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UNIDO and the World Summit on Sustainable Development

Innovative Technology Transfer Framework Linked to Trade for UNIDO Action

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

economy environment employment

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Innovative Technology Transfer Framework Linked to Trade for UNIDO Action

prepared by

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2002

Contents

Abbreviations

AAITPC	-	Africa-Asia Investment and Technology Promotion Centre
CDM	-	Clean Development Mechanism
EST	-	Environmentally Sound Technologies
EU	-	European Union
FDI	-	Foreign Direct Investment
GDP	-	Gross Domestic Product
GNI	-	Gross National Income
ICT	-	Information and Communication Technologies
IPA	-	Investment Promotion Agency
IPR	-	Intellectual Property Rights
IPU	-	Investment Promotion Unit
ITPO	-	Investment and Technology Promotion Offices
LDC	-	Least Developed Country
MVA	-	Manufacturing Value Added
NIC	-	Newly Industrialising Country
OEM	-	Original Equipment Manufacturer
SID	-	Sustainable Industrial Development
SME	-	Small and Medium-sized Enterprises
SPX	-	Subcontracting and Partnership Exchange
TRIMs	-	Trade Related Investment Measures
TRIPs	-	Trade Related Intellectual Property Rights
UNCED	-	United Nations Conference on Environment and Development
UNCTAD	-	United National Conference on Trade and Development
UNFCCC	-	UN Framework Convention on Climate Change
WSSD	-	World Summit on Sustainable Development
WTO	-	World Trade Organisation

Executive Summary

Context and introduction

This paper is an input into the UNIDO initiative on "Technology Transfer: Assessing Needs - Promoting Action" to be launched at the 2002 World Summit on Sustainable Development (WSSD) where technology transfer from industrialised to developing countries is likely to emerge as an important issue. The terms of reference for the paper are to (a) summarise the current understanding on the process of technology transfer and its contribution to adaptation and innovation, (b) identify linkages between technology transfer and trade, taking account of Trade Related Intellectual Property Rights (TRIPs), (c) assess the UNIDO technology transfer operations in general, and (d) based on the above research, prepare a "Technology Transfer Framework Linked to Trade for UNIDO Action".

Given UNIDO's commitment to sustainable industrial development (SID), the technology transfer issues are considered within the context of SID, which has three dimensions, economic development, enhancing social welfare and environmental soundness. Ideally, technical cooperation should contribute positively to all three dimensions. In practice, this is not always possible and therefore programmes which target at least one of the three dimensions with measures to limit any adverse effects on the other two are considered to be compatible with SID.

Technology transfer is a transaction or a process through which technological know-how is transferred normally between businesses or agencies representing businesses. This is the micro-level "business model" of technology transfer in which the transaction or collaboration takes place because both the parties (the supplier and the acquirer) perceive gains. The focus of the business model is not simply on technology transfer but also on its integration with the other dimensions of the business to ensure that it makes a contribution to improving the competitiveness and performance of the business. Without such motivation and effectiveness in implementing it, development of technological capability will either not take place or will be inappropriate.

Technology transfer is also an issue of some prominence at the macro level in negotiations between developed and developing countries especially in the context of trade liberalisation and protection of the environment. This is referred to here as the macro-level "political bargaining model" of technology transfer.

The business model of technology transfer and the framework

The technology transfer framework proposed here is based on available evidence from the East Asian late industrialisers with appropriate adaptation. It identifies two categories of countries requiring support for enhancing their capabilities through technology transfer ((a) very late industrialisers, and (b) slow industrialisers, including economies in transition) and three technology transfer routes ((a) through trade and aid to strengthen indigenous production for domestic markets (Route 1), (b) through FDI and contracting to develop export oriented firms (Route 2), and (c) through the supply chain of capital equipment and materials to develop local sub-contracting capacity (Route 3).

