free and open-source software
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GPL	General Public Licence
GVC	global value chain
ICTSD	International Centre for Trade and Sustainable Development
IPR	intellectual property right
LDC	least developed country
NIS	national innovation system
OECD	Organisation for Economic Co-operation and Development
STI	science, technology and innovation
TNC	transnational corporations
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
VC	venture capital
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Chapter 1.
Introduction

Technological learning and innovation are essential for economic growth and development and are major determinants of long-term improvements in income and living standards. While in the more advanced economies technological progress involves the generation of new knowledge that can be applied to productive activity, for developing countries technological progress is strongly influenced by their ability to access, adapt and diffuse technological knowledge that has been generated abroad.

For this reason, the implications for trade and development of the technology gap between developed and developing countries and the question of how to promote transfer and diffusion of technology have been part of international discussions for decades.

The varied approaches to this issue that have developed over time and the rich literature that it has generated are indicators of the complexity of the issue and of the challenges that conceiving and managing the process of transfer of technology presents for both firms and policymakers.

1.1 What do we mean by transfer of technology?

The literature on transfer of technology uses a rich variety of concepts and definitions but no clear consensus exists about the nature of this process. The context in which the process takes place, as well as the concept of technology itself that is used strongly influence the definition of transfer of technology. For example, in developed countries the concept often refers to the process whereby universities or research centres provide access to technologies created there through a variety of mechanisms for interaction with market operators.

The term "transfer of technology" may also be applied to the process by which a technology developed for a specific use or sector becomes applicable in a different productive setting. Transfer of technology may refer to a process that takes place within or across national boundaries, and on a commercial or non-commercial (concessionary) basis. It may refer to the physical movement of assets or to immaterial elements such as know-how and technical information, or most often to both material and immaterial elements. Transfer of technology may be linked to the movement of physical persons or more specifically to the movement of a specific set of capabilities.

The Draft International Code of Conduct on the Transfer of Technology that was negotiated under UNCTAD auspices between 1978 and 1985 defined technology as the systematic knowledge for the application of a process that results in the manufacture of a product or the delivery of a service. Technology is not a finished product or service as such, although it can be critical for its delivery or performance. Technology does include the entrepreneurial expertise and professional know-how to deliver products and services (UNCTAD, 1985). Similarly, Burgelman et al. (2008) propose that "[t]echnology refers to the theoretical and practical knowledge, skills, and artefacts that can be used to develop products and services as well as their production and delivery systems. Technology can be embodied in people, materials, cognitive and physical processes, plant, equipment and tools."

On the basis of the above definition of technology, the Code defined transfer of technology as "the transfer of systematic knowledge for the manufacture of a product, for the application of a process or for the rendering of a service and does not extend to the mere sale or lease of goods". From this, five categories of transactions could represent transfer of technology as follows:

- The assignment, sale and licensing of all forms of industrial property, except for trade marks, service marks and trade names when they are not part of technology transfer transactions;
- The provision of know-how and technical expertise in the form of feasibility studies, plans, diagrams, models, instructions, guides, formulae, basic or detailed engineering designs, specifications and equipment for training, services involving technical advisory and managerial personnel, and personnel training;
- The provision of technological knowledge necessary for the installation, operation and functioning of plant and equipment, and turnkey projects;
- The provision of technological knowledge necessary to acquire, install and use machinery, equipment, intermediate goods and/or raw materials which have been acquired by purchase, lease or other means;
- The provision of technological contents of industrial and technical cooperation arrangements (UNCTAD, 1985).

Although narrow (for example, this list does not include transactions in the context of non-commercial operations such as intergovernmental technical cooperation), this definition of transfer of technology has the advantages of being comprehensive and precise. However, the negotiations on the Code never came to fruition and an internationally agreed definition of what constitutes transfer of technology does not exist. This has implications for the interpretation of a number of international instruments that call on developed countries to engage in, promote or facilitate transfer of technology.

In this context, broader notions about the kind of activity that constitutes transfer of technology have emerged since the abandonment of the work on the Code. These tend to take a broader view of transfer of technology, as a process that includes the facilitation of the diffusion of technological knowledge among users in developing countries and pay much attention to general issues related to the development of technological capabilities. Thus, for example the Intergovernmental Panel on Climate Change defines transfer of technology as “the broad set of processes covering the exchange of knowledge, money and goods amongst different stakeholders that lead lo the spreading of technology for adapting to or mitigating climate change. In an attempt to use the broadest and most inclusive concept possible, the Report uses the word ‘transfer’ to encompass both diffusion of technologies and cooperation across and within countries.”[1] From this perspective, the availability in the economy of the abilities to adapt and master foreign technology become as important, if not more, for successful transfer of technology than the formal design of the specific transaction on which the Code focused. This broader concept of technology transfer will be the one that underpins the analysis in this report.

A distinction between the notions of “transfer” and “diffusion” of technology may be necessary in this context. In general, the literature on technology diffusion tends to apply that term to the progressive adoption of a particular kind of technology among a given population and give to this concept a more passive connotation. Transfer of technology tends to refer to a more proactive process in which users seek to acquire the knowledge to effectively use a technology and to master its material and immaterial elements. There is an element of purposefulness in transfer of technology that may not be present in diffusion processes. Transfer of technology also involves the agreement of at least two parties whereas diffusion is not a bilateral transaction.

In spite of all these conceptual difficulties, the understanding of technology and the relationship between technology, innovation and development, and policymaking, has improved in the past two decades (ICTSD, 2012). Discussions on technology transfer have become a recurring issue in a variety of international forums, such as the Earth Summit of 1992 in Rio de Janeiro, and in the United Nations Framework Convention on Climate

Change (UNFCCC). The deliberations at the World Trade Organization (WTO), WIPO and the Commission on Intellectual Property, Innovation and Public Health (CIPIH) of the World Health Organization (WHO) have addressed the acquisition, use and learning from technologies that span from the public domain to the current scientific frontiers.

Following through the early 1990s, the growing importance of intellectual property and efforts by developed countries to protect the strategic interests of their rights holders and knowledge industries had made intellectual property rights (IPRs) a key component in the General Agreement on Tariffs and Trade (GATT) negotiations and the WTO agreements. This resulted in the adoption of the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS Agreement) in 1994 and was a strong indication that IPRs were now the key element of trade and technology relations in a globalized world. Its proponents argued that the TRIPS Agreement would lead to increased levels of investment, technology transfer, and innovation, globally and in developing countries as well.

1.2 Context of the discussion

From early days, the international discourse has failed to develop a constructive and positive response addressing country-level and development-relevant technology transfer needs. This reality still holds true today. As a result, and despite the broad international consensus on the importance of technological change for development, the technological divide has been widening internationally, regionally and within national boundaries, with the technological marginalization of the poor.

The technology gap among developing countries is increasing, with several developing countries spearheading change (UNCTAD, 2012a; Ocampo and Vos, 2009) while many others experience technological poverty.

The lack, UNCTAD has maintained, of a systematic approach in fostering STI for development and the resulting lack of local technological capacities, infrastructure, institutions and finance, prevent developing countries from absorbing technology and achieving sustainable development paths (United Nations, 1990; UNCTAD, 2003a, 2003b, 2003c and 2004). Furthermore, the fundamental issue of financing technology transfer has grown more acute during the last twenty years, given the strengthening of intellectual property rights regimes, the full-blown commercialization of research and development activities and the ever-deepening linkages between industry and academic institutions.

As this report will show, while the term “transfer” suggests a unique direction of movement, successful technology transfer in practice is often a collaborative and complex process whereby knowledge and information move in many directions and human capacities evolve and develop to ensure the completion of the transfer. Technology transfer often requires an adaptation of the technology to the conditions and circumstance in the transfer destination to improve its effectiveness and impact potential, commercial or otherwise. Technology transfer rarely happens without financial support. It may take the shape of finance available to risk-takers and entrepreneurs or as incentives provided by Governments to improve access to technology in sectors such as health, education and public infrastructure.

At the most basic level, technology transfer occurs when there are sufficient incentives to commercialize a given technology in a new location through trading products, licensing or investing. However, incentives can vary widely: technology is transferred when it makes commercial and financial sense or when it satisfies institutional interests and requirements, including strategic national interests and social and economic development policy, as well as regulatory and legal requirements.

Technology transfer depends on many factors including the geographical position of origin and destination markets, market size and competitiveness, commercial prospects, the level of development of human capacities and skills, governance, and infrastructure. Several of these factors are mandates of policymakers and are elements of a national development strategy.

There are no sure-fire singular policy prescriptions that can work to ensure increasing technology transfer to developing countries in order to fill their technology gap. There is, however, some evidence that some environments and practices are more conducive to technology transfer, resulting in the creation of economic value through innovation. Identifying some of these is the main purpose of this report.

1.3 Outline of the report

This report reviews some basic concepts underlying technology and knowledge transfer theory and practice and presents some concerns that may inform the policy choices of developing and developed countries in this field.

Chapter 2 describes the knowledge and technology gaps that exist between developed and developing countries, and analyses the dimensions that determine technological capabilities with the intention of providing a clear contour of the target areas for transfer of technology policies. Chapter 3 studies the various channels of technology and knowledge transfer and discusses their relative performance and the opportunities and challenges they present for policymakers.

Chapter 4 looks into the importance of building effective innovation systems and absorptive capacities in order to enable transfer of technology and innovation through the various available channels. Chapter 5 covers the issue of the relationship between national and international property rights frameworks and the effectiveness of transfer of technology efforts.

Chapter 6 describes the scope of technology and knowledge transfer needs from the development perspective in a number of key sectors and applications of technology. Chapter 7 presents a discussion of the process of economic discovery that leads from technology transfer to innovation and how properly understanding and supporting this process is vital for positive development outcomes. Finally, Chapter 8 develops a number of conclusions.

Chapter 2.
Technology and knowledge gaps

Technological progress and innovation have long been recognized as fundamental drivers of economic growth and development and have often been identified as key determinants of international differences in per capita income (see, for example, Parente and Prescott, 1994). In this sense, explicit or implicit policies to promote technological upgrading have always been a major concern of economic policy. However, over the last few decades, accelerated technological change combined with the competitive pressures of globalization have added to the relevance of technology and innovation for competitive strategies at the level of the firm and for development policy at the level of the economy.

2.1 Development and technological convergence

The convergence with advanced industrial economies in terms of income per capita, economic diversification and human development experienced by a number of developing countries in South and East Asia has been linked to their investment in human capital development and technology (Nelson and Pack, 1999; Yusuf and Nabeshima, 2007; Fofack, 2008). The narrowing technology and innovation gap between, first, Japan, then the Republic of Korea, and more recently China, India and South-East Asia, and developed market economy countries, manifests itself as a reduction in the overall development divide (Mathews and Hu, 2007; Lucas, 2007).

Conversely, a common characteristic of least developed countries (LDCs) and their economies is the weakness of their technological and innovation capabilities.[2] Many LDCs have seen an absolute deterioration of their scientific and research and development structures, often directly linked to political disruptions, civil strife and the consequential weakening public spending, arising from fiscal deficits and conditionalities of structural adjustment programmes (Teferra and Altbach, 2003). The ensuing generalized deterioration of STI activities have become a major constraint for growth and economic development, leading many countries to lower positions on the technology ladder and towards an increasingly marginalized position in the global economy.

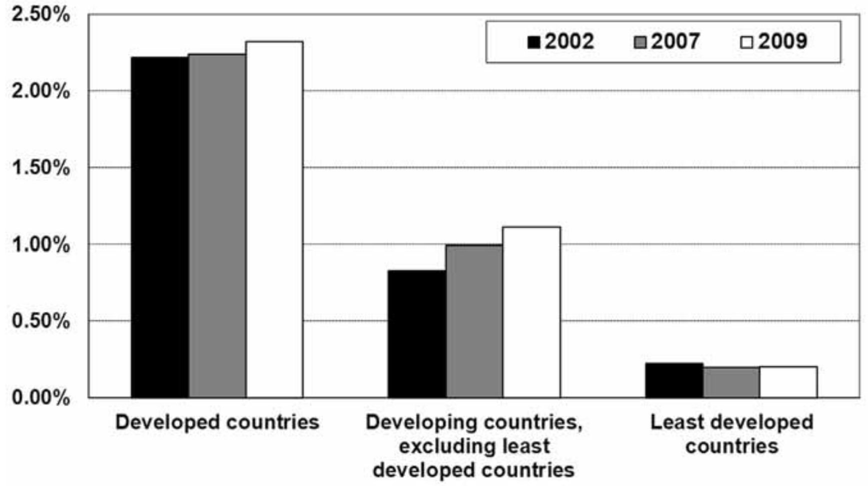
For most developing countries, whose economies operate far from the technological frontier, this greater focus on STI policy translates into a renewed interest in the question of transfer of technology. In order to develop a favourable environment where incentives encourage transactions that transfer technology, many developing countries have enacted national policies and supported international and multilateral agreements and deliberations aimed at stimulating technology transfer. Yet technological convergence remains elusive and only a few developing countries have succeeded in building strong STI capabilities. A brief presentation of the main dimensions of the technology gaps that separate developed and developing countries can facilitate the discussion of the possible means to promote transfer of technology.

2.2 Technology and knowledge gaps

Major aspects of the technology and knowledge deficits in many developing countries are easily discerned by observing such indicators as the share of gross domestic product (GDP) devoted to scientific and technological research (figure 1) or the low share of manufacturing and technology products in exports (figure 2).

However, a more comprehensive and actionable perspective can be gained by making an assessment of the development of absorptive capacities for technology and the functioning of

Figure 1. Expenditure on research and development as a percentage of GDP (2002, 2007 and 2009)

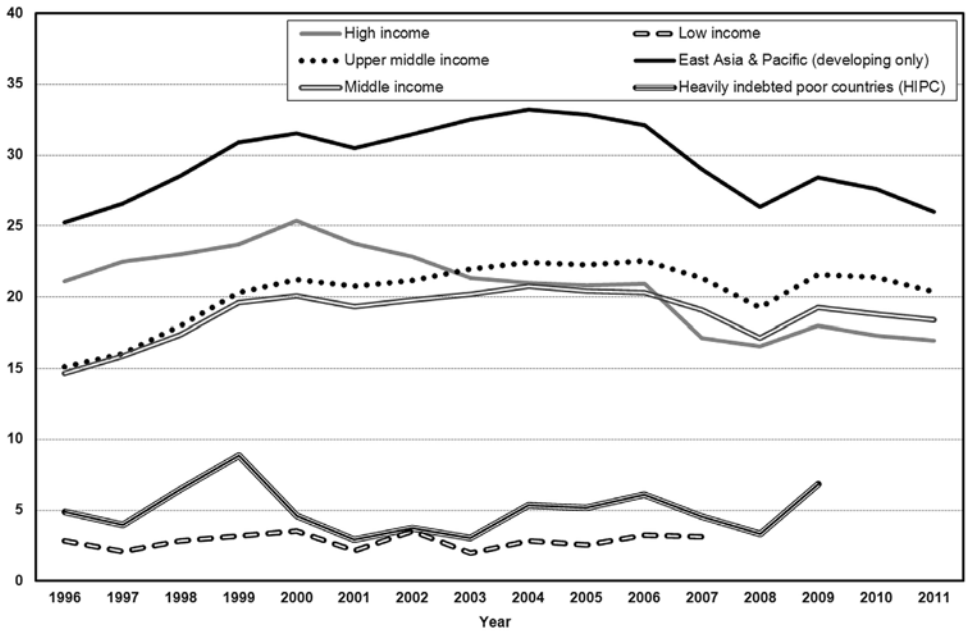


Source: UNESCO.

the national innovation system. For this, technology and knowledge stocks and flows, as well as the supporting institutional and policy frameworks, must be brought into the picture.

Technology gaps, or distance to the frontier, can be defined as the differences in technological or knowledge advancements between firms or countries. In the context of this report, the gap represents the differences in technological and innovation capabilities between developed and developing nations. The identification and measurement of the gap can be a good starting point for informed policy action. In this regard, the objective of this section is not to provide country rankings, but to present an overall picture of the unevenness of the international distribution of technological and innovation

Figure 2. High technology exports (percentage of manufactured exports)



Source: World Bank, based on United Nations Comtrade (accessed 13 January 2013).

capabilities. This graphical depiction of the gap will help to assess the magnitude of the challenge ahead for LDCs in terms of technological capabilities. It may also give some pointers to the areas where action can bring about more results in terms of enhanced transfer of technology.

Measuring technological capabilities

Measuring the technological or innovative capabilities of a country is not an easy task. The ability to innovate depends on a wide variety of interrelated economic, social and institutional factors, and some of these factors or their interrelations may be difficult to measure (Smith, 2005). A variable may be a good indicator for a specific part or parts of the system, but not necessarily a reflection of its overall performance. Despite the potential difficulties associated with the measurement of innovation, important efforts have been undertaken by scholars and international organizations to identify and quantify key dimensions of processes and outputs in the system. Institutions such as the European Commission, the Organization for Economic Cooperation and Development (OECD), UNCTAD, the United Nations Industrial Development Organization (UNIDO), the United Nations Development Programme (UNDP), the World Economic Forum and the World Bank have constructed composite indicators to summarize the overall technological capabilities of a country, allowing also for cross-country comparisons.

Although the above mentioned indicators generally attempt to measure the same phenomenon, there are differences between them. The differences stem mainly from the fact that technological capability reflects a heterogeneous phenomenon that is composed by several elements and which may be interpreted differently by different institutions. In this context, indicators may differ in three main ways. First, the number of variables used to construct an index is varies considerably. For instance, the Global Innovation Index (Cornell University/INSEAD/WIPO) uses 84 indicators, the Summary Innovation Index (European Commission) includes 25 indicators, and the Innovation Capability Index (UNCTAD) uses only 6 indicators. Second, there are differences in the choice of variables of a specific indicator. For example, human capital is commonly assessed through variables such as literacy rate, average years of schooling and secondary school enrolment ratio, tertiary enrolment ratio, or percentage of research and development personnel in the population. However, different institutions will chose different variables, on their own or combined, to assess the human capital base in their country. Third, there are different aggregation methods to construct the synthetic index. Some indices, such as the Technology Achievement Index (UNDP) or the Knowledge Economy Index (World Bank) use simple arithmetic averages of the normalized variables. In contrast others, such as the Global Innovation Index (Cornell University/INSEAD/WIPO), the Global Summary Innovation Index (European Commission), the Innovation Capability Index (UNCTAD) or the Global Competitiveness Index (World Economic Forum) use weighted averages to construct their indices.[3]

Besides methodological issues, it is important to note that the indices also differ in terms of the countries and the years covered. An important reason is the availability of reliable data. This factor can determine to a large extent the variables used, and the countries and the time periods covered by the analysis. As the Global Innovation Index also points out, a lot of innovation is happening at the local and regional level, and this is not always appropriately measured in aggregate statistics on the country level.[4] Finally, in many developing countries innovation is probably happening in the informal sector without being captured by any official statistics.[5]

Despite the differences between these indicators and the variables used to construct them, there are also similarities. All of them tend to measure in different ways the same factors, for example, human capital, infrastructure, public or private research and development expenditure, and innovation outputs (patents or publications).

In fact, the country rankings generated by these indicators present very high correlation

Table 1. Innovative capability and absorptive capacity: indicators, definition and variables

Indicator	Definition	Variables
Innovative capability		
Innovative input	Total efforts and investments carried by each country for research and development and innovative activities	Total research and development expenditures as a percentage of GDP Public research and development expenditures as a percentage of GDP
Scientific output	It denotes the result of research and innovation activities carried out by the public S&T system (e.g. scientific and technical publications)	Number of scientific and technical journal articles per million people
Technological output	Total output of technological and innovative activities carried out by private firms (e.g. patents, new products)	Number of patents registered at the United States Patent and Trademark Office per million people
Absorptive capacity		
International trade	This represents the openness of the national system – the more open the system, the more capable to imitate foreign advanced knowledge	Openness: (export+import)/GDP Export of high-tech products as a percentage of GDP
Human capital	This is the key absorptive capacity variable typically emphasized by technology-gap models	Tertiary education: Tertiary enrolment ratio; Secondary education: Secondary enrolment ratio
Infrastructures	A greater level and quality of infrastructures (e.g. network, transportation, distribution) increases the country's capability to absorb, adopt and implement foreign advanced technologies	Electricity: Number of kilowatts of electricity consumed per hour per capita Telephony: Number of fixed and mobile phone subscribers per 1,000 inhabitants
Quality of institutions and governance systems	A better and more efficient governance system tends to increase the country's commitment to technological upgrading as well as its imitation capability	Corruption Perception Index (Transparency International)
Social cohesion and economic inequality	A national system with a greater level of social cohesion and within-country income equality is in general characterized by a higher degree of trust and knowledge-sharing, hence supporting the pace of diffusion and adoption of advanced knowledge within the country	Gini Index

Source: UNCTAD based on Castellacci and Natera (2013).

coefficients (Archibugi et al., 2009). This points out a certain convergence in terms of (i) the key measurable factors that influence technological capabilities, and (ii) the methodologies used to measure and aggregate those variables.

Depicting the technology gap in terms of an aggregate indicator that attempts to capture the overall technological capabilities of countries could provide a convenient simplification. However, this could hide important developments in some of the key parts of the innovation system. For this reason this chapter follows the approach of Castellacci (2011) and Castellacci and Natera (2013), who analyse the technological gap and the evolution of national innovation systems in terms of two main dimensions: innovative capabilities and absorptive capacities. These dimensions also cover the main factors incorporated in the construction of the synthetic indices mentioned above. Thus, this approach allows us to obtain a picture of the technological gap that is consistent with other measurements and at the same time keeping a systemic approach in the analysis. The following section presents the methodology and the graphical depiction of the technology gap.

Table 2. Countries in the sample and economic grouping

Developed countries	
	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland, United States of America
Developing countries	
Asia	Cambodia, China, India, Indonesia, Iran (Islamic Republic of), Jordan, Malaysia, Mongolia, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Viet Nam
Latin America	Argentina, Bolivia (Plurinational State of), Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay.
Africa	Algeria, Botswana, Burkina Faso, Ethiopia, Lesotho, Madagascar, Mauritius, Morocco, Mozambique, Senegal, South Africa, Tunisia, Uganda, Zambia
Transition economies	
	Armenia, Azerbaijan, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Tajikistan, Ukraine

Source: UNCTAD.

Methodology and the graphical description of the gap

Technology-gap models argue that two dimensions determine the ability of a country to catch-up: (i) absorptive capacities, that is, the ability of a country to imitate foreign advanced technologies, and (ii) innovative capabilities, that is, the extent to which the country is able to produce new advanced knowledge (Castellacci and Natera, 2013). Each dimension is composed of a set of indicators, which are also recurrent in many of the synthetic indicators produced by other authors. These factors, as well as the variables that measure them, are described in table 1.

Our analysis of the gap makes use of the CANA database [6] to construct a measure of the technology gap at two different points in time, 1980 and 2008. We map the gap in terms of two dimensions (absorptive capacities and innovative capabilities) and six indicators: innovative input, scientific output, technology output, international trade and human capital. It is important to mention that in the analysis conducted here we do not include social cohesion or quality of institutions, since the policies needed to improve these factors are outside the scope of this report. The analysis considers a sample of 86 countries – those for which complete information was available for all the variables mentioned. Table 2 presents the list of countries included in the sample as well as their corresponding economic grouping.

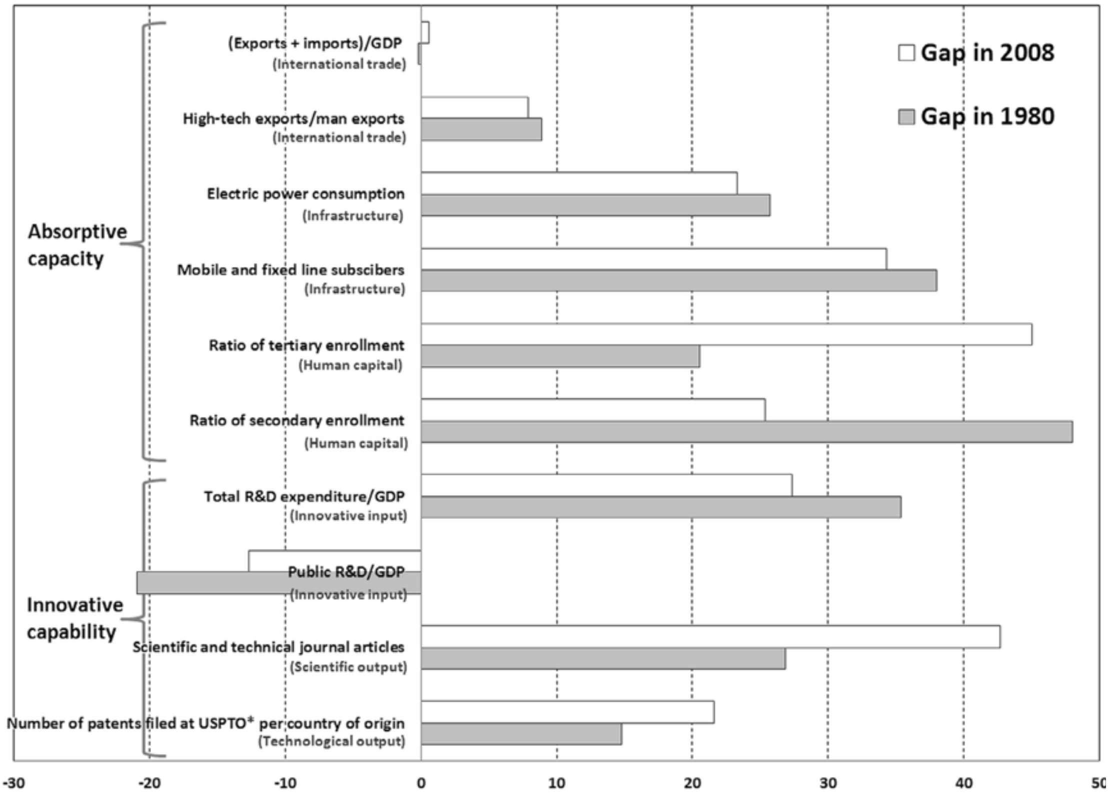
Figure 3 presents the technology gap between developed and developing countries at two different points in time, 1980 and 2008. The technology gaps presented in the figure are calculated as the differences in the average value of the variables mentioned between developed countries and other country groupings. In other words each bar in the figure is computed as follows:

$$Gap_i = AVC_i - AVDC_i$$

Where, Gap_i is the gap for variable *i*, AVC_i is the average value of variable *i* in developed countries, and $AVDC_i$ is the average value of variable *i* for developing countries. For the sake of simplicity and graphical representation variables have been normalized to a scale from 0 to 100, for each year analysed.[7]

As observed in the figure, in terms of innovative capability, the gap has increased notoriously during the years analysed, particularly in scientific and technological output. On the other hand the gap in terms of innovative input seems to have partly decreased. The average difference

Figure 3. The technology gap: Developed versus developing countries (1980 and 2008)



Source: UNCTAD. * United States Patent and Trademark Office

in total research and development expenditure (as a percentage of GDP) between developed and developing economies has decreased as a result of two factors: an average decrease in research and development expenditure in the developed world and an average increase in developing countries' expenditure.

In the case of public research and development expenditure, the gap is expressed by negative figures. This is the consequence of a marked feature of the innovation systems of developing countries where, in contrast to developed ones, there is little private-sector expenditure in science and technology and the public sector supports a much larger share of these activities (technological centres, universities and research and development institutes) (UNCTAD, 2010).

In terms of absorptive capacities the gap has decreased slightly in terms of infrastructure while the results are mixed in terms of human capital. Whereas the gap in terms of secondary enrolment has decreased, the gap related to tertiary education has increased. Although tertiary education enrolment has augmented in developing countries, it has done so faster in developed ones, which explains the increase in the gap. In terms of international trade, which aims to measure the degree of openness, the gap is rather small, in comparison to other indicators.

This gap analysis shows that while some conditions for catching up have improved, especially in terms of absorptive capacity, the gap has widened in some of the indicators related to innovative capability. This picture is consistent with the findings of Castellacci (2011)[8] who finds that the variables associated with human capital and infrastructure have experienced a process of convergence, while the opposite is true for variables associated with innovation capabilities.

There is another factor which has become crucial in the acquisition and diffusion of knowledge and thus has important implications for overall development – Internet. Its presence or absence has given rise to the so-called digital divide. As in many technologies, the divide is not only produced by the access, but by the quality of such access and by the ability of users to profit from it. Given the importance of this issue the digital divide is analysed in the following section.

Narrowing down the technology gap is a necessary condition to accelerate convergence in terms of income and productivity levels and thus foster development. This section has shown that the gap remains considerable in many key variables of the national innovation system; policies are needed to reduce this gap. That is the matter of the discussion in chapter 4.

2.3 Technology gaps and poverty

A combination of inadequate incentive structures and institutional and policy weaknesses has led to technology being inaccessible to billions of people. The important contribution of scientific progress, embedded in technology and innovation, to the achievement of development goals is indisputable. The most notable effects are related to poverty eradication through improving primary education, achieving gender equality and the empowerment of women, and making progress on key health issues, in particular on improving infant and maternal health. Given that many of the world's poor live in or near to vulnerable natural environments, dealing with climate change and sustainable development issues and technologies is unavoidable.[9]

While the knowledge needed to address these needs is scientific and technological, the trigger rests squarely in the policy domain. Technology policies need to be in context with the actual conditions of poverty and the particular social, economic and educational problems and constructs that it creates. Technology needs to be seen as an enabler, rather than an applied solution that is brought in when needed. This is difficult to realize given the fact that many people living in poverty are often more exposed to crisis situations generated by natural or man-made disasters. For the countries that face the most pressing poverty problems, STI challenges seem to be becoming increasingly difficult. While some

Figure 4. Expenditure on research and development as a percentage of GDP

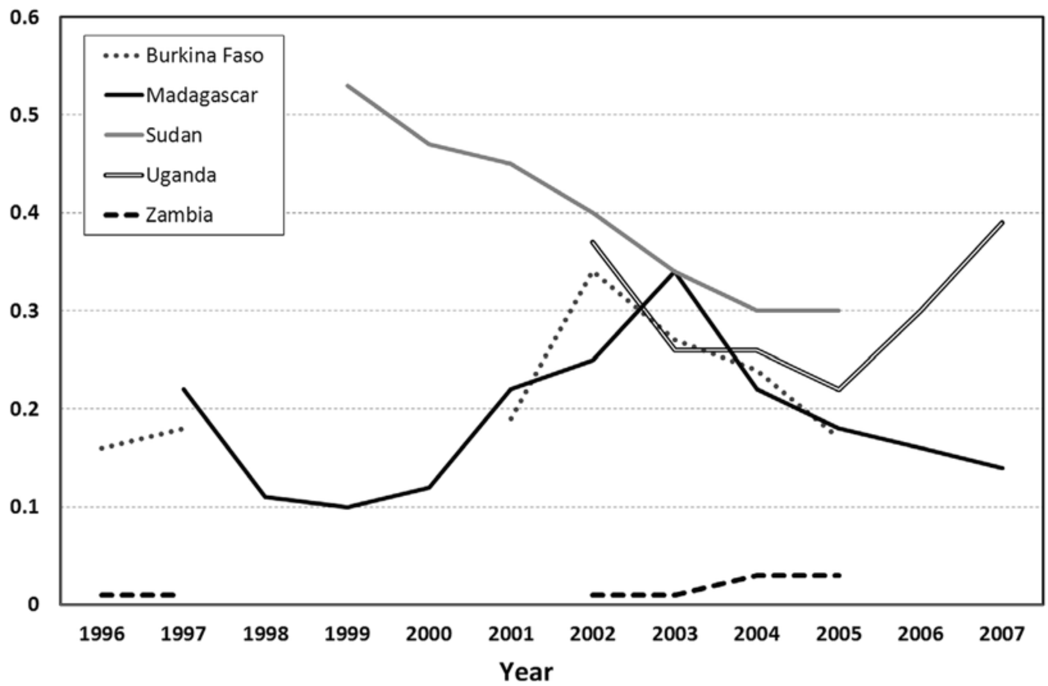


Table 3. Patents and GDP: Global share by income group

Patent applications

Country	High income	Upper-middle income	Lower-middle income	Low income	World
Percentage in 2001	85.8	11.7	2.3	0.1	100
Percentage in 2011	67	29.8	3.2	0	100

GDP

Country	High income	Upper-middle income	Lower-middle income	Low income	World
Percentage in 2001	64.8	24.8	9.5	0.9	100
Percentage in 2011	54.6	32.2	12.1	1.2	100

Source: WIPO Statistics Database and World Bank, October 2012.

data is available describing conditions for technology transfer and absorption in poor countries, it is typically scarce and compiled with very erratic time, while what is available addresses STI inputs rather than results or outcomes of public and private activities.

In order to give a modest and admittedly imperfect insight into the state of affairs, the following table and figures present data from six LDCs for which there was what could be considered a minimum continuity in the data series. The data has been obtained from the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute of Statistics Data Centre Database.