The very late industrialisers are developing countries with small manufacturing sectors. Typically, they are in the World Bank "low income" or the UN LDC category. Most of the domestic enterprises will be small or medium sized enterprises (SMEs) engaged in agro-processing or light manufacturing mainly for the domestic market.

The slow industrialisers are countries which have sizeable manufacturing sectors (with the contribution of manufacturing to GDP of about 15 per cent or higher) but with limited success in gaining international competitiveness and export growth.

Typically, the very late industrialisers need to start with Route 1 in a few selected sectors and upgrade their production processes and product quality with the help of imported mature technologies acquired through purchase or licensing possibly as part of an aid package. Some appropriate product innovations can also be developed under this route. The very late industrialisers can graduate to Route 2 after some experience within Route 1. The slow industrialisers with more industrial experience and larger domestic markets will probably have more technology transfer through Route 1 than the very slow industrialisers. In addition, there could be scope for increased technology transfer through Routes 2 and 3.

Technology transfer can be one of the ingredients for the development of technological capabilities but it cannot by itself develop them. Other complementary requirements are:
(a) conducive government policies;
(b) effective learning strategies and ability to learn at the level of enterprises, and
(c) a favourable learning and innovation context (local clusters of competitors, suppliers and customers, active trade associations, supporting institutions for training, development and application of technology and financing).

Leapfrogging and ICT

The very late and slow industrialisers find it discouraging to contemplate slow acquisition of capability in stages, starting from "low-tech" labour-intensive production and progressing to more advanced technological levels, especially during a period of rapid technological change. If leapfrogging is simply rapid industrial development, it can be achieved within the stages model. As the late industrialisers have shown, growth based on the domestic advantages such as low labour costs and imported technologies followed by acquiring higher level technological capabilities can be very rapid. Each country's trajectory of technology and industrial development will be different, the differences being related to the precise nature of the technologies acquired, company strategies and capabilities including combinative capabilities and market and demand conditions.

Much has been made of the potential of ICT and biotechnology to transform the process of economic development. For the very late and slow developers, the main advantages are likely to be from the use of the technology rather than gaining capability in them. Entry into services such as the 'higher-tech' software development and lower-tech 'back office' data processing and call centres are possible with adequate complementary capabilities. In the long-term, improved access to international knowledge (important for scientific and technological development) and improved education and training through ICTs would play an important part in developing the basic requirements for industrial capability building.

There are possibilities of developing capabilities in ICTs in the more advanced slow developers through technology transfer combined with development of local capability in hardware manufacture for the domestic market and exporting and (i.e. following Routes 1, 2 and 3) and more advanced software development, a strategy successfully followed by the Republic of Korea, the Taiwan Province and more recently China.

World trade reforms and technology transfer

Recent reforms in the world trade system have raised concerns about the ability of developing countries to develop their capabilities and competitiveness. These are related to the general reduction in protection and other trade related reforms such as TRIPs (which require members of WTO to implement an adequate legal framework for protecting intellectual property) and TRIMs (or Trade Related Investment Measures).

TRIPs need not limit technology transfer within the business model. Firms choose to supply technology for short-term financial gain or long-term strategic advantages even where there is some risk of misappropriation of proprietary knowledge. The tighter enforcement of IPR protection may enable owners of know-how to share it with greater confidence that it will not be misappropriated. Under TRIMs, foreign investors cannot be required to agree to minimum local content and therefore the scope for developing local suppliers will have to depend entirely on their actual and potential competitiveness.

Within the political bargaining model, the concerns of the developing countries are implications of trade liberalisation measures for their industries. With respect to TRIPs, the main concerns are:
(a) the high cost of certain proprietary products (e.g. new drugs);
(b) tighter restrictions on copying products and technologies, and
(c) the cost of enforcing IPR laws.

The cost of proprietary products is an issue regarding the use of a product and not the acquisition of technology and therefore beyond the scope of this paper. Some amelioration is possible through changes in patent protection rules and strengthening competition. Aid specifically directed at access to certain important drugs is also a possibility. The cost of enforcing IPR laws may be a problem that technical assistance can help with.