The chosen indicators show that there has been no distinguishable improvement in the technology transfer or absorptive capacity of the observed countries over the last decade. More specifically, figure 4 shows that expenditure on research and development as a share of GDP has either decreased or grown very little, and

Figure 5. Expenditure on research and development per capita (purchasing power parity $)

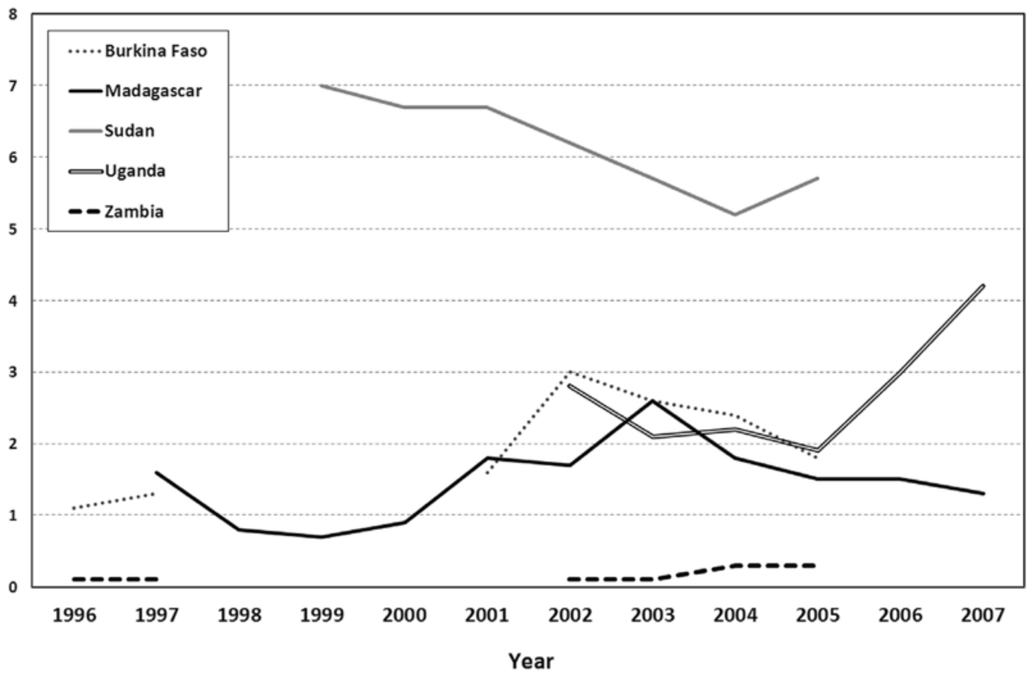
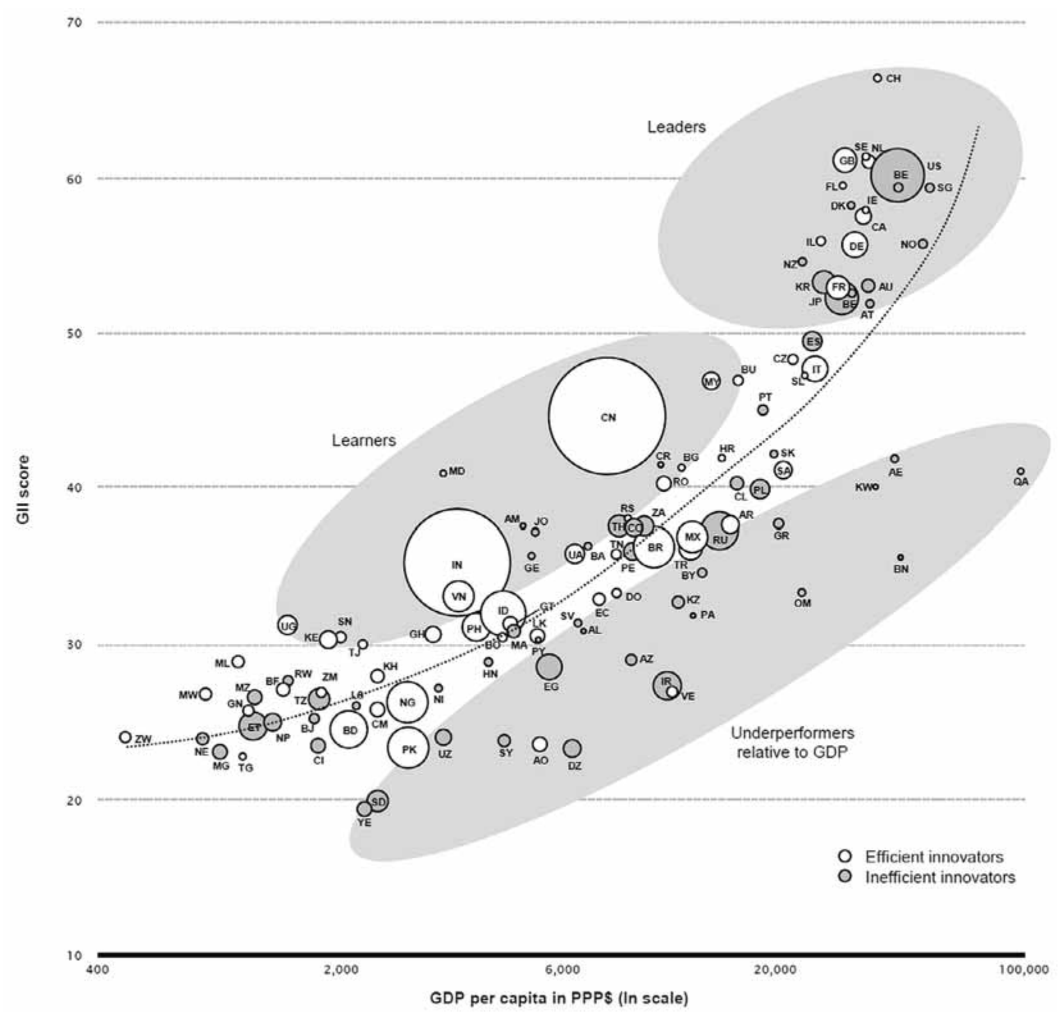


Figure 6. Innovation and GDP per capita – Global Innovation Index 2013



Source: Cornell University, INSEAD and WIPO (2013).

from a low base, indicating that STI remains an unaddressed issue both from the point of view of public-sector decisions as well as private-sector choice.

Figure 5 illustrates that the amount of resources assigned to research and development have remained very limited and there are no clearly distinguishable trends, except that expenditures have been at levels insufficient to generate any critical mass required for innovation-led development. Absolute and relative numbers of researchers in LDCs have not seen significant improvements during the last decade and the basic human capacities needed for technology absorption and STI-led development remain sparse.

Focusing on more concrete science and technology outputs, it is also fair to say that the share of low-income countries in global patenting is small both in absolute terms and as compared to their share in global GDP (table 3).[10] Taking a more holistic view of how to measure innovation, one also sees that five out of the six mentioned LDCs rank towards the bottom of the Global Innovation Index (figure 6).

The message is more mixed here however. Madagascar and the Sudan underperform relative to their GDP, while Burkina Faso and Uganda overperform relative to their GDP. In fact, Uganda is in the “learners group” of the Index. Zambia, in turn, barely performs above the mean.

The picture that emerges from the above data is that in spite of a general consensus affirming the role of technology as a fundamental component for enhancing the growth prospects overcoming the economic marginalization of people living in poverty, the technology gap between developed and developing and between advanced developing countries and LDCs continues to widen. The following chapter will explore the role of the various channels of knowledge and technology transfer in this process and their potential to contribute to reversing it.

Chapter 3.
Channels of technology and knowledge transfer

Economic interaction between countries occurs through trade, financial flows, including foreign direct investment (FDI), and the movement of workers, managers, professionals and academics. Such interaction affects the global allocation of resources and serves as a conduit for the transfer of technology. The role and impact of trade and FDI on technology transfer may not be easy to separate. Indeed, these channels of technology transfer, though independent to some degree, can be related: the impact of FDI on technology transfer can be linked to trade openness and to some extent to the business links created through the movement of people. It follows that technology transfer is often analysed by considering trade, FDI and, to a lesser extent, migration, as channels of access. Therefore, national and international policies reflecting on trade, licensing, movement of people and foreign investment are seen as having a primary effect on technology transfer.

3.1 Trade

International trade influences the global allocation of resources and shapes the development of national sectors and industries. It therefore plays an important role in determining global knowledge and technology transfers. This notion is based on two assumptions. The first is that as goods are traded, the technology embodied in them is transferred too. In particular, the import of capital goods is often associated with development. However, a very significant part of the knowledge embodied in capital goods or necessary for their productive use is tacit knowledge, which is not easily transferable, or not at all.

The second notion is that an important determinant in technology transfer is the cost of access. The case for trade liberalization argues that reducing legal, regulatory and political barriers to trade, and in particular for goods that have a high technology component, would reduce the cost of technology transfer. From this perspective, restrictive trade practices make it inherently costlier for local firms to adopt technologies, while open trade may affect economic growth by lowering the barriers to technology adoption.

However, trade in itself is not a neutral conduit of technology transfer. Technological innovation requires upfront investment and risk-taking and innovative firms do so knowingly that intellectual property regulation will assist them in appropriating – at least partly – the returns on their innovation.[11] Such firms seek to control the spread of their innovations in terms of rate and geographical reach. Therefore, technology transfer through goods imports will, even in a completely open trade environment, risk being below levels optimal for local economic development. This opens possibilities for active policy.

Given the obvious implications of trade for technology transfer for development, the issue was addressed in the WTO’s TRIPs Agreement. From a development perspective, TRIPS article 66.2 states that developed countries need to help in “promoting and encouraging technology transfer to least developed country members in order to enable them to create a sound and viable technological base”. The fundamental message of WTO is that increased trade openness can increase growth by lowering the barriers of technology transfer. Nevertheless, there have been questions over the effectiveness of article 66.2 as a number of analysis have found either that its impact has been modest or that its reporting system is insufficient to monitor implementation and therefore to provide evidence-based feedback to policymakers (Correa, 2007; ITCSD, 2011; Moon, 2008; WTO, 2010a; WTO, 2010b).

Schiff et al. (2002) find that, in the context of North–South trade, openness to trade has a greater impact on total factor productivity in technology-importing developing countries than investment in research and development. This perspective assumes that the majority of technology transfers in a country actually occur through importing capital- or technology-intensive goods. Furthermore, trade openness needs to be matched with policies that improve a country's capacity to identify and absorb technology. The human capacity to adapt and put to use imported technology needs to be developed locally. Therefore, the policy recommendation on the question of whether to import versus develop technology is not clear cut: countries can more effectively use imported technologies if they have local STI activities in the private sector and academia generating the necessary human capital.

While most economic literature argues that countries with closed trade policies do not fully benefit from technology transfer by importing technology imbedded in goods and services, this is a moot point, as relatively few countries actually pursue non-liberal trade as a matter of policy. However, openness to trade works the other way as well. Developing countries that succeed in developing an exporting sector are incentivized to continuously improve their productive and soft technologies and stimulate innovation to meet international standards and remain or improve their competitiveness in global markets.

3.2 Licensing

Licensing represents an important mode of international technology transfer. However, it can present serious difficulties when there are large differences between the potential partners in the transaction regarding their access to information and knowledge and, therefore, in their negotiating power. From the perspective of the licensee, the decision to obtain a licence will involve exercising a judgement on the growth potential and size of the market for the product, and the licensee's confidence in the human capital and services infrastructure that will allow the necessary adaptation to the licensed product or production technologies and bring it to market. The main concerns of the licensor will be achieving a royalty that will be sufficient incentive to take the risk of potential problems, such as repatriating the said royalties, product leakage into unlicensed markets and reverse engineering of proprietary technologies.

In general, reliance on licensing as a mode of technology transfer is directly related to the availability of technological skills and research and development support for adaptation and learning (UNCTAD, 2007). This means that its use is linked to the overall level of technological sophistication of the economy and tends to be more prevalent in developed and some emerging economies. For this mode of transfer of technology to be fully operational, countries need to develop a functional innovation system and individual firms need to acquire adequate absorptive capacities for technology.

3.3 Foreign direct investment

Foreign direct investment can play an important role in the development process of host economies. In addition to providing capital, employment and, in some cases involving local partners in established international value chains, FDI is a vehicle of technology and knowledge transfer, including for many soft technologies, such as managerial skills, marketing, or knowledge of standards and regulations in export markets. However, the success of FDI in any developing country is subject to the receptiveness of that country, which is defined by its economic and policy capacities and capabilities.

Typically, the technology spillovers resulting from FDI materialize through demonstration effects, labour turnover and/or vertical linkages.

Demonstration effects occur when local firms acquire knowledge or technology from foreign firms through imitation or reverse engineering. Labour turnover describes technology transfer that occurs when former transnational corporation (TNC) employees are employed by local enterprises or establish their own firms, that is, through the physical movement of people in the local economy. Vertical linkages describe technology transfers that occur when local firms are engaged in the TNC value chain, as suppliers. The requirement of meeting the necessary technical specifications and quality standards means that these local firms frequently need to improve their products and services, including through adopting improved technology and enhanced practices. Vertical linkages can also be from foreign suppliers to domestic buyers (forward linkages), whereby local capacities and competencies are developed to handle a technological advance.

Whatever the transfer path, it is clear that if human capital in the host country is lacking, TNCs may not engage in hiring locally or partnering with local firms and trade prospects may suffer, causing a decrease in opportunities for knowledge and technology spillovers.

Recent UNCTAD work (UNCTAD, 2013b) looks into the role of FDI in global value chains (GVCs), including the possible contribution of GVCs to technological learning among the enterprises of developing countries. The study finds that among the various possible governance types for GVCs, in those cases where the lead firm takes direct ownership of the operations and engages in intra-firm trade, FDI impact does tend to be positive in terms of knowledge transfer, especially in developing countries, although the degree of horizontal and vertical spillovers varies by country and industry. The findings conclude that although there are real potential benefits, these are not automatic and policy must take account of several potential risks, such as the creation of a certain dependency on a narrow technological base. According to this research, policy actions to enhance linkages between international and local firms as well as inter-institutional linkages, the provision of general STI support, and an appropriate IPR framework can maximize the potential positive impact of participation in GVCs.

In the case of the LDCs, UNCTAD research (2007b) finds little evidence of a significant contribution by FDI to technological capability accumulation in LDCs in particular, in spite of market liberalization and openness to foreign investors documented through a substantial growth of FDI in the 1990s. The rather limited contribution of FDI to technology transfer in these countries seems to be due to the nature of the relationship of TNCs with the host country economy, the policy priorities of LDC Governments and the generally low absorptive capacity of those countries.

A separate aspect of FDI as a channel of technology transfer concerns the internationalization of research and development operation of TNCs. The UNCTAD *World Investment Report 2005* discusses this trend, which increases opportunities for technology transfer as well as improves the conditions for technology creation in the new environment. This may enable some host countries to strengthen their technological and innovation capabilities, but can marginalize others that fail to establish linkages to global innovation activities. The *World Investment Report 2005* suggests that the internationalization of research and development is not a new phenomenon, as international firms have always needed to adapt technologies locally to achieve commercial success in their host countries, and, in many cases, some transfer of research and development was necessary. Increasingly, TNCs are setting up research and development facilities in developing countries that go beyond adaptation for local markets. This is an important shift in innovation potential as conservative estimates suggest that TNCs account for close to half of the global research and development expenditures and at least two thirds of business research and development expenditure.

Since FDI has the potential to be an important mode of technology transfer, policymakers may provide and justify temporary measures aimed to attract it. However, while such externalities of FDI may justify public support for it, the extent of technology spillovers is not knowable in advance and therefore the amounts Governments should commit require judgement and consideration of comparable conditions and experiences in other countries.

The key issue is how to attract FDI that delivers clear development gains and this includes benefiting from technology inflows. One set of instruments that has been developed in this regard is often referred to as performance requirements (UNCTAD, 2003). These take the form of stipulations, imposed on investors, requiring them to meet certain specified goals with respect to their operations in the host country. They are and have been used by developed and developing countries to enhance various development objectives including technology transfer. For instance, Sutton (2004) describes the use of domestic content requirements in China and India in the car industry, and suggests that while such policies may not always be appropriate or successful, in the examined cases the "infant industry" had been successfully nurtured and manufacturers have not turned away from local suppliers with the liberalization of the trade regimes following WTO entry.

By contrast, in the computer hardware sector in Brazil, the domestic components industry was particularly affected by competition from Asian imports after joining WTO on 1 January 1995. In 1990, local providers supplied over 80 per cent of the inputs for Manaus Industrial Park [12] electronics firms. However, by 2000 that figure had dropped to 37 per cent, with resulting losses in jobs and productive capacities. This was in spite of the requirement that foreign investors receiving tax benefits and other FDI incentives develop production capacities and invest 5 per cent of their revenues in research and development (ECLAC, 2010).

Another policy option is the establishment of explicit requirements for technology transfer of foreign investors. Such requirements were relatively uncommon among several developing countries surveyed by UNCTAD (2003). The research found that evidence on the effectiveness of technology transfer requirements was scarce and suggested that the outcomes of such policies would be insignificant. Other studies have reached similar conclusions (Urata and Kawai, 2000; Blomström et al., 2000) while underscoring that a country's level of education and the competitive pressure faced by firms were both positively related to the amount of technology transfer through FDI. This finding reinforces the general notion that successful technology transfer is critically dependent upon local absorptive capability. In any case, certain performance requirements that may include aspects of technology transfer among their objectives have been specifically proscribed by the WTO Agreement on Trade-Related Investment Measures as they are inconsistent with articles III and XI of GATT (1994).[13]

Policymakers may choose to implement local content requirements tied to technology transfer of foreign investors, such as obliging them to use local technology suppliers and scientific staff, and cooperate with public research institutions. The question is, do such measures provide incentives for local technology stakeholders, advancing their knowledge and absorptive capacities, or do TNCs treat this issue as a tax or tariff and work to ensure minimum formal compliance, but not more. Such polices need to be based on empirical evidence generated through transparent and unbiased surveys and research and indicating that there is a positive experience of technology transfer for the technology and sector under review.

Another question relates to policies that promote joint ventures. There seems to be empirical evidence of productivity gains (presumably resulting from a combination of technological upgrading and the introduction of new managerial practices) from FDI through joint ventures (Harrison and Rodriguez-Clare, 2009). In the case of China, for example, the approach has been to obtain technology transfer through the requirement of the establishment of joint ventures or joint production in exchange for market access in a number of key industries. The impact on productivity seems to have been much larger when the joint venture involved state-owned enterprises (Harrison and Rodriguez-Clare, 2009).

3.4 Movement of people

Human capital is a fundamental determinant of a country's absorptive capacity and of its capability to benefit from technology transfer. As such, it is a key component in the workings of the transfer channels of trade, FDI and licensing (UNCTAD, 2007b).