A further issue of concern is the continuing protection of agricultural and agro-processed products, which works against developing countries and needs addressing in international negotiations.

Environmental aspects and technology transfer

The main environmental aspects related to technology transfer are concerned with (a) reducing the unfavourable environmental effects of industry and (b) ensuring that new investment is environmentally sound technology (EST). If a technology being transferred is environmentally sound, it can be accommodated within the business model. However, problems arise when the installation of ESTs incurs a higher private cost while its benefits are externalities as far as the producer is concerned.

At the country level, the main instruments are regulations which may include incentives or sanctions, peer pressure, and information and support provided by international agencies. In addition, the burden of formulating and implementing policies at the national level could be reduced by international agreements. For example, exporting countries could agree to enforce EST regulations for the technologies they export. The technology importing country could also reduce the cost of regulation by adopting specified industrialised country regulations (for example, EU regulations).

Transfer of ESTs under international environmental agreements is the cause of contention between developing and industrialised countries. Based on Agenda 21, developing countries demand increased efforts by developed countries on technology transfer while the latter argue that most of the relevant technology is proprietary knowledge owned by businesses and therefore governments cannot transfer it. Businesses who own the technologies consider the issue of transfer within the

business model, weighing the benefits of protecting the technology against the possible benefits and costs of transferring it. The conflicting positions show the sharp difference between the business and political bargaining models of technology transfer. Resolution of this impasse requires (a) a proper understanding of the nature of the technology transfer process and (b) an incentive structure for the transfer of technology by firms who own it. On the former, it is necessary to understand that technology is not a commodity that can be transferred as a whole and in usable form through a transaction.

An incentive structure for companies transferring ESTs, similar to the mechanisms of emissions trading which provided commercial incentives for Annex I countries (industrialised countries) to achieve emissions targets could reconcile the business and political bargaining models of technology transfer. Companies transferring ESTs (rather than national governments in the case of emission control) could be credited for the environmental and / or development effect of the transfer. The credits could then be traded or used for making tax payments. Agreement of national governments to redeem the credits and careful governance and valuation of transfer activities are needed for such schemes to work. An alternative is a technology clearing house which would compensate the supplier and gain revenues from supplying the technology, but again careful consideration is needed in managing the arrangement and valuing the technology.

Summary of conclusions and recommendations

The business model of technology transfer has been used to suggest development paths for technology transfer based on mutual advantage for the acquirer and the supplier. The framework identifies technology transfer routes for countries with a limited industrial base (the very late developers) and countries with a significant industrial base that have been slow to gain competitiveness and grow. The focus of policy analysis is on identifying the obstacles that have hindered technology transfer and development of technological capabilities and the role of domestic policies and international agencies in removing the obstacles.

The framework can be used to carry out a strategic assessment at the national level to identify appropriate sectors, the possible role of enabling generic technologies (for example, elements of ICT) and short-term and long-term policies required for creating an enabling environment for developing technological capabilities.

A general examination of UNIDO's technology transfer related agencies and activities shows that UNIDO is well placed to take a leading role in technology transfer within the UN system. However, the recommendation based on the analysis in this paper is that some reorientation in the overall strategy is required to focus greater attention on more appropriate technology in the very late developers. Collaboration between branches within UNIDO is needed to deal with the balance between development and environmental objectives, implications of trade reforms and the role of new technologies.

Based on the reorientation, a strong case could be made out for increased financial and technical assistance from donors to support technology transfer initiatives. The support is likely to be forthcoming because some of the donors recognise the imbalance in the current status quo on trade agreements that disadvantage developing countries. International policy initiatives to redress some of these balances have also been recommended. Further policy oriented research is needed in a number of areas addressed in this paper (see section 8 for the list of recommendations).

1. Introduction and outline of paper

International technology transfer is now being recognised as having played an important part in the industrial development of the most successful late industrialisers of the second half of the 20th Century. Appropriate technology transfer, under the right policy and business conditions, contributes to learning and development of capability, which in turn contribute to competitiveness in domestic and international markets. Based on our assessment of the role of technology transfer, the aim of this paper is to develop a framework for enhancing the contribution of technology transfer to sustainable industrial development in countries that have been less successful in this respect so far.

This paper is an input into the UNIDO initiative on "Technology Transfer: Assessing Needs - Promoting Action" to be launched at the World Summit on Sustainable Development (WSSD) in Johannesburg (26 August - 4 September 2002). The state of international cooperation on technology transfer is likely to be a high-priority topic with developing countries seeking more effort and concessions from developing countries. In this context, the paper (a) identifies the problems that have hindered technology transfer, (b) outlines the process of developing capability based on technology transfer and (c) outlines the possible role of UNIDO and others in overcoming these problems.

In order to develop a framework of practical relevance and value, it must be firmly based on our understanding of technology transfer and acquisition of technological capabilities from past and current experience. However, it is also necessary to stretch the lessons to make them applicable to strategies for sustainable development in the less successful countries. Account must also be taken of the implications of new technologies, for example information and communication technologies (ICT), for the process of acquiring technological capability and any resulting changes in development priorities.

We start with an introduction to the notion of sustainable industrial development within the broader concept of sustainable development (section 2). This is followed by an examination of the nature of technology transfer and the contribution it makes to capability development (section 3), the lessons from East Asian latecomer industrialisation (section 4) and implications for technology transfer for countries which have been less successful in developing their capabilities (section 5). Implications of the trade regime under WTO, and especially TRIPS, for international technology transfer are considered in section 6. In section 7, the lessons and framework are related to UNIDO's involvement in technology transfer and a path for future action is sketched out. The main conclusions and recommendations are summarised in section 8.

Our paper is based on (a) the existing literature on technology transfer and related sustainability and trade issues, particularly in relation to the poorer developing countries, (b) our own previous empirical research in this area, (c) discussions with UNIDO staff, and (d) examination of relevant UNIDO documentation (including web pages and print publications). We have endeavoured to identify cases from the literature and our own experience that demonstrate aspects of the framework we consider are important. In addition to the documents requested from UNIDO during the assignment, we were sent other documents which we have attempted to incorporate into our considerations where possible.

In addressing the brief given to us by UNIDO we have needed to interpret a number of terms, concepts and issues in order to construct our terms of reference for the paper. These will be covered in more detail in the relevant sections, but they include an understanding of:

(a) The meaning of 'sustainability' within the context of technology transfer and industrial development.
(b) What is meant by 'technology' and 'technology transfer'.
(c) The type and range of technologies to be included in the study.
(d) The scope of the proposed framework in relation to UNIDO's mission, especially with regard to countries, industries and size of enterprises.

One important question we needed to address was the extent to which we examined the relationship between technology transfer and innovation. We know that UNIDO recognises the development of innovative capability as being one of the longer-term outcomes of successful technology acquisition as well as the role of national systems of innovation in the transfer processes and capability building. However, within the context of the WSSD the discussion is likely to focus on the least developed countries (LDCs[1]) and other industrially less developed countries, for which the immediate need is to climb the early steps of the technology ladder more through learning than innovation. Therefore we have focused on sustainable development in these countries and the practical methods for acquiring, absorbing and adapting technology within the context of globalisation. We have also considered the ways in which the gaps that exist in terms of financing and managing the process can be bridged.