The problem of the loss of technological capabilities through the "brain drain" phenomenon has been long recognized. As it is difficult to predict developments in technology and innovation, the production of expertise and human capacity understandably suffers a delay as reaction by educational institutions cannot be instantaneous. Therefore many developed countries and regions with strong research institutions linked to innovative industries attract scientific talent from the world over and often from developing countries. It has also been shown that skilled researchers from developing countries contribute to the stock of patents abroad.[14]

While the temporary movement of skilled persons, such as consultants, technicians or high-skilled professionals, may have a limited impact and may even increase a country's overall skill endowment, a permanent migration of educated professionals will almost certainly result in a loss in a country's stock of human capital and decrease its capacity to receive technology transfers. The negative effect may be smaller if the migrants were not employed, or offset to some extent if new business or investment linkages with a knowledge component emerge between migrants and their home economies or if there are opportunities for temporary or permanent return.

For such potential positive effects of international migration ("brain gain" or "brain circulation") to materialize firms in the home countries need to provide reasonable employment opportunities and conditions. These are more likely to emerge as the economy develops and, particularly when scientists and engineers are concerned, its technological sophistication increases. Here again, the absorptive capacity for technology and positive policy support through an effective national innovation system (NIS) are key determinants. There is no doubt that developing country experts will profit from working abroad and further developing their knowledge, skills and network. Therefore, developed countries should regard such movement as a mechanism to export knowledge and transfer technology to developing countries, in particular soft technologies related to processes in production, management, entrepreneurship, marketing and similar. An important problem is that all too often movement of people is under the sole purview of an immigration authority which may not receive policy input from a trade, development aid or technology policy authority (Sumanta et al., 2004).

Developed countries could also consider providing financial support facilitating the movement and training of researchers, technologists and entrepreneurs, in particular from LDCs, to improve technology transfer especially for technologies that are important for public services and infrastructure development such as health, sustainable energy and agriculture, or governance (UNIDO, 2008). However, a number of studies show that attracting teachers and human capital to developing countries is much more beneficial, and less costly, than sending human resources to be trained abroad (Grogger and Hanson, 2013).

Also, if students from developing countries are sent abroad for graduate studies, it is important to devise policies to build bridges between the local human capital pool and those expatriates who choose to locate themselves abroad (Agrawal et al., 2008). Successful technology transfer may also depend on the use of these expatriates who have dual cultures, and may "translate" advanced technology to developing country stakeholders.

Finally, donor agencies financing development projects should consider increasing the participation of researchers, scientists and engineers from developing countries as a matter of formal policy and explicitly stated as reporting requirements.

Chapter 4.
Innovation systems and absorptive capacities

As has been underlined in the above discussion of the various modes of technology transfer, the practical success of any such undertaking depends on the absorptive capacities that are available at the level of firms and on the existence of an enabling innovation ecosystem in which firms can operate. In this sense, technology transfer cannot replace the building of national absorptive capacity. A close interdependence exists between both processes, with absorptive capacity playing the leading role in the relationship. How effectively absorptive capacities are developed also depends on the characteristics of the innovation system, including the set of incentives with which firms and other agents are confronted. If incentives to adopt technology are present, efforts to develop absorptive capacity are more likely to be deployed by firms.

A discussion of the relationship between innovation systems and absorptive capacities and how they both contribute to improving the effectiveness of technology transfer processes follows in this section.

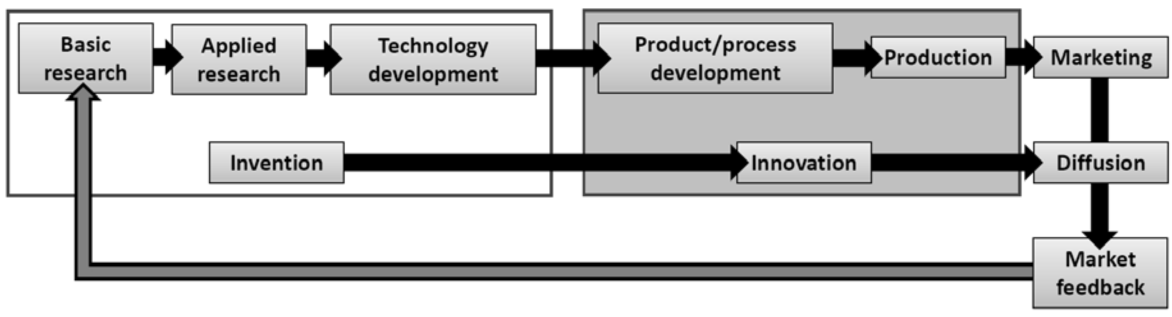
4.1 Innovation systems

Science and technology became an explicit area of policy concern in several developed countries during the first half of the twentieth century. Early on, the focus was on increasing investment in fundamental science and research and development, and maximizing impact by translating research results into products and services. The rationale for public intervention was that research in science and technology was systematically underprovisioned in a market economy, that is, it developed under conditions of market failure.[15] The typical policy response was the provision of public finance for scientific and technological research.

Until the mid-1970s, thinking on innovation processes used a linear model to describe the flow of knowledge and technology, from fundamental and applied science, to technology research and development, and finally through efforts to effectively imbed any new technology in a commercially viable product or service. The linear model established science and research and development as the basis of innovation and therefore led policymakers to focus on financing and supporting scientific activities. Such a linear approach to innovation policy is represented in figure 7.

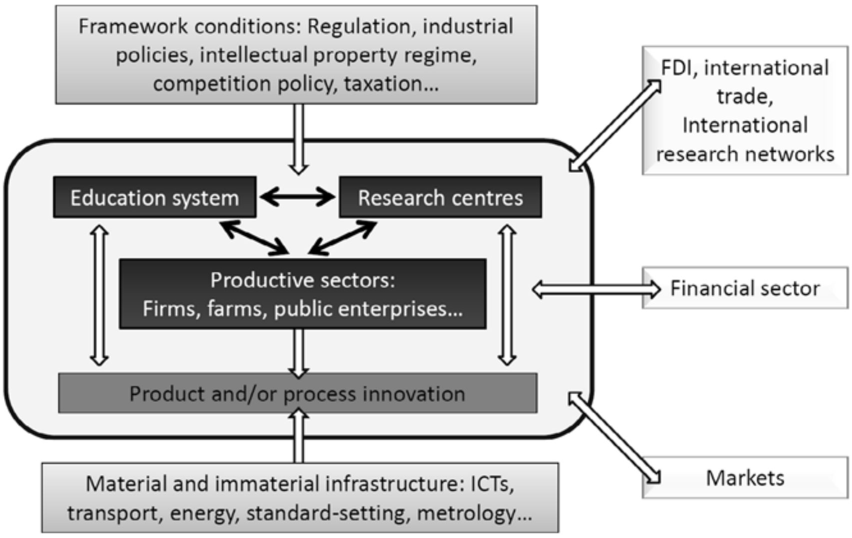
The linear model is sometimes presented as a "technology push" model, as this scenario was an acceptable depiction of a pre-information-

Figure 7. Linear innovation



Source: Schumpeter (1939), Godin (2005).

Figure 8. A schematic diagram of a national innovation system



Source: UNCTAD (2011d).

age economy in developed countries. Another, later formulation of the linear model of innovation was the "market pull" model in which feedback was introduced between market research and research and development functions in firms (Rothwel, 1994). The simplicity of the model made it useful for policymakers (Godin, 2005) in particular when funding decisions were at hand. This was helped by establishing frameworks for official statistics on research and development that followed the taxonomy of the linear model and reinforced its importance for understanding innovation and developing science policy. Statistics on research and development are still seen as a valid proxy for measuring. The chief criticism of this model holds that, in real life, feedback loops are numerous and diverse and appear at each and every stage of innovation.

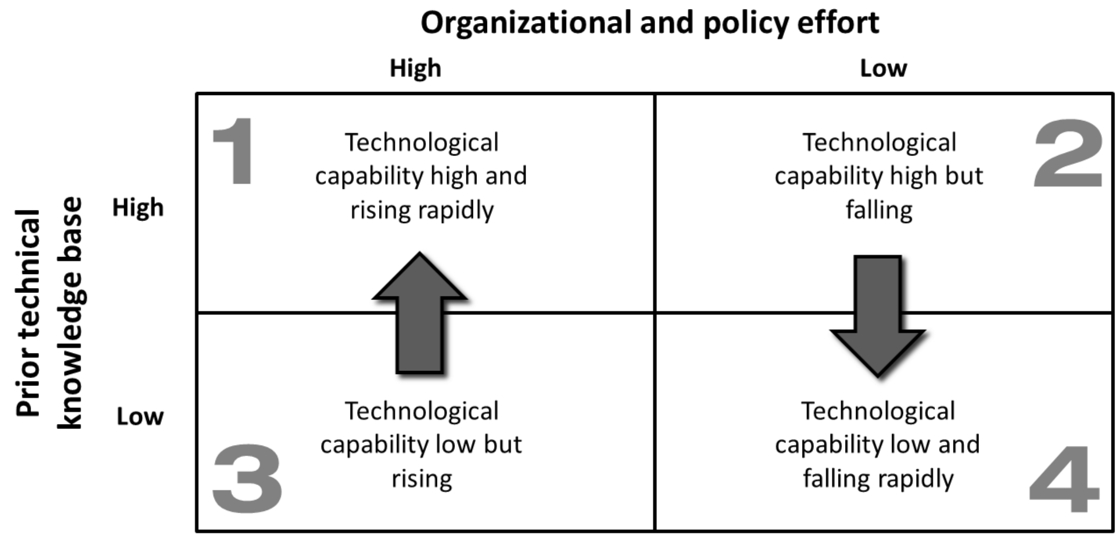
Since the 1980s, thinking – and increasingly policymaking – on STI has been strongly influenced by approaches that consider innovation as a systemic phenomenon and try to understand how it emerges, spreads across the economy and creates the conditions for continuing change in the system itself.

Figure 8 presents the fundamental elements and interactions in a typical NIS. Innovation systems theory suggests that in addition to market failures there are system failures that justify policy intervention (Niosi, 2002). In addressing the issue of insufficient innovation, policy would include a consideration of aspects such as the ability of firms to learn, the connections between the various players, infrastructures, incentives, institutions, regulations and practices that may impede innovation (Freeman, 1987; Lundvall, 1992; Nelson, 1993).

Building an innovation system that can support technology transfer involves addressing at the same time both market and systemic failures, combining action on horizontal issues such as education, training, access to finance, or knowledge dissemination with vertical ones supporting specific sectors or technologies. At the same time, they need to develop incentives to collaborative interactions between firms, universities and research centres. The need for a highly sophisticated understanding of policy interactions and for strong coordination and collaboration among ministries, agencies and other public and private actors, can represent a strain for the human and institutional resources of many developing countries.

The NIS approach underscores a key aspect of technology transfer: the importance of tacit knowledge. Tacit knowledge is informal and implied. For example, the habitual use of complex equipment can create tacit knowledge

Figure 9. Dynamics of technological capabilities



Source: ICTSD (2003).

that defies explicit codification, even by experts. Tacit knowledge cannot be appropriated simply by buying equipment or receiving a set of operation instructions. It is not easily transferable. Any technology that is transferred through trade and licensing will rely on the existence of sufficient tacit knowledge.

An innovation system is the key to capturing tacit knowledge because it is developed over time through practice and interactions in environments specific to a particular technology. The effectiveness of an NIS will, therefore, be largely defined by how it incentivizes and supports such learning interactions. The critical question is whether public policy has created a framework to improve the number and quality of interactions between institutions that generate knowledge, such as universities and research centres, with the firms and institutions, in the productive or public service sectors that aim to absorb the transferred technology.

4.2 Absorptive capacities

The crucial importance of the ability of an economy - and its entrepreneurs, firms and institutions - to recognize the potential value of new or novel knowledge and technology, and to transfer and assimilate it with the objective of bringing to market a product or a service, has been repeatedly noted in this publication. This ability is often called “absorptive capacity” and together with its innovative capabilities, it determines if and to what extent a firm, an industry or, indeed, an economy, can use existing and new knowledge to compete. As noted before, the process of technology transfer and the evolution of absorptive capacity for technology are interlinked and interdependent. Thus, enabling technology transfer involves developing absorptive capacities through, among other things, investing in a skilled workforce, guiding skills formation in strategically important sectors, and supporting the interaction between academic institutions and firms in order target and incentivize for potential skills in demand (UNCTAD, 2011).

Absorptive capacity is the outcome of historical development paths and success, or the lack off, in developing and applying STI policy. Its major determinants are the economy’s existing knowledge base and the support and incentives that policies provide to technological learning and innovation processes within firms, and to the emergence of linkages between knowledge institutions and the productive sectors. This is illustrated in figure 9, which describes the dynamic relationship between the level of the existing knowledge base and intensity of policy effort.

For policymakers, the message is clear: the policy effort is a critical element as the knowledge base can only be developed over the medium to long term and can deteriorate quickly. Developing country firms, sectors and industries, and indeed entire economies, with a proactive and intense policy effort can progress from quadrant three to quadrant one and achieve higher technological capabilities. On the other hand, weak STI policy almost ensures the loss of existing capabilities and dependency on technology and knowledge imports.

The prior technological knowledge base determines the ability to make, recognize, adapt, adopt and generate value using new or novel knowledge or technology. Establishing a knowledge base is necessarily a matter of policy and determining what level suits current development goals requires an important degree of interaction among firms and academic, training and educational institutions. Organizational and policy efforts refer to the commitment and political will of firms and institutions to internalize new or novel technologies and knowledge. This necessarily means taking decisions to provide funding and a reasonable time horizon to solve problems in identifying, adapting and absorbing technology. Provisions for experimentations, testing and iteration that enforce learning at technological as well as institutional and inter-institutional levels will be needed (ICTSD, 2003).

Prior knowledge can be understood as human capital expressed as aggregate levels of education, and industrial and labour skills. A uniform level of technical competency across industries as well as a level of general scientific knowledge, coupled with an awareness of practice in process and soft technologies such as management, logistics or finance, are important elements. The role of entrepreneurial and managerial skills should be emphasized in this regard since entrepreneurs and managers are the ones making decisions on technology adoption at the firm level.

In practice, national, sector and firm level absorptive capacity will be different, lesser or greater, than the aggregated human capital and sum of the capacities of resident individuals. As already noted, this happens because a number of institutional and organizational factors influence absorptive capacity. For example, firms or institutions will have one or more individuals or units that will act, spontaneously or on assignment, as an entry point – or gatekeepers – to new or novel knowledge and technology. The success of absorption will, in part, depend on the relationship between them and other units that function in support or as management, and that provide linkages and support (or impede) communication flows to the rest of the organization (Cohen and Levinthal, 1990). In other words, the nature of communication flows between an organization and its environment, as well as inside the organization, will determine the success of the absorption and technology transfer outcomes.

Absorptive capacity development is also linked to the incentives provided to firms to engage in technological learning. Technological opportunities for innovation do not materialize ready for immediate implementation. In practice, they may be ambiguous and unstructured and difficult to assimilate. However, incentives to invest in own research and development are diminished for most firms in developing countries because of the difficulties in containing knowledge spillovers. Large firms and institutions may have the capacity to engage in establishing and protecting their research and development using intellectual property rights. On the other hand, small firms or industries and sectors where firm size and financial and organizational capacities are insufficient to use intellectual property protection, can benefit from positive government policy to correct for this recognized market failure.

As chapter 7 will discuss in more detail, whether any innovation comes out of technology transfer is fundamentally uncertain. The commercialization of a newly acquired technology is subject to numerous factors and circumstances, many of which may evade the control or influence of the innovating firm or institution. If a firm or institution actively manages its absorptive capacity and capacity formation processes, this can reduce some of the uncertainty in predicting the commercial outcome of a transferred technology. Conversely, if a firm stops investing in its absorptive capacity, especially in an industry that is technology intensive, it may quickly loose its ability to innovate. In other words, insufficient ongoing investments in developing absorptive capacity makes technology transfer difficult even when technological opportunities are clearly identified. Underinvestment can result in a firm being “locked out” of subsequent technological developments and should become a matter of concern with respect to national policies.

Many firms and institutions will react to objective indicators such as a decrease in revenues or profitability, a drop in market share or an exodus of its most competent staff. Often, these are a result of an inability to predict, adapt and absorb technology. An often cited example, because of its utmost clarity, is the transformation of the calculator and business machine industry where electromechanically designs and products where replaced with electronic devices (Majumdar, 1982). Firms, such as Friden Inc. or Marchant Calculating Machine Co., that were unable to acquire the technology to produce a better and more affordable electronic product, eventually failed. Tushman and Anderson (1986) call this type of technological shift “competence destroying” and explain that firms with poor absorptive capacity due to insufficient prior knowledge may not be able to easily develop new competencies internally.

This is as much a management issue as one of technological learning. A more recent case is the decline of Gateway computers, which failed to recognize the potential of portable computing while exploring home electronics and entertainment markets where innovation is somewhat limited by industry standards while acquiring an overly similar competitor with no apparent technology transfer potential.[16]

By contrast, the often-cited positive cases of Apple and Google show that absorptive capacity can be, if not developed internally, bought through mergers and acquisitions.[17]

The importance for absorptive capacity development of linkages between firms and knowledge-generating institutions (universities, research laboratories) was noted above. It is sometimes suggested that for many developing countries, and in particular for LDCs, it can be a misguided effort to develop advanced research and development capacities. The rationale is that due to their limited resources, investment should focus on bringing new products or services to market by using available technologies to improve production, that is, on innovation, rather than on discovery and invention that is the primary outcome of research and development activities.