2. Sustainable industrial development: meaning and issues

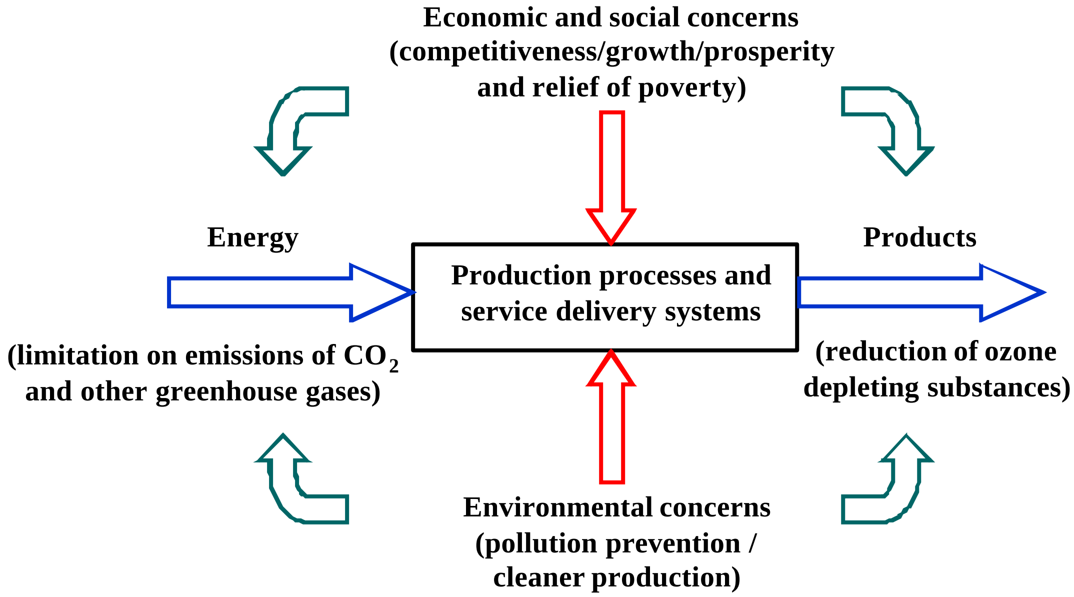
It is necessary to start with a definition of "sustainable development" in general and introduce the notion of "sustainable industrial development" within its context. Sustainable development has a number of dimensions. To complicate matters, different individuals and countries emphasise different dimensions depending on their priorities. For example, a Western environmentalist viewpoint puts greater emphasis on policies to protect the environment and conserve resources (influenced, for example, by the Montreal and Kyoto protocols), while representatives of developing countries are likely to seek faster improvement in the livelihoods of their citizens. Production is therefore subject to a number of pressures and influences as shown in Figure 1. The challenging task is to set out and implement a balanced strategy of sustainable development. The following definition attempts to provide such a balance:

"Sustainable development calls for improving the quality of life for all of the world's people without increasing the use of our natural resources beyond the earth's carrying capacity. While sustainable development may require different actions in every region of the world, the efforts to build a truly sustainable way of life require the integration of action in three key areas."*(Source: "Johannesburg Summit 2002, World Summit on Sustainable Development", UN Department of Public Information, DPI/2233 - October 2001 - 30M)*

This three key areas (or dimensions) referred to in the above definition are:

(a) economic growth and equity;
(b) conservation of natural resources and the environment, and
(c) social development

Figure 1: Production and the sustainability agenda



UNIDO's sustainable industrial development (SID) concept is consistent with the broad aspirations on sustainable development set out above. Recent documentation refers to the simultaneous pursuit of economic, social and environmental objectives *(WSSD Industrial Source Book: UNIDO Preparatory Activities for Rio + 10, undated)*. Elsewhere it has been stated that in practice, UNIDO technical cooperation programmes that foster sustainable industrial development are those that target at least one of the three dimensions, while at the same time considering the implications for the other two dimensions … *("UNIDO Technology Management Activities in the Context of the Investment and Technology Promotion Programme" – presentation by JM De Caldas Lima at IAMOT 8th International Conference on Management of Technology, Cairo, 1999).*

In the late 20th Century, industrial development based on export competitiveness was the major driver of economic development enabling a number of countries to increase the standard of living of their citizens**.** For example, during the period 1980 to 1999 China's GDP per capita grew by 350 per cent and that of other East Asian countries by 200 per cent, while for South Asia the growth was 87 per cent and for Sub-Saharan Africa GDP per capita fell by 15 per cent. The economic growth performance of African countries has therefore clearly fallen far behind other industrialising and developing countries in relative and absolute terms. UNIDO's focus on LDCs (not just in Africa) has the objective of enabling them to integrate into the global economy in a manner that increases their industrial and economic growth. This fits in with the economic aspect of sustainability. At the same time UNIDO suggests that any assessment of policies directed at the development of industry should include an examination of the intended or unintended consequences for social and environmental, as well as economic sustainability *(WSSD Industrial Source Book).*

Within this context of UNIDO's remit, this paper focuses on the role of technology transfer in achieving sustainable industrial development where sustainability is interpreted as:

(a) socially responsible economic growth (incorporating the economic and social dimensions), and
(b) conservation of resources and the environment.

For technology transfer, there can be some conflicts because of (a) differences in the levels at which technology transfer and policy negotiations take place and (b) different dimensions of sustainability. Typically, technology transfer takes place between business enterprises (or agencies representing business enterprises) based on considerations of commercial advantage for both parties. We refer to this as the business model of technology transfer.

Policy negotiations are typically between countries or groups of countries (e.g. industrialised countries vs developing countries). At this level, the extent and type of technology transfer is a bargaining chip in the broader negotiations encompassing trade and the environment and therefore we refer to this as the political bargaining model. Discussions and agreements at the policy negotiation level do not always appreciate the complexity of the process of acquiring technological capability and the private sector transactions involved in the transfer process. This can cause problems in arriving at a satisfactory structure of international policies for technology transfer

There can also be a conflict between the economic and environmental dimensions of technology transfer if the acquisition of an environmentally sound technology (EST) incurs a higher private cost while its benefits are externalities for the investors. There is also the issue of the cost of regulation for the developing country. There is a role for international agreements here. For example, EST regulation could be enforced by the exporting country for new equipment and technologies and developing countries could free ride on industrialised country regulation for existing technologies and incremental investment (Hecht, 1999).

The political bargaining aspects associated with trade and environmental issues are considered further when examining policy implications in sections 6 and 7. In the next three sections, we concentrate on technology transfer at the micro level within the business model.

3. Technology transfer and the development of capability

Evidence from the early and late industrialisers shows that technology, as the commercial application of scientific knowledge, has been a major driver of industrial and economic development (Mytelka and Ernst, 1998). Businesses acting entrepreneurially (within the context of a network of competitors, suppliers and customers, the national and international business environment and government policies and agencies) have been the major actors in developing technological capabilities and competitiveness (see for example the discussion on Malaysia's semiconductor industry by Chen (1999), and Taiwan Province's textiles and electronics industries by Gee and Kuo (1998)). For late industrialised and industrialising countries of East Asia, export-led economic growth has been based on the success of industrial enterprises in selected sectors. The late industrialised countries are the four “Asian tigers” - Republic of Korea, Singapore, Hong Kong SAR of China and Taiwan Province of China. The industrialising countries of East Asia are Malaysia, Thailand, to a lesser extent Philippines and Indonesia and more recently People’s Republic of China. Henceforth in this paper, the late industrialised and industrialising countries as a group are referred to as “late industrialisers”.

There are of course many differences among the late industrialisers regarding (a) the business environments and policies, (b) levels and trajectories of industrial development and (c) the role of foreign direct investment and technology transfer. However, in all cases the role of international technology transfer by a variety of methods has played an indispensable role. Technology is the means by which a firm transforms inputs into outputs (products or services). More widely, technology supports the firm's activities from the design of products and processes through improved information technology for material management, accounting, human resource management, marketing and internal and external communications. Some technology may be specific to the products and processes, while others (for example ICT) are generic. All firms have some level of technological capability, which is the result of the historical process of technology accumulation.