However, in practice a certain level of research and development capabilities is essential for the ability to absorb technology. Cohen and Levin (1989) suggest that, even at the level of the firm, absorptive capacity is a by-product of its research and development because the role of research and development goes beyond simply assessing the practical and commercial potential of available technology.Research and development activities are needed to leverage extra-firm and extra-industry technological knowledge, including that originating from government-funded research, local and public academic and research institutions, or knowledge that is a result of international cooperation in scientific and applied research. Research and development enables a firm or institution to develop active relationships with the research departments that are independent, public or located in other firms, in partnership and for the purpose of joint commercial ventures (Audretsch et al., 2002).

Chapter 5.
Intellectual property rights and technology and knowledge transfer

A recurring question in technology transfer is its relationship with a country's intellectual property regime and, by consequence, its effect on economic growth. The IPR environment in a technology-receiving country can be an important positive or negative incentive for technology owners seeking business opportunities. While this issue is often cited with regards to willingness of foreign technology owners to invest, the same incentive effects would also apply to local entrepreneurs.

Intellectual property rights take on a variety of forms including copyrights, patents, trademarks and trade secrets (non-disclosure).[18] Each IPR has particular economic characteristics, terms and duration of legal protection and impact on technology transfer, mainly depending on the level of development of the technology recipient. The common wisdom underpinning the current international governance of IPR is that their international harmonization is an important facilitator in achieving protection at the international level – the Paris Convention for the Protection of Industrial Property (the Paris Convention), the Patent Law Treaty and the Patent Cooperation Treaty[19] are examples of this.

On the other hand, there is also the idea that increasing the level of IPR protection, usually to the level found in developed countries, including capacities to prosecute and provide legal remedy, is needed in developing countries as well if they are to expect international transfers of technology, or likewise the development of domestic innovative firms with significant research and development capacities. However, whether there is sufficient evidence to validate the view that strong IPRs are a necessary condition for innovation and technological development is a contentious issue in the literature (see, for example, UNCTAD ,2007b, or Boldrin and Levine, 2013).

Technology transfer is the key development dimension of any international discussions and processes related to IPRs. This is visible in a more general way in the work programme of the WIPO.[20] More specific attempts to establish an operational framework for the technology transfer implications of IPRs were undertaken first through the Draft International Code of Conduct on the Transfer of Technology of UNCTAD, and later through the TRIPS agreement and the WTO through its Working Group on Trade and Transfer of Technology.

More specifically, article 7 of TRIPS notes that IPRs should contribute to "transfer and dissemination of technology…in a manner conducive to social and economic welfare, and to a balance of rights and obligations". Article 8.2 recognizes that countries may wish to prevent "practices which unreasonably restrain trade or adversely affect the international transfer of technology".

However, translating such statements into policy practice leading to change in the technological situation of developing countries has proved challenging. In addition, past positive country experiences may be difficult to replicate given the changes in the legal and commercial environment within which developing countries operate today, compared to the ones in which the most significant processes of technological catch-up took place.

Nevertheless, such experiences can point to a range of policies and outcomes that can guide policymakers away from preconceptions and rigidness. For example, the experience of Japan in its successful move up the technology ladder is often seen as being due to a well-managed patent system together with favouring licences for technology transfer through outright restrictions on FDI (Hoekman, 2004).

However, weak IPRs and the identification of technologies that were innovative but, from a patent perspective, were at the end of their IPR life, or in the public domain, encouraged creative imitation in the Republic of Korea and established its technological and industrial capacities. This allowed the country to move ahead with increasing domestic research and development in the 1980s, including a strengthening of the IPR regime (ICTSD, 2003; Maskus, 2000).

A number of countries have followed policies similar to the Republic of Korea's use of creative imitation as a starting point and seeking to transfer technologies that were, from an IPR perspective, accessible, affordable or in the public domain. Brazil, China, India, Malaysia and Mexico are often cited as examples. As industrialization and the technological sophistication of production processes has evolved, the depth and complexity of their absorptive capacities has grown, and IPR regimes have been strengthened, resulting in an increase in FDI, followed by a growth in licensing as a mode for technology transfer.

As developing countries move up the income scale the role of IPRs increases as a technology transfer vehicle. International trade in technology goods that are under active patents responds positively to improvement in the enforcement of patent rights among middle-income and large developing countries (Smith, 2001). An important reason is that these countries represent a competitive imitation threat if IPRs are weak, whereas stronger patent regulation may incentivize technology producers to increase exports (Smith, 2001). However, trade flows to low-income countries may not respond to the strength of IPRs and their implementation.

This has an important implication for policy metrics: while patents can be used to estimate technology transfer flows to medium-income countries with a certain absorptive capacity for technology, they may be only of minor relevance for assessing technology transfer flows to low-income countries and LDCs. For many LDCs, IPRs are completely off the policy map.

This realization underscores the importance of countries taking full advantage of TRIPS and other multilateral treaties flexibilities, which do not conflict with the fact that those countries may have upgraded their intellectual property (IP) legislation in full to the required international standards. Striking the right balance between the use of flexibilities and fully implementing treaties commitments demands skills not always present in developing countries, thus, the help of international expertise becomes critical. It is ill-advised for developing countries to move beyond minimum TRIPS standards, while local requirements for the registration of patents and copyrights should be as pro-competitive as possible.

Conversely, the assessment of compliance of a WTO member State within the TRIPS framework needs to avoid acquiring a legalistic tone. A "soft law" approach based on multilateral monitoring of achievement of jointly established targets and performance has been suggested as a possible and sufficiently effective mechanism to achieve compliance (Hoekman, 2004). This may be more suited to the needs of developing countries and LDCs, as well as compensating the fact that many developed countries did not have to subscribe to similar multilateral disciplines during their primary phases of industrialization. With regards to other aspects of the implementation of TRIPS, about which developing countries have expressed serious concerns, in particular article 66.2, it has been suggested that a more standardized reporting methodology would help identify best practices (Moon, 2001).

As developing countries develop their absorptive capacities and grow their economies, the implementation of the IPR regime may tend to strengthen. There have even been suggestions (Hoekman, 2004) that developing countries should adopt higher standards for patentability with respect to novelty, inventiveness and utility than those found in developed countries. For now, in developed countries these may be stricter in order to avoid strangling access to knowledge through undue patent expansion. In fact, stricter patent criteria are not constrained by TRIPS as long as such protection does not contravene the provisions of the agreement. An approach of a stricter interpretation may also require the following considerations for developing countries. First, due to the non-discrimination principle, there could be a negative effect on domestic innovation and patent acquisitions, although this is unlikely to be a significant effect in the majority of developing countries. Secondly, most developing countries lack adequate resources for carrying out substantive patent examinations. Finally, a stricter interpretation would require a more thorough consideration of the substantive patent process, especially the pre-application and post-application process.

Improving IP protection has a cost and a developing country opting for a tailored IP regime meeting its development would see the cost of implementation augmented by the cost of devising and managing flexibilities and the cost of engaging in potentially consequential legal processes at the WTO (Finger, 2000; WHO, 2005). Least developed countries had initially until 1 January 2006 to apply the TRIPS Agreement's provisions. This deadline has been recently extended to 1 July 2021, or until such a date on which they cease to be an LDC member, whichever date is earlier.[21]

Protecting and expanding the global commons of scientific knowledge and technology should be a key policy concern. This would include actively supporting that knowledge obtained through publicly funded or procured research and technology be distributed under public and open licences. Consideration should be given to regulating the use of compulsory patents in this regard.[22]

Innovation policymakers in developing countries should also consider that there is a vast amount of knowledge and technologies already in existence with recently expired patents and in the public domain, or under compulsory or open and public licences. Significant results in terms of transfer of technology could be achieved if mechanisms were put in place in developing countries to encourage entrepreneurs and academics to explore these possibilities before, or at the very least as well as, opting for importing or developing their own proprietary solutions.

A final consideration when assessing the role of IPRs as incentives for innovators from developing countries, particularly those from smaller economies, relates to the significant costs that may be involved in their use for protection in large international markets, exports to which may represent the only possibility to achieve a competitive scale. Patent registration and maintenance in the European Union exceeds $40,000 and is as much as five times the cost of patenting in the United States (London School of Economics, 2006). A comprehensive patent registration, including North America, Europe and select middle-income developing countries would reach the vicinity of $150,000.[23] Enforcing through litigation may also require very large financial means while reckoning with an uncertain outcome.

Chapter 6.
Technology and knowledge transfer and development: Challenges and opportunities

Technology and knowledge transfer needs will vary greatly by country and will depend on the structure of the economy and the level of industrialization, as well as overall development. A number of challenges and opportunities that relate to specific sectors or development issues can be considered, either because of the acuteness of the development problems at stake or because of the high potential return of improving support for innovation. From this perspective this chapter will look at technology transfer aspects of climate change, health, agriculture, and free and open-source software.

6.1 Climate change

Science, technology and innovation is the key to mitigating the impact and adapting to the consequences of climate change, which represents a burden that falls disproportionately on developing countries. While the international community agrees that rapid development and deployment of green technologies are critical to dealing with climate change, markets are failing to generate results and the technology transfer agenda under the UNFCCC remains a key contentious issue.

The UNFCCC addresses technology transfer issues in several important ways. In article 4, "Commitments", the Convention mentions the need for international cooperation for the transfer of "technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases". It goes on to note that developed countries need to provide financial resources supporting technology transfer to developing countries. Furthermore, the achievement of developing-country commitments under the Convention will depend on the availability of such funding, while a special reference is made to the particular case of vulnerable and least-developed economies. Article 11 defines the financial mechanism that would provide financing for, among other actions, transfer of technology.

The Clean Development Mechanism (CDM) was developed as the central instrument for transferring green technologies from developed to developing countries. It was promoted in 1997 at the third UNFCCC conference and was significant from a technology-transfer perspective as it involved allowing developed countries to count emissions reduction from CDM investments in developing countries towards meeting their legally binding obligations. Reductions would count only for projects that would not be commercially viable under normal circumstances. The assumption was that CDM projects would bring with them new technologies or innovative applications and, most importantly, the accompanying know-how.

According to some reports (Serres, 2008 and 2009) [24] about one-third of CDM projects claimed that they enabled technology transfer. The reports found that the rate of technology transfer was significantly higher than average for several host countries, including the Plurinational State of Bolivia, Ecuador, Guatemala, Honduras, Indonesia, Kenya, Malaysia, Mexico, Pakistan, South Africa, Sri Lanka, Thailand and Viet Nam, while lower than average for Brazil, China, and India. It was noted that tariffs on imported equipment could have affected the extent of technology transfer involved in CDM projects. South–South technology transfers accounted for about 10 per cent of the total, with the technology originators being predominantly located in Brazil, China, India and the Republic of Korea. The reports noted that when an increasing number of similar projects are implemented in a country, the rate of technology transfer declines. The recipient country's technological capabilities also influence technology transfer, mainly through the level of its capabilities to absorb technology (Glachant, 2008 and 2010). High-tech and energy projects such as wind turbines or solar panels generated more transfers, while traditional sectors such as agriculture or construction materials created less.

Another report that looked at some 1,000 CDM projects gives a lower estimate (26 per cent) of projects that involved an element of technology transfer, most of which concerned equipment deployment, but much smaller elements of learning and capability building. A broader concept of technology transfer that includes international collaboration whereby actors from the host country would carry out significant development, improvement or adaptation of technology concerned only 0.6 per cent of those projects (Das, 2011).

While individual projects under CDM may have been successful, on the whole the mechanism has failed on quantity: the magnitude of technology transfers achieved is anecdotal while their impact on climate change is barely measurable.

Intellectual property rights remain an open question as they are often cited as both an enabler or as a hindrance to technology in the climate change literature.[25] What is clear is that UNFCCC annex I countries, as a matter of principle do not support any weakening of IPR policy to accommodate low carbon and renewable technology diffusion in developing countries, nor are they keen to see IPR discussions being moved out of the TRIPS and WIPO regimes where there is already an established dialogue on IPR and development.[26] From these countries' perspective, rather than on IPRs the focus should be on the capacity of developing countries to innovate, transfer and adapt green technology solutions. Such positions are supported by major multinational companies such as those participating in the Alliance for Clean Technology Innovation,[27] which argue that without IPR protection, "companies will be highly reluctant to share their technologies and know-how with others".[28] While the precise meaning of the word "share" can be debated, it is a fact that 77 per cent of all renewable energy patents in 2005 were held between European Union countries, the United States and Germany (OECD, 2008).

Consensus about how the mechanisms for the transfer of clean and environmentally sound technologies can be rendered more effective remains elusive. However the fact remains that, from the perspectives of development, poverty reduction and energy poverty, these technologies are a priority. In this regard, the Secretary-General of the United Nations published a report in 2012 that included a number of policy options related to (a) strengthening international cooperation to close implementation gaps in terms of capacity, funds, technology and political commitment; (b) promoting "big push" technology transfer, including hardware, to developing countries; (c) building indigenous capacity and providing equitable access to overcome technology gaps; and (d) promoting partnerships with or solutions by the private sector and non-governmental organizations, supported by further privatization, liberalization and trade. The report concluded that a global technology facilitation mechanism is needed. Such a mechanism would include a global network of technology transfer and information mechanisms would aim to promote investment and technology transfer, by promoting partnerships among existing global and regional centres, online technology information platforms, clearing houses, technology instruments of international agreements, relevant economic partnership agreements, international financial institutions and technology funds (United Nations, 2012).

From the point of view of developing countries, a practical conclusion of the above considerations is that, in parallel to their efforts to advance an effective action programme for transfer of climate-change-relevant technology in the context of international processes and negotiations, they should seek to strengthen policies and practices in order to maximize South–South technological collaboration and cooperation, as progress in this direction may be more easily achievable. UNCTAD (2012b) proposes a number of principles that could inform policies in this regard. Developing countries should also increase efforts to develop clear and focused national strategies that take advantage of technologies under public licences, in the public domain and using local knowledge and resources.

6.2 Technology transfer and health, medicine and pharmaceuticals

The debate about whether local production of pharmaceuticals should be fostered as a matter of public policy and whether this is desirable from an access to medicines perspective provides the main interface between technology transfer issues and health policy in developing countries.

The WHO resolution WHA 61.21 on a Global Strategy and Plan of Action on Public Health, Innovation and Intellectual Property, adopted in 2008, proposes that local production is a means of contributing to the overall goals of promoting innovation, building capacity and improving access to medicines. A recent analysis of a number of country experiences (UNCTAD, 2011) shows that the conditions under which technology transfer results in strengthening local production, and the ways and means in which this promotes greater access to medicines, are highly complex and thus require an evolved policy response founded on the existence of substantive capacities in governance and public health, intellectual property and STI policy. For example, a joint study by the WHO, WIPO and WTO (WHO et al., 2012) has pointed out that local pharmaceutical production alone does not necessarily contribute to improved access to medicines so that it is important that incentives for local pharmaceutical production are not just guided by a country's industry policy, but aim explicitly to improve people's access to medicines and are accompanied by strengthened pharmaceutical regulatory capacity.

An important development observed in Brazil, China and India is that as their pharmaceutical firms grow and act increasingly on the global level, their product portfolios become increasingly less geared towards supplying medicines, vaccines and diagnostics to poor populations at home and in other developing countries and LDCs. These developments provide opportunities for new entrants, while the conditions of technology transfer and access to technology play a critical role. Countries that have achieved most progress in their production had absorptive capacities receptive to technology transfers through technical collaboration and licensing arrangements with multinational pharmaceutical companies and from parent to subsidiary company. The ability to tap into human resources with technical and managerial expertise acquired abroad is a critical factor.

There are several ways in which local production affects access to medicines. It may increase competition and lower the prices of drugs. Even when wholesale import prices from large producers are cheaper, local production may find advantages in better distribution networks, marketing, cooperation with other firms and local government support. In fact, a number of pharmaceutical firms in developing countries have roots in pharmaceutical distribution services. Local production can cater to specific local health needs that may be underserved by larger international producers. On the other hand, a small local market may not be able to sustain a local production at an economical justifiable level. Tariff policies aimed at protecting local production may result in significantly higher medicine prices (WHO et al., 2012).

Developing countries should help local companies improve their attractiveness as technology transfer partners and encourage them to identify and access technologies appropriate for their absorptive capacity. Governments can enhance regional trade and cooperation in order to create larger, regional markets, in particular through a mutual recognition of certifications and approvals with trading countries. In this regard, international cooperation can play a role in providing technical training and capacity building in certification and approval and for participation in international standard-setting bodies in the pharmaceutical sector.

Improvement in health-related transfer of technology in the context of national development should not be incidental, and therefore STI and technology transfer polices for health and medicine should be part of an institutional and policy framework that must address the following (UNCTAD, 2011):

- A systematic assessment of national and regional public health needs with reference to local production of medical products with a view to generating information on the market viability and public health considerations;
- The ability of countries to create a threshold of absorptive capacity (in terms of availability of human skills to engage in production, management and marketing, and relevant scientific and physical infrastructure);
- A favourable policy framework that promotes domestic and foreign investment into production of medicaments and technology transfer;
- A rational intellectual property rights regime that explores flexibilities;
- Policies and mechanisms to promote access to locally produced medicines.

6.3 Agriculture, technology transfer and global competitiveness

A functional agricultural sector is a fundamental element for the economic transformation of developing countries and particularly LDCs. This entails building productive capacities in agriculture and identifying linkages between agriculture and other sectors and industries. At the highest policy level, the question of sustainable economic development is inextricably linked to promotion of technological change and innovation in agriculture.