A fundamental point when understanding how technology is acquired is that it is not just a physical thing but also comprises knowledge embedded in hardware and software. UNIDO recognises this when it defines technology as "a system of knowledge, techniques, skills, expertise and organization used to produce, commercialise and utilise goods and services that satisfy economic and social demands *(UNIDO Manual on Technology Transfer Negotiation, 1996)*.

Gee (1993) similarly defines technology as a set of knowledge contained in technical ideas, information or data; personal technical skills and expertise, and equipment, prototypes, designs or computer codes. Transfer of technology therefore can be in any of the above forms or their combinations, some embodied in the equipment supplied while other in the forms of expertise, training and software. The focus in this paper is on the contribution of international transfer of technology to the improvement of technological capability of business enterprises in developing countries. The advantages technology transfer offers could be:

(a) a production process or part of a process which improves production efficiency, reduces costs, improves quality control and/or reduces environmental pollution;
(b) a product which is of better quality, has greater functionality, better appearance, less damaging to the environment in its use; or
(c) a combination of process and product as production of a better product often requires changes in processes.

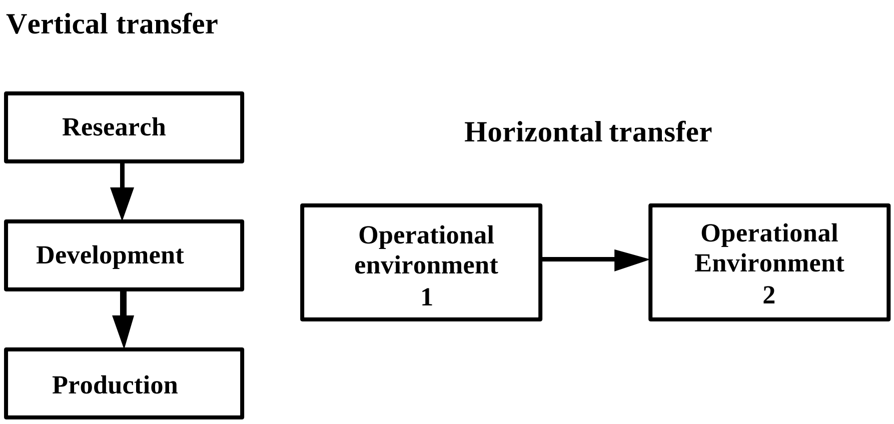
The transfer to developing countries will generally be horizontal, transfer of established technology, rather than vertical, transfer of innovation from research and development to production (see Box 1 for details).

For the acquirer, most of the benefits from technology transfer are in the form of lower costs or better or new products in the short term. The longer-term strategic benefit of the development of technological capability, eventually including the ability to innovate, depends on the effectiveness of learning. The acquirer may see no private gain from the technology, which is solely for the purpose of reducing environmental pollution. However, environmental soundness may be bundled within the new technology, for example by using low radiation computer screens or cadmium-free NiMH batteries. This may be a consequence of equipment manufacturers' strategic and marketing choices or regulations in the exporting country. Alternatively, the technology may be environmentally sound per se (for example, see the solar lantern case study in Box 2). If ESTs have to be installed because of enforcement of regulations or other pressures and there is a cost attached to the technology but no direct private gain to the acquirer, their acceptance becomes more difficult.

Box 1: Vertical and horizontal transfer

A distinction is usually made between vertical and horizontal transfer. Vertical transfer refers to technology being transferred from research to development to production. Thus it follows the progressive stages of invention, innovation and development, with the technology becoming more commercialised as it proceeds through each stage. Vertical transfer can be within one organisation or a transaction between, say, a research institute and a manufacturing company.