In its *Technology and Innovation Report 2010*, UNCTAD asserts that improving agricultural performance in developing regions depends on technology and innovation in raising agricultural production and incomes of all farmers, including smallholder farms. The main challenge is to strengthen the innovation capabilities. The focus should be on incremental improvements in processes, products, inputs, or equipment needed to adapt existing technologies to the local environment in ways that enhance productivity and lower costs.

Smallholder farmers are a particular concern regarding technology transfer and innovation policy. They often represent a majority of the farming community but their farms are technology poor and inefficient. They are also less resilient to external shocks and this increases their dislike of risk and reduces their willingness to explore technology and innovation, as these are business propositions that require a higher risk tolerance. Given these particularities, STI and development policy need to develop a particular perspective on smallholder farms, ensuring that they are well networked into all available technological support mechanisms.

Successful technology transfer in agriculture depends on good knowledge flows and the convergence of different areas of science and technology, and indigenous capabilities, into an agricultural innovation system. Policies that combine local knowledge sources with technology transfers from abroad will improve the sector’s attractiveness for public and private investments and advance agricultural technologies and innovation capacities. A pointed example is the case of Brazil, which has made important progress in tropical agriculture technology and productivity while focusing on its specific agricultural and environment conditions. However, international cooperation, and in particular South–South cooperation, can provide important opportunities for technology transfer. Triangular cooperation, where a developed country sponsors South–South technology sharing efforts, has also shown promise as a model for the international transfer of agricultural technologies (UNCTAD, 2010).

Technology and knowledge transfers need to be contextualized into the specific agricultural and socioeconomic problems that are identified in a particular region or locality. This means that learning and knowledge brokerage processes have to be introduced and structured. Technology needs to support the development of new and higher value-added markets, products and services but is dependent on effective processes of technological adoption and learning among farmers and other rural stakeholders, including non-farmer entrepreneurs.

In line with the previous considerations, a major international effort to evaluate the relevance, quality and effectiveness of agricultural knowledge, science, and technology was implemented through the International Assessment of Agricultural Knowledge, Science and Technology for Development 2004 and 2007 (IAASTD, 2008).[29] Some key conclusions were that:

- Participatory collaboration in knowledge generation, technology development and innovation can very significantly add value to science-based technology development and the achievement of sustainability goals;
- Indigenous and local knowledge and practice play a central role in technology generation, access and use, and the innumerable innovations resulting from local and traditional knowledge typically are overlooked, undervalued and excluded from official innovation support systems;
- Modern ICTs are critical in achieving effective collaboration and merit larger investments and support;
- The complex role of institutions and governance practice ought to be looked at more closely because it is these factors that enable or constrain the realization of development and sustainability;
- The predominant focus on public and private research as the locus for research and development is linked to an underappreciation of the important role of multi-agent involvement in knowledge production;
- More emphasis ought to be given to a sustainable use of natural resources in agriculture, to establishing decentralized, locally based, highly efficient energy systems and an energy-efficient agriculture, and to the promotion of local–global partnerships.

6.4 Free and open-source software

Software is a major subsector of information and communication technologies and one that is particularly amenable to technology transfer given its ephemeral nature – it exists as pure applied knowledge and can be produced and distributed independently of the hardware platforms that it uses to operate. One particular type of software – free and open-source software (FOSS) – has particular qualities that encourage a closer look when considering technology transfer issues.

Free and open-source software is used for writing text, email, Internet browsing, spreadsheets, statistics and data management, and the like. In application, it is no different than any other software. However, FOSS has explicit copyright and end-user licences that permit users to copy and redistribute software without restrictions. This makes FOSS particularly easy to transfer and absorb – indeed, its copyright and end user licence were created to promote transfer and absorption. The most popular licence, the so-called General Public Licence (GPL), imposes a unique restriction: all copies, regardless of how much the software was altered, must also use the GPL and thus permit further unrestricted copying.

Free and open-source software is different in two important ways which are interlinked and interdependent and make it particularly relevant for technology transfer purposes. First, FOSS licences require that authors of a particular program make its source code publicly available. Access to the source code allows anyone to copy or technically alter the performance and features of a program. It also allows ambitious computer scientists to learn how world-class software is designed and developed. Proprietary software keeps its source code secret and users may not be able to assess the underlying technology.

Second, FOSS permits “looking under the hood” and therefore supports important human capacity development in ICT and computer science. This is a particularly important issue given the challenge of improving absorptive

Box 1. FOSS initiatives in developing countries

Obligation to use FOSS in the government sector - Ecuador
In April 2008, the President of Ecuador, Rafael Correa Delgado, signed decree No.1014 that makes it mandatory to use free software in most public administrations of Ecuador. General policies on free software include adoption and use of open standards and free software, minimization of buying proprietary software licences, reuse of previously developed software, implementation of cost-benefit analysis, diffusion of benefits from FOSS use and training of public officials. In 2009, the Public Enterprises Organic Law was passed, which obliges state-owned enterprises to use free software. Article 32 in the University Teaching Organic Law, which was passed in 2010, specifies that companies that distribute software have the obligation to grant higher education institutions compulsory licences at preferential fees for the use of the software for academic purposes. It also establishes that higher education institutions shall have the obligation to use FOSS.

Utilization of open source in health care - Nigeria
The eHealth Nigeria, a non-profit organization, was founded in 2009 with the purpose of helping to create a sustainable and reliable health-care system in Nigeria with effective electronic and mobile health systems. The electronic and mobile health systems such as the Electronic Medical Record system and the Open Data Kit were developed by the organization using OpenMRS (Open Medical Record System), which is a collaborative open-source project to develop software to support efficient health care in developing countries. The Electronic Medical Record system specific for Nigerian health care was developed to manage the medical history of each patient by using unique patient identities. This has reduced the omission of patient information and has made it easier to collect, aggregate and visualize public health data in Nigeria. The Open Data Kit was developed to support health workers in the field to collect patient information through mobile telephones. The work of eHealth Nigeria is, as well, raising the awareness of the benefits of using ICT. With the increasing contribution of e-health to public health, the Government of Nigeria has developed the Health Sector Reform Programme with an emphasis on the deployment of ICT.

Promotion of the software industry - Thailand
The Software Industry Promotion Agency (SIPA) in Thailand developed six major strategies in 2009 with the aim to enhance the economic value of the local software industry by up to 5 billion Thai bhat until 2008. One of the strategies to enhance Thai IT competitiveness focused on the promotion of open-source software and its use among SMEs with the expenditure of about 51 million Thai bhat. The Open-Source Promotion Project aimed to encourage government agencies to use it in cooperation with local software companies. Thai SMEs were urged to use local software solutions and applications for their business processes and productivity. In order to raise awareness regarding the use of local software technologies in business, SIPA organized the Buy Thai First campaign and the Thailand Software Fairs. Recently, the agency announced the five missions for Thai software promotion, with a budget of 220 million Thai bhat, which are: software-industry policy, development of software business, research and development innovation, intellectual property and a software-business one-stop service.

Open-source software for education - Indonesia
The POSS ITB, a network of universities in Indonesia, aiming to accelerate the use of FOSS in the community, initiated the Open Source Software School project to provide FOSS to schools. It was introduced to Junior high school in Sekolah Menengah Pertama in 2008. The chosen software was Ubuntu Server 8.10, Edubuntu 8.10, Moodle and Crayonpedia. The POSS ITB network trained teachers and some students as well.

National Programme for FOSS Technologies - Saudi Arabia
The King Abdulaziz City for Science and Technology created the national FOSS programme "MOTAH" with the aim to encourage the use of FOSS and to contribute to software development that supports the Arabic language. This programme has several collaborations with other initiatives. The King Abdullah Initiative for Arabic Content benefits from its use by developing computer software based on open source, such as the search engine Naba, the morphological analyser Alkhaleel, the Arabic Interactive Dictionary, Arabic essay scorer and so forth. Technical and consultant services using FOSS technologies are assisting government sectors in implementing eGovernment. In addition, the cooperation with the Committee of International Trade will encourage the usage of FOSS among promising small- and medium-sized enterprises.

National strategy for ICT - Egypt
The Ministry of Communications and Information Technology launched a new national strategy for the ICT sector for the period of 2012–2017. Open-source software is one of the key areas to develop in the strategy. The Government aims to promote open-source software through encouraging its use in education, training and related research and development. As well, Government offices will receive training to use open-source software. A particular target is raising the capabilities of local companies to develop, operate and maintain information systems based on FOSS. The Government will give priority to viable open-source solutions bidding for government tenders and will remove procedural barriers for the approval of open-source products for Government use. The Minister of Communications and Information Technology formed a committee to formulate an open-source software strategy in November 2012. The strategy will support a gradual transition to FOSS the public sector while creating an integrated system to develop an open-source software industry in Egypt.

capacity and therefore the likelihood of a successful technology transfer in many developing countries.

Box 1 describes some recent initiatives of FOSS deployment in developing countries. The advantages of using FOSS for improving ICT technology transfer to developing countries are many:

- FOSS can reduce dependency on expensive and imported proprietary technology and the accompanying ICT consultancy services that are often tied up with various non-disclosure agreements;

- FOSS, through its open code and public licences, promotes knowledge-sharing, technology transfer and unrestricted cooperation on knowledge and technology development and use, resulting in increased absorptive capacity;

- FOSS enables the development of local computing skills and home-grown ICT services industries that can become more than just fronting businesses selling imported technology and software licences;
- FOSS is fully IP compliant: it needs and uses copyright to maintain and promote its openness. While its spirit is anti-restrictive and pro-technology transfer, it does not confront current IP regimes, national or international, from a formal, technical or legal perspective. Countries, institutions, businesses and individuals that switch from using pirated software to FOSS work to fulfil their obligations as designated by WIPO and WTO TRIPS;
- FOSS allows easy localization: Any FOSS program can be translated and altered to suit the linguistic, cultural, commercial and regulatory needs and requirements of any location, and all this without having to seek permission from the original authors or exchanging terms and conditions while using legal intermediaries and consultants;
- Finally, many experts feel that FOSS is more secure, more reliable and more stable. While this point is by nature inconclusive, what is true is that technical issues with FOSS programs can be fixed locally by local experts.

Free and open-source software policy is a national STI issue. While international cooperation and awareness-building may be useful, it should focus on promoting the idea that government policy bodies need to be aware of FOSS and consider its explicit inclusion in their innovation systems, ICT and e-strategy programmes, in e-governance activities and in procurement policies.

When Governments need to choose a particular technology, the decision to go with FOSS, or a proprietary, or a mixed solution, they must be aware that this is a policy issue and not a purely technical or cost-accounting consideration. The reason for this is that because FOSS generates important and positive economic externalities, including improvements in technology transfer flows and development of absorptive capacities, software choice – and technology choice in general – should not be relegated to oversimplifications and assessments along the lines “what works” (even though FOSS actually works better most of the time) or how costs stack up from an accounting perspective. Accounting “analyses”, often referred to as “total cost of ownership” or “TCO” calculations, are notorious for ignoring local economic conditions. This is particularly true for developing countries and LDCs where labour costs are low and IP piracy is a common but undesirable mode of technology transfer, and where positive externalities, such as the development of local intellectual capital through FOSS use should not be ignored.

Chapter 7.
From transfer of technology to innovation: The centrality of the discovery process and economic knowledge

The central argument of this chapter is that transfers of technologies are done to stimulate innovation in the developing (or least developed) countries, but what is transferred is a technology (and at best a technological knowledge that will support the efficient adaptation/operation and maintenance of the technology) but not the innovation. Of course, the effectiveness and efficiency of the transfer of technology and know-how is an important part of the problem, but not less important is the discovery of the relevant economic knowledge, which is about whether the transferred technology will work (or not) economically.

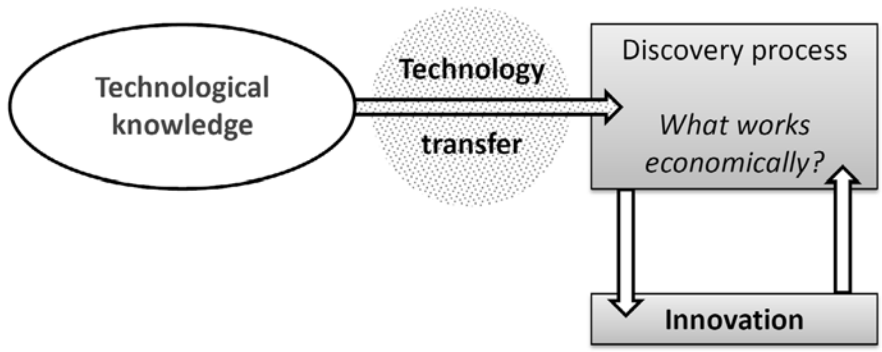
7.1 Technological knowledge and economic knowledge

Economic knowledge is the crucial knowledge about what works and what does not work economically (see Phelps, 2013). The crucial point here is that the essence of innovation consists of the generation, transposition or adoption of business ideas (not technical ideas), and the fundamental question concerns the origin of the business ideas for innovation. Obviously, new business ideas do not come from scientific breakthrough or even from the research laboratory; they come rather from the business sector. Entrepreneurs draw on their personal observations and private knowledge, in combination with the shared pool of public knowledge, in coming up with conceptualizations that lead to a new method or product that might "work". As put forcefully by Phelps (2013, page 27): "A modern economy turns people who are close to the economy, where they are apt to be struck by new commercial ideas, into the investigators and experimenters who manage the innovation process from the development and, in many cases, adoption as well". This does not mean that science and research and development are not important. Actually, they are very important in order to materialize the new business ideas and to assist business people on technical matters. This simply means that the centre of gravity or the fundamental locus of innovation is the business sector and not the science and technology sector.

The consequence of such a role reversal is straightforward for the exploration of the factors and conditions of a successful transfer of technology: even if the technological knowledge has been perfectly transferred from the North to the South (or from the South to the South), we cannot take it for granted that this knowledge will work economically in the new setting. This point is crucial and helps to understand the difference between the concept developed here and the whole approach of "appropriate technologies". The appropriate-technologies approach expresses a fair process of adapting a technology in order to configure it with an operational form or design that fits the new (developing country) environment. This is of course a fully relevant approach, but it does not solve the problem of economic experimentation and the generation of the economic knowledge that will translate the appropriate technology into an innovation.

The history of transfer of technologies is full of cases of failure that were not caused by the failure of the technology itself but simply because it did not work economically in the new setting. Such a conceptualization offers, therefore, new insights into success and failure. This means, as the diagram below shows, that the transfer of the technology is not the end of the story, but rather the point at which the discovery process must start. The term – discovery process – refers to the process of determining whether the transferred product or

Figure 10. From transfer of technology to innovation through the discovery process



method can be developed and, if developed, determining whether it will be adopted. Through internal trials and market tests, a modern economy adds to its knowledge of what can be produced and what methods work, and to its knowledge of what is not accepted and what does not work. And if a transferred technology goes on to be developed and adopted, thus becoming an innovation in the new setting, it does create economic knowledge. (Failure also adds knowledge of a sort – the economic knowledge of what apparently does not work.)

Figure 10 describes a linear sequence of operation starting from the existence of a technology in the North and its transfer to the South, which is followed by the discovery process and the generation of the economic knowledge. Such a sequence is probably not the best way to succeed in developing new activities and stimulating innovation in the developing economy.

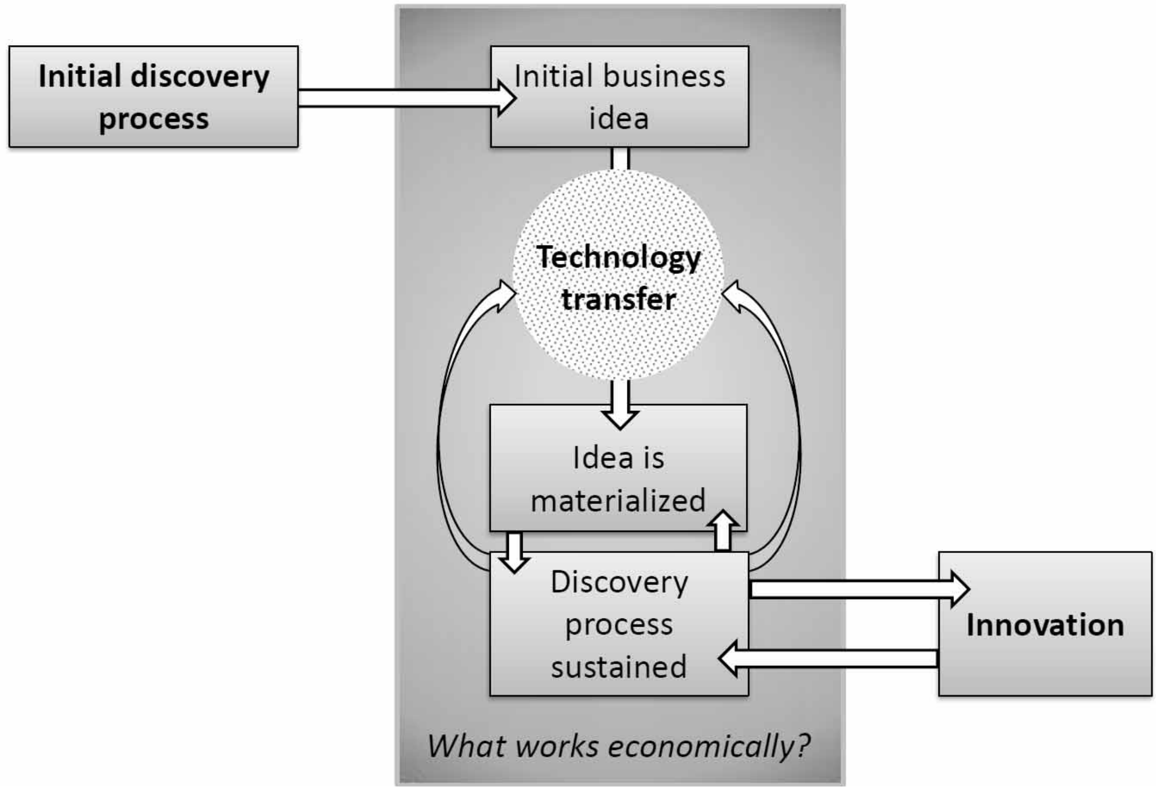
Many transfer operations fail simply because the aim was to “find a home for” an available and public technology, without worrying about economic needs and business ideas to be tested and experimented in the developing economy: when it comes to technology transfers, the technology-push logic almost inevitably leads to failure (Arora, 2007).

Another, more effective, way involves the discovery procedure as the initial event – this process discovers both the economic value of a business idea and at the same time the need to acquire some elements of technological knowledge that are currently missing; such a discovery calls, therefore, for a transfer of technology which is fundamentally demand driven and will provide – if successfully carried out – an appropriate supply response for the development of the business idea (figure 11).

In the case described in figure 11, the discovery process happens twice:

- First, it generates a business idea coming from the business sector (a process involving vision, intuition, observation, imaginativeness, creativity and insight into a new direction that might turn out to meet desires or needs that could not have been known before). But this first process does not continue until the materialization of the idea to the stage of experimental testing in the economy because some technologies are missing. We call this process first-order discovery;
- Second, the discovery process is undertaken after the idea has been materialized into a new product or process (thanks to a successful transfer of technology) and will generate the economic knowledge about the question as to whether the new idea can work economically (being developed, implemented and adopted). This is the second-order discovery process through which the business idea is tested experimentally in the real economy.

Figure 11. From the discovery process to innovation through a transfer of technology



The operation of transfer of technology is thus undertaken while all the uncertainties about the economic value of the business ideas remain. The first discovery procedure is a first approach to reduce economic uncertainty; however, it is not sufficient, since the idea cannot be materialized unless the transfer of technology has been accomplished – opening then the possibility for full economic experimentation (second-order discovery). The operation of transfer of technology is therefore characterized by high uncertainty that can be formulated in terms of an inter-temporal consistency problem: the fixed cost of the transfer of technology is incurred while the knowledge about its economic value is not yet available.

There are two ways to deal with this problem. In the first place, it is possible to organize and manage the first-order discovery process in such a way that a significant part of the economic uncertainty will be eliminated through this first process; second, it is possible to contain the costs of the transfer until the full economic knowledge will be produced through the second-order discovery process.

A clear advantage of the first way to solve the inter-temporal consistency problem is that the earlier economic knowledge is gained (through the first-order discovery process), the more possible it is to adjust the channel for transfer of technology to what we know about the economic viability of the business idea. For instance, licensing might be the appropriate channel if it is rather clear that the business idea will work economically. On the contrary, public–private partnership and other collaborative networks (possibly publicly funded) might be better channels when the first-order discovery process raises a big question mark about the economic value of the idea.

It should be acknowledged that the centrality of the discovery process for the stimulation of innovation and the diversification of the economy is not a new thing in development economics. According to Hausman and Rodrick (2002) and

Rodrick (2004), there is a key role for entrepreneurs in LDCs and that is to discover what the country is good at producing. For a developing economy, there is a great social value in discovering the relevant specializations, since this knowledge can orient the investments of other entrepreneurs.

7.2 A case study: Learning from a failure

The following case study was carried out and published by researchers at the Ecole polytechnique fédérale de Lausanne (Munoz and Foray, 2011). This case involves a Tanzanian entrepreneur based in the region of Mafinga. He is very active in the transport sector and also very interested in the question of renewable energies. He has a new business idea for a new activity: collecting and treating the vast stocks of wood shavings that are scattered everywhere in the surrounding forests to commercialize them with a view to producing electricity, particularly for a wood pulp factory and more generally for TANESCO, the national operator for the production and distribution of electricity. This is the first-order discovery process which leads to a business idea.

But for this activity to reach a minimum threshold of operational efficiency, the entrepreneur needs a modern machine to collect and treat the wood shavings. Such a machine exists in the Emmental region of Switzerland, a forest area where a whole innovation ecosystem focussing on the exploitation and management of forests has long been in existence. Machine manufacturers and users interact closely to improve the technology and the numerous iterations result in products (machines) that are sophisticated and very specific.

Thanks to a particular "connecting structure" that will be explained below, the Mafinga entrepreneur becomes informed about the availability of the technology in Switzerland. His visit to the Emmental region is very fruitful and the exchange of knowledge takes place despite the language barrier. The people in the Emmental are interested and happy to be involved in this operation and the Mafinga entrepreneur is both filled with wonder by the technology and with enthusiasm by the economic prospects conjured up by such a machine operating in Mafinga. It seems that a Swiss machine will soon be purchased, adapted and delivered, and that the knowledge required for starting up the installation, maintenance and solving any technical problems that arise will be transmitted. The Swiss Agency for Development and Cooperation covered the transfer costs, while the capital needed to purchase the equipment was provided by the local entrepreneur and local banks in the United Republic of Tanzania.

7.3 Technological and knowledge transfer as a fair process

So far the story is one of an ideal technology transfer, a model operation that any developed country Government would proudly add to its list of development cooperation achievements (for example. in its reporting within the framework of article 66.2 of the TRIPS Agreement). It can be called an ideal operation because certain fundamental economic principles have been respected.

The origin of the operation is a real entrepreneurial and business idea corresponding to the launching of a new economic activity. The transfer operation is demand-driven and matches the real need of a domestic entrepreneur. The identified technology is a private technology owned by a small company specialized in the design of specific technological solutions. The fixed development costs have therefore already been covered by developed-country markets and the equipment in question can be reconfigured and adapted at a relatively low cost (Arora et al., 2001). The intellectual property stakes are not very high, and thus no obstacle, as it involves capital goods and activities aimed at improving the efficiency of a local process, and not final consumer products that could be reimported. The transfer operation itself is a source of motivation and interest for everyone concerned.

Of course, the Mafinga/Emmental project is a small scale operation and the innovation is not a radical one. But the notion of innovation relevant for policymaking in developing countries ought to be much broader just because the cumulative effect of widely distributed small improvements can be as significant for growth as the impact of discrete, “high-order” innovations (Trajtenberg, 2009). Concerning the small scale of the project, this is the standard scale of operation when it is driven by a local entrepreneurial initiative. And it is obvious that a successful innovation – even at a small scale – is likely to generate post-innovation competition that may play a significant role in triggering further innovation, as well as demonstration effects and other kinds of spillovers.

7.4 Information and finance issues

The Mafinga/Emmental technology transfer case is also an ideal one in the sense that the huge informational and financing problems – that usually impede such operations – have been solved thanks to the mobilization of specific instruments and capabilities.

One important issue in any transfer of technology is of course informational. Basically, the Mafinga/Emmental operation can be qualified as a very low-probability, hard-to-predict event. On the one hand there is a Tanzanian entrepreneur who does not know Switzerland and has no information regarding the fact that the Emmental region has an innovation ecosystem in the domain that interests him. On the other hand there is a small company in the Emmental that has never had the opportunity to work with entrepreneurs from one of the LDCs. How can a connection be established between the two?

The informational task is considerable and cannot under any circumstances be accomplished by the governmental agencies responsible for development and technology transfers. The best these agencies can do is to help projects that are ready and therefore for which the precious connections between supply and demand have already been established. Identifying a local demand and a local supply and establishing the connection are tasks that are beyond the fields of expertise of these agencies. Indeed, offering government incentives so that supply and demand are revealed and coincide will not suffice. Neither the Tanzanian entrepreneur nor the small Emmental company have the capacities to seize this type of incentive and respond to it.

The task is thus indeed a search problem: the supply must be relentlessly sought, the demand must be sought with the same determination and the relationship between the two must be meticulously constructed. In this respect, we are involved in an operation worthy of *haute couture* and not ready-to-wear! A specific and complex informational tool is therefore required – a search and connecting agent (SCA) – without which thousands of entrepreneurs in developing countries will never be connected with other thousands of companies in developed countries. Actually, the role of such an SCA is central in the Mafinga/Emmental story. It succeeded in building the needed connection thanks to its deep knowledge of both ecosystems as well as of the technologies (renewable energy) involved in the operation.

Once the connection has been established and the operation decided upon, specific financing must be found in order to:

- Cover the costs of adjustment and reconfiguration of the technology in accordance with the new natural, technological and economic environment in which the latter will be used;
- Cover the transfer costs of the operational and practical knowledge necessary for starting up the installation, equipment maintenance and the solving of any new problems that may arise. This knowledge transfer implies that the technicians in Emmental are able to go to the United Republic of Tanzania, no doubt several times.

These are the main costs to be covered (working on the hypothesis that the purchase price of the machine is assumed by the entrepreneur with the aid of local banks).

Experience shows that determining the appropriate method of financing is no trivial matter. First, the uncertainty associated with starting a new activity is coupled here with the uncertainty related to the fact that this activity will be carried out in a country that is very little developed. The uncertainty, informational asymmetries and moral hazard are considerable and are likely to permit opportunistic behaviour on the part of entrepreneurs. It will therefore be difficult to attract private investors and even development funds set up by banks as part of their corporate responsibility.

Second, the public agencies responsible for setting up financing geared towards development projects often have a philosophy that is not suited to the entrepreneurial realities associated with the Mafinga project. Indeed, like any good entrepreneur, the person in Mafinga observed that the local system was inefficient (the paper factory uses a great deal of energy and the wood waste is left in the forest areas) and wants to turn this inefficiency into a business opportunity. The public agency will retort that it would be better to correct the generic inefficiency and thus improve the general state of the system rather than help an entrepreneur to take advantage of it.[30] It is clear that two philosophies are in direct opposition here – each one eminently respectable but no doubt incompatible with the other. A confrontation of philosophies – admittedly familiar to development specialists – is always surprising and alarming when this confrontation becomes an obstacle to the progress of the project.

The public agency seeks actions directed towards achieving a perfect system that is durable and tenable and, as a financier, cannot conceive philosophically of an entrepreneur whose project aims to exploit the imperfections and deficiencies of the system. But by feeding on the system's imperfections, the Mafinga project recaptures the very essence of an entrepreneurial activity, which is to construct itself on the observation and exploitation of certain inefficiencies. The public finance agencies with this type of philosophy will find it extremely difficult to agree to support projects that are based on the flaws of the system.
This issue was addressed at the level of the Swiss Agency for Development and Cooperation during the funding decision process. At some point the public agency considered that it would be more socially profitable to support and undertake actions to increase the energy efficiency of the pulp and paper factory so as to reduce wood consumption and ultimately improve the local forest ecosystem. But doing that would have eliminated the potential business opportunity identified by the entrepreneur. It took a long time for the agency to agree that some policy interventions and aid from external donors – even when targeting efficiency and sustainability – can create distortions and reduce economic dynamism under the form of entrepreneurial initiatives, innovation and spillovers.

7.5 Second-order discovery processes

The chipper is now based in Mafinga and fully operational; the whole technological (including tacit) knowledge has been transferred successfully. However, the chipper is not being used regularly. The reason for this is that the operators of the wood pulp production factory did not keep their promise to purchase chips at reasonable prices. The local entrepreneur is looking for other more reliable buyers but so far no other users of woodchips have turned up. Interpreted within the framework presented above (figure 12), this means that while the initial idea was fine and the transfer of technology succeeded, the fully materialized business idea failed – at least this is what the second-order discovery procedure has shown.

This interesting story underscores the fact that even in the case of a perfect entrepreneurial-driven operation of transfer of technology the activity may fail. This is because – as already described – there are in fact two sequences of the discovery process. The first-order initial discovery process (before the transfer of technology), which produces the entrepreneurial vision and idea but has not been tested economically because of some supply issues to be solved before proceeding to the economic experimentation, and the second-order discovery process (after the transfer of technology), which generates the economic knowledge showing whether the business idea, supported by the transferred technology, works economically or not.

In the Tanzanian case, the initial business idea was there, the transfer of technology worked efficiently, but the second-order discovery process highlighted the flaws of the new activity. Moreover, none of the two possible ways to deal with the time consistency problem were taken: the first discovery process (that is, the business case) was not complete enough so that major sources of problems were not identified ex ante; the lumpiness (indivisibility) of the technology made it difficult to contain the costs of the operation.

The Mafinga/Emmental case also shows the importance of institutions and organizational framework conditions for improving both the transfer of technology and the entrepreneurial discovery process. It is now clear that transfer of technologies are an essential part of a broader process that involves: (a) undertaking a first-order discovery process (initial business ideas coming from the business sector and including the identification of the missing technological knowledge); (b) solving the supply problem identified initially (transfer of technology) which involves addressing information, coordination and finance issues; and (c) launching a new activity (second-order discovery process and generation of economic knowledge about what works economically).

7.6 New tools addressing information and financing problems

Given the apparently random nature of the connection, the Mafinga/Emmental project seems at first glance to be a random event and as such it could be argued that there is no reason why it should have happened. But it did happen. As Galileo is said to have murmured after officially recanting his statement that the Earth moves around the sun: “and yet it moves!”. What is going on?

The question is to know what structural conditions, economic institutions and policies would increase the likelihood of there being X > 1 transfer operations between entrepreneurs in developing countries and enterprises in developed countries? Two main characteristics are observable: one was central to solve the informational problem; the other was to clarify the question of finance.

The Mafinga/Emmental project would never have come into being without the intervention of an SCA, an expert knowing on the one hand the world of business and entrepreneurs in Mafinga, and on the other that of the SMEs in the Emmental region of Switzerland. Other examples or other projects could show in a similar fashion the centrality of these agents. This involves irreplaceable expertise for identifying local entrepreneurial needs and the supply of private technologies and bringing the two elements together. In short, this expertise provides invaluable “economic intelligence” by producing information and constructing a microsocioeconomic space linking supply and demand and generating the needed assets to succeed in the transfer operations.

The first tool, therefore, corresponds to the availability in sufficient quantity of these SCAs that are familiar with both demand and supply. For the expertise of these agents to be effective and operational, they should be specialized in a given sector (renewable energy for example) and regional space.

In terms of policy, a key problem is easily identified: this is an activity that has great social value and yet is very poorly remunerated. If such an agent fails to connect nodes, he bears the full cost of his failure. If he is successful, he will only capture a negligible fraction of the social value generated by the technology transfer operation. Ultimately, with free entry to this market, connecting agents produce private costs and social gains. It is no great surprise that we will not see a sufficient number of connecting agents in the economy. So the first best policy response to this externality that limits the supply of SCAs is to subsidize this activity. An interesting institutional arrangement would be similar to the model of "contract research firms", which are the primary vehicle for doing government-funded for-profit social science research in the United States. If each Government orders services from already existing SCAs, we can predict the growth of this market and the sustainable development of a supply of SCAs. To help such a market to grow, we suggest that an accreditation system should be built (modelled on ISO standards) for SCAs that perform well in the technology transfer operation. Such an accreditation system, indicating know-how and skills in managing technology transfers from rich countries to LDCs, could help to decrease information asymmetries and transaction costs between the principal element (Governments) and agents (SCAs), thereby increasing the efficiency of such a market.

Another option would be for governmental agencies of the developing economies to take explicitly this task of connecting ecosystems (including searching for and identification of opportunities in the developed world) and to develop internal capabilities and networks accordingly.

The combination of high uncertainty, asymmetric information and moral hazard, and the fact that research and development or technology transfer, typically do not yield results instantaneously (figure 12), call for the design of specific funding mechanisms. One question could be whether such mechanisms could be provided by venture capital organizations (VCs) as in the standard situation of high-tech ventures in developed economies.

While research and development or transfer of technology projects carried out by small entities and entrepreneurs are often characterized by considerable uncertainty and informational asymmetries, permitting opportunistic behaviour by entrepreneurs, VC organizations employ a variety of mechanisms to address these information problems. [31] In short, the environment in which VCs operate is extremely difficult. It is the mechanisms associated with the VC funds that are critical in ensuring that they receive a satisfactory return. These circumstances have led to VC organizations emerging as the dominant form of equity financing for privately held technology-intensive businesses. At the same time, there are reasons to believe that private VC funds will be inadequate in the case of funding transfer of technology and the materialization of a new business ideas in the context of a developing economy, and therefore that there is a central role for public funding (public VC programmes, public-sector seed capital, SME support agencies).

There are several arguments for public investments to support transfer of technologies and economic experimentation in the socioeconomic context of a developing country: inadequacy of the structure of venture investments vis-à-vis many types of projects; the very limitation of the VC industry; a potential role for public VC programmes in certifying projects to outside investors and another potential role for public VCs in encouraging knowledge spillovers:

- The structure of venture investments may make them inappropriate for many projects (venture funds tend to make quite substantial investments, even in young firms, and so VC organizations are unwilling to invest in projects that require only small capital infusions);
- The VC industry is limited: VCs back only a tiny fraction of technology-oriented businesses and VC funds are highly geographically concentrated. Such limitations make any interest of VCs to most innovation-related activities in developing countries very unlikely;
- If public VC awards could certify that projects are of high quality, some information problems could be overcome and investors could confidently invest in these firms;
- Finally, public finance theory emphasizes that subsidies are an appropriate response in the case of activities that generate

positive externalities such as technology diffusion.

All these reasons for which public VC should replace private VC are valid in the case of a project such as the one described above. In particular, the situation is a typical case where the financial requirements are too small in relation to the average financing scale; the fact that the project is located in a developing country increases the informational problems to such an extent that the customary monitoring mechanisms set up by the VC may seem insufficient or increase the costs too sharply compared to the anticipated profitability; finally, the project will generate spillovers (effects of demonstration and emulation) that in themselves represent a rationale for public financing.

A public VC fund can therefore be an important tool; that is to say, a public financing mechanism addressing the problems of entrepreneurship and entrepreneurs' projects given the difficult context and circumstances of developing countries, and particularly the LDCs.

7.7 Technology platforms and optimizing discovery and transfer iterations

When, as in the Mafinga/Emmental case, the second-order discovery process demonstrates that the business idea does not work economically, the cost of the failure is likely to be high since all the private and public expenditures of the transfer of technology have been already engaged. This is certainly one critical issue to be addressed in order to increase the efficiency of resource allocation into technologies' transfers.

Given this complex iterative process between economic knowledge and technology transfer and development, and given the fact that the initial business idea – even if it has been fairly produced through entrepreneurial vision and initiative – cannot be tested economically before the transfer of technology is operated, it is critical to design organizational structures and institutions that help (a) to increase the likelihood of economic success of the initial business idea; (b) to maximize iterations between the development and experimentation of new business ideas and the transfer of technologies needed to materialize the new ideas.

Organizational structures are of course critical as conditions for a successful management of the whole process. An example of organizational form is presented below before proceeding to the general discussion.

The terms "technology platform" or "production centre" are used to designate forms of organization explicitly aimed at facilitating efficient and rapid iteration between economic knowledge (business ideas) and transfer and learning of the technology, its adaptation to local conditions, the assimilation of subsequent improvements and its generalization.

These essentially involve technology development centres, devoted to a specific domain and partly financed by public development assistance as well as public–private partnerships. These centres provide a certain number of technological services to assure the development of appropriate innovations. They help to structure and test initial business ideas; they pinpoint and structure demand for technology from local entrepreneurs to materialize the initial ideas. They also ensure the updating of technological knowledge and its diffusion. Crucially, they facilitate access to the financing of innovation by local banks, either by simply supporting the project in question, or by creating credit lines from developed countries. One such platform is described in box 2.

Technology platforms constitute a very attractive organizational innovation when there are important lacunae in terms of both the economic knowledge and the technology supply. Such platforms can maximize iterations between the discovery procedures and the production of the economic knowledge on the one hand, and the transfer of technology and other supply development on the other. They represent a method of coordinating and adapting resources whose assembly is by definition problematic. They provide a better understanding of local technology demands. Finally, and perhaps most

Box 2. Cleaner Production Centres

The Cleaner Production Centres (CPCs) were set up as part of a collaboration between the Swiss Federal Secretary of State for the Economy (SECO), UNIDO and several developing countries. The CPCs offer a wide range of services relating to clean technologies (SECO, 2005):

- Information on state-of-the-art technologies;
- On-site consultancies in production companies or the service sector and special services such as eco-audits, project evaluation, introduction of ISO 14000, and the like;
- Support in drafting investment projects to submit to banks and the search for financial resources;
- Training for workers, consultants and students.

The CPCs are autonomous organizational units with their own board of directors representing local industries and services. Each centre receives technical support from a Swiss reference centre. These reference centres are reputed institutions in the relevant area.
The CPCs help local entrepreneurs to find solutions for financing technologies. In addition, Switzerland has set up green credit lines combining a guarantee of credit from a short-listed local bank with a partial reduction of repayment in event of a successful investment.

The first CPC was created in Colombia in 1998. Then other CPCs of various forms were developed in Egypt, Morocco, Peru and Viet Nam. This is a rather successful model that recognizes the centrality of economic knowledge and the need to do more than “simple” transfer of technologies. Cleaner Production Centres are about supporting firms and entrepreneurs in experimenting new business ideas through various forms of assistance and services (including technologies, management and finance).

The transfer of technology may involve training, software (such as environmental control systems) or hardware, or a combination of all three, including supplies, provision of services, licences, documentation, and creation of joint ventures.

importantly, they anchor the technological development in the local economy, endeavouring to couple it to an industrial dynamic.

In the STI Policy Review of Peru, UNCTAD (2011) provides another example of a “platform” that includes among its functions serving the same kind of objectives: maximizing iterations between the development of technological knowledge and the economic discovery process. Centres for Innovation, Technology and Entrepreneurship are aiming at both supporting the development of technologies and technological capabilities and helping economic experimentation through the provision of services such as information, quality control, productivity improvement and management.

7.8 Innovation and technology transfer channels

The main channels of technology and knowledge transfers are reviewed in chapter 3 of this report. It is now important to ask how these channels can help respond to the inter-temporal consistency problem (the temporal gap between the execution of the transfer of technology and the economic experimentation of the business ideas).

In other words, how is each channel managing the need for optimal iterations between technology development and economic discovery process?

In the case of the transfer of technology, there are two families of transactional modes. These provide an important taxonomical distinction and have important implications on the questions raised in this section.

In one case, the transfer of technology appears as just one element of a transaction that exceeds its scope. In such situations, transfer of technology is a joint product (or a by-product) of the main transaction. This includes transactional modes such as FDI, joint ventures and subcontracting (see chapter 3). In all these cases, the business idea has already been experimented (that is, before the transfer of technology is undertaken) or at least the uncertainty about whether it will work economically has been significantly minimized. After all, any FDI exhibits some of the features and organizational characteristics of a platform as described above. However, the problem here is more about whether the transfer of technology – as a joint product – will generate local spillovers (knowledge and training) to the rest of the economy rather than whether the underlying business model is commercially sound.

In the alternative case, the transfer of technology is the main object of the transaction and appears as the main economic operation. Within this second family we have: licensing, the sale of capital equipment, materials and high-tech systems technical cooperation, assistance and training contracts. In such cases the problem of a gap between the transfer of technology and the discovery process may arise, as in the Mafinga/Emmental case. Therefore, for this family of transfer of technologies the role of sophisticated organizational structures (such as platforms) is central – aiming at optimizing the iterations between technology transfer and the experimentation of the business idea.

7.9 Innovation as a technology transfer outcome

It is very plausible that there are thousands, perhaps tens of thousands, of entrepreneurs in developing countries such as the person in Mafinga, with an intuition or even a business plan and an urgent need of a given technology from the North to apply it. Moreover, there are countless small and medium-sized specialized companies in developed countries that possess real technological treasures which they would have no trouble sharing (Arora et al., 2001). So where does the problem lie?

There seem to be three critical obstacles, that have been clearly identified with the Mafinga/Emmental case and that are difficult to overcome. This chapter has briefly stated what they are – information/coordination, finance and the temporal gap and inconsistent phasing between the transfer of technology and the corresponding discovery process of the economic knowledge – before developing some potential solutions.

The creation of innumerable technology transfer operations between entrepreneurs in developing countries and SMEs in developed countries requires an answer to two sorts of problems: an informational problem and a financing problem. By creating and supporting an industry of intelligent search and connecting agents and financing public VC, we can predict that a developed country will be at the origin of a large number of technology-transfer operations between entrepreneurs in developing countries and its own SMEs, thus realizing the extraordinary technology transfer potential that so far has not been achieved, resulting in an incredible social waste.

However, informational and finance solutions are insufficient. As demonstrated above, one critical issue is the problem that what is transferred is technology while what is desired is innovation. This means that a successful transfer of technology is only one part of the whole story and perhaps not the most critical. The critical dimension is the discovery process that will reveal whether the new business idea – as materialized in a new product or service thanks to a transfer of technology – can work economically in the new setting.

To avoid failures at this stage (that will be very costly, since the cost of the transfer of technology is already incurred) it is crucial to optimize the iterations between the process of technological development and transfer and the process of the discovery of whether the new idea will work economically. It is therefore crucial to design institutions and organizations that can carry out such iterations. It is suggested that technological platforms can be an interesting solution in such a perspective.

Chapter 8.
Conclusions

This report has reviewed the issue of technology transfer to clarify what the term means, how it can contribute to building technological capabilities and promote development, how technology is transferred, what elements influence whether technology is successfully transferred and the role of intellectual property rights. It also outlines key sectors where technology transfer is critical and outlines the need for policymakers to consider how technology transfer can be translated into innovation that supports economic growth and development.

There is no consensus on how to define technology or technology transfer, and various definitions have been used in different contexts. This can create confusion and make international agreements that cover technology transfer difficult to implement. Despite the difficulties inherent in defining and measuring technology and its transfer, building technological capabilities, and broader STI capabilities, is central to economic growth and development. The concept therefore remains highly important in both conceptual and theoretical as well as policy terms.

Conceptually, technology gaps – or gaps in technological capabilities and access to technologies – among countries or groups of countries explain a significant part of the development gaps that exist between them. These gaps are endemic and persistent, but it is possible to reduce them through a process of technological learning and catching up, which a select group of developing countries have successfully managed in the past century. Successful technology transfer has contributed to catching up in those countries, although their experiences varied widely in many respects. This has created renewed interest by developing country policymakers in the issue of technology transfer and how it can contribute to development.

The report outlines the various approaches that have been pursued to measure technological and related innovation capabilities, and the technology and innovation gaps that exist between countries or groups of countries. Different indices have been created to measure technological and innovation capabilities at the country level. They provide a means to benchmark countries along standard criteria and to calculate technology and innovation gaps. These measures provide an idea of the extent to which a country (or group of countries) lags behind those countries at the frontier, and the need for policy action to reduce those gaps. Benchmarking exercises indicate that significant gaps persist, and that while for some elements of the composite indicators the gaps have declined in recent decades, for others they have increased. This reflects the persistent nature of technology and innovation gaps and the continued imperative for policy action to promote catching up and reduction of these gaps in many developing countries.

The current state of knowledge on how to design and implement policies that achieve technological catch-up remains incomplete. There are likely to be many possible paths and no single solution that is generally applicable to all countries. The report outlines the main channels through which technology is transferred internationally between countries, namely trade, licensing, foreign investment and the movement of people. One challenge is to promote stronger flows of technology through these channels. A second challenge is to build the domestic capabilities required to adapt, use and master these technologies and to translate them into innovation that promotes economic growth and development. In order to respond to each of these challenges, developing-country policymakers must develop solutions to various problems that are outlined in the preceding chapters. How to build domestic absorptive capacity and strong innovation systems are two key questions raised by the second challenge. The role of intellectual property rights in promoting or impeding technology transfer, technological progress and innovation in countries at different levels of development remains an important consideration.

This report outlines the diversity of sectors and applications in which technology transfer can play a major role in developing countries. Given the cross-cutting nature of technology, the coverage is selective and includes climate change, health, agriculture and free and open-source software. The final chapter recounts a recent episode of a practical effort to implement a technology transfer transaction in a developing-country context. It serves as a reminder that technology transfer is critical, but that in terms of development impact the key question that must be answered is how to successfully translate technology transfer into local innovation that is economically relevant.

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Notes

[1] Methodological and Technological issues in Technology Transfer.
http://www.grida.no/climate/ipcc/tectran/362.htm

[2] See UNCTAD (2007).

[3] For reviews of some of these indicators see Archibugi et al. (2009) or Andreoni (2012).

[4] See Cornell University, INSEAD, WIPO (2013), Global Innovation Index – The Local Dynamics of Innovation, Geneva.
www.globalinnovationindex.org

[5] See the WIPO Project of the Committee for Intellectual Property and Development (CDIP) studying the role of innovation and IP in the informal sector, available at www.wipo.int/econ_stat/en/economics/studies/; and de Beer et al. (2013).

[6] The CANA dataset contains 41 indicators for 134 countries, over the period 1980–2008, measuring six key country-specific dimensions: innovation and technological capabilities; education system and human capital; infrastructures; economic competitiveness; political–institutional factors; and social capital. For a complete description of the dataset see Castellacci and Natera (2011). The dataset is publicly available at http://cana.grinei.es.

[7] Variables are normalized according to the following formula:

$$NormV_{iy} = \frac{Variable_{iy} - Variable(MIN)_y}{Variable\ (MAX)_y - Variable(MIN)_y} * 100$$

where $NormV_{iy}$ is the normalized variable of country *i* in year *y*; $variable_{iy}$ is the original value of the variable of country *i* in year *y*; and $Variable\ (Max)_y$ and $Variable\ (Min)_y$ are the respective maximum and minimum values of the variable in year *y*.

[8] The author analyses the dimensions shaping the dynamics of technology in 131 countries over the period 1985–2004, and undertakes tests for technological convergence.

[9] See www.un.org/News/Press/docs/2013/sgsm15145.doc.htm

[10] WIPO (2011) and WIPO (2013), *World Intellectual Property Indicators Report*, Geneva.

[11] WIPO (2011), *World Intellectual Property Report – The Changing Face of Innovation*, Geneva.

[12] The Manaus Free Trade Zone is a major important industrial park in Latin America that today hosts more than 500 firms that generate more than US$25 billion in revenue and nearly 100,000 jobs. It is located in the capital of Amazonas State, where it was established in 1967.
http://tinyurl.com/manusfreezone

[13] For example, GATT 1994 article III item 5 states: “No contracting party shall establish or maintain any internal quantitative regulation relating to the mixture, processing or use of products in specified amounts or proportions which requires, directly or indirectly, that any specified amount or proportion of any product which is the subject of the regulation must be supplied from domestic sources”. A number of disputes have been filed in WTO for the use of local content requirements in programmes for the development of renewable energy (Japan versus Canada, United States versus India, still pending as of January 2014).

[14] A recent WIPO project for its Committee on IP and Development provided evidence on the patterns of skilled-worker migration, focusing on the specific case of inventors. See Miguélez and Fink (2013).
www.wipo.int/export/sites/www/econ_stat/en/economics/pdf/wp8.pdf

[15] Commonly mentioned causes of such market failure are the public good characteristics of knowledge and associated positive externalities, the uncertainty and riskiness of investments in STI and related problems of asymmetry of information, and the indivisibility and large scale of many STI research projects.

[16] See http://news.cnet.com/gateway-from-pc-powerhouse-to-buyout-bargain/2100-1042_3-6204782.html

[17] *Business Week*, http://tinyurl.com/apple-acquisitions; *New York Times*, http://tinyurl.com/apple-intrinsity; *The Verge*, http://tinyurl.com/apple-authentec; *Forbes*, http://tinyurl.com/google-forbes; Xconomy.com http://tinyurl.com/google-xconomy.

[18] WIPO World IP Report (2011).

[19] The Paris Convention, Patent Law Treaty and Patent Cooperation Treaty are multilateral treaties administered by WIPO.

[20] At the 2007 General Assembly, WIPO member States adopted 45 recommendations (of the 111 original proposals) made by the Provisional Committee on Proposals Related to a WIPO Development Agenda.
http://www.wipo.int/ip-development/en/agenda/recommendations.html

[21] See http://www.wto.org/english/tratop_e/trips_e/tripfq_e.htm

[22] An alternative view on the issue of publicly funded research and technology is presented in: http://www.wipo.int/export/sites/www/econ_stat/en/economics/wipr/pdf/wipr_2011_chapter4.pdf

[23] Figures developed by KAGAN BINDER PLLC Intellectual Property Attorneys.
http://www.kaganbinder.com/docs/7-EstimatedPatentCosts.pdf

[24] This analysis covered technology transfer claims from 3,296 projects.

[25] Paragraph 81, United Nations (2011) "Synthesis report on best practices and lessons learned on the objective and themes of the United Nations Conference on Sustainable Development", note by the Secretariat, A/CONF.216/PC/8.
http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N11/213/65/PDF/N1121365.pdf

[26] United States House of Congress voted on 10 June, 2009 (432-0) on the Foreign Relations Authorization Act reminding that IPR policy "it shall be the policy of the United States that, with respect to the United Nations Framework Convention on Climate Change, the President, the Secretary of State and the Permanent Representative of the United States to the United Nations should prevent any weakening of, and ensure robust compliance with and enforcement of, existing international legal requirements as of the date of the enactment of this Act for the protection of intellectual property rights related to energy or environmental technology".

[27] The Alliance for Clean Technology Innovation is a group of clean technology products and services companies: 3M, Air Liquide, Alstom, ExxonMobil, General Electric, Microsoft, Philips, Siemens, and Vestas.

[28] See http://tinyurl.com/acti-ipr

[29] The IAASTD report was sponsored by the Food and Agriculture Organization, the Global Environment Facility, UNDP, the United Nations Environment Programme, WHO and UNESCO,

and its results were considered by 64 Governments at an intergovernmental plenary in Johannesburg, in April 2008.

30 This is assuming that the social cost of correcting the inefficiency is smaller than the welfare gain of removing it.

31 First, business plans are intensively scrutinized. Once the decision to invest is made, VCs frequently disburse funds in stages. Managers of these venture-backed firms are obliged to ensure that money is not squandered on unprofitable projects. In addition, the VCs intensively monitor managers, often contacting firms on a daily basis and holding monthly board meetings during which extensive reviews of every aspect of the firm are conducted.

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