Horizontal transfer refers to an established technology being transferred from one operational environment to another. The technology is already commercialised and the purpose is to disseminate the technology and extend its application into other contexts. This type of transfer is used by companies wishing to maximise the return from their technology, but being unable to do this by direct selling of end products in a market. Horizontal transfer is more common when technology is being transferred from industrialised to developing countries. There is usually no further improvement or change to the technology unless it needs to be modified to suit local circumstances or environmental regulation, in which case when it is adapted and/or refined there will need to be a linkage between vertical and horizontal technology transfer.



In most cases, technology transfer implies a transaction or a longer-term collaboration in which two parties (the acquirer and the supplier of technology) are directly involved. This may not always be the case. For example, technology may be acquired by reverse engineering or from publicly available knowledge. These routes of technological acquisition require a certain level of capability. Reverse engineering also raises the issue of protection of intellectual property. Publicly available knowledge could be a source of technological knowledge but by and large it is unlikely to be commercially usable without a high level of adaptive and innovative capabilities.

Therefore, in discussing technology transfer in this paper, the focus will be on a transaction or a collaborative relationship between an acquirer and a supplier. Typically, both the parties will be business enterprises, though the acquirer may be an agency representing businesses (for example, the Jabalpur Garment Makers Association in Madhya Pradesh, India, which decided to purchase pattern cutting equipment to share to be installed in a purpose built garment making centre because the equipment was too expensive for individual firms to buy). The supplier may be an NGO *(see the case of the treadle irrigation pump described later in Box 9)* or a consulting firm working for an aid agency *(see the solar lamp case in Box 2).* The motivation for most suppliers will also be commercial advantage.

Box 2: The solar lamp *

Many people in rural Africa still have no access to electricity. Urban Africans also have problems with mains supplies, which are either too expensive or unreliable. In Kenya, for example, most householders use kerosene and candles for lighting and many also spend significant amounts of hard earned cash on dry-cell batteries for torches, which are thrown away after use. In recent years solar energy has been seen as a solution, but the cost of installing even a modest solar home system puts it out of reach of the majority of families in developing countries.

A practical and low cost alternative to a complete solar system is the rechargeable solar lantern. However, most of those available have a number of technical shortcomings related to poor construction and quality of light, and the relatively sharp drop-off in performance after a period of use. The main reason that an effective solar lantern has not been developed is that, for manufacturing companies in developing countries, new product development for local markets is expensive and risky.

On the global scale, however, the potential for solar lantern products is huge with around 2 billion people worldwide without access to electricity. The Intermediate Technology Development Group (ITDG), based in Britain, therefore secured funding for a project to develop an improved lamp, the Glowstar, for use in developing countries. By using customer information as a starting point and working together with local manufacturers, ITDG has provided technical know-how to develop this improved lamp which meets all the criteria demanded by customers, and employs appropriate manufacturing and assembly techniques which allows it to be produced locally. It has also set in place facilities to provide capital outlay for mass production tooling as well as providing assistance with local marketing of the product.

When full-scale production is reached the lamp is expected to sell for about US$ 75. Although this is still a sizeable investment for poor households, communities can pool resources and share benefits, so it would allow the poor to climb the first step on the `energy ladder'. It can also radically improve safety in homes where kerosene lamps and candles pose serious fire hazards, and help with education standards as children are able to study after nightfall.

* *Based on the case described in Williams S (2000), Let There be Light!, African Business, Issue 258, October.*

The term technology transfer suggests a single transaction resulting in the acquirer gaining complete command of the technology. Familiarity with the technology is not necessary for a user who will be more concerned with factors such as the ease of use, reliability and ease of remedying faults. This is an obvious point but one which needs making because when bargaining at the macro level and considering the potential of new technologies such as ICT, the distinction between access to the products of a technology and the ability to use, adapt and develop it are missed. This issue is discussed further in section 5 when considering the implications of new technologies and leapfrogging possibilities. The distinction between using a technology and gaining capability in it is well illustrated by turnkey projects which provide very little by way of further developing capability unless specific provision for capability transfer is included in the transaction *(see the case of the Kuwait dectricity generation and water desalination utility in Box 3).*

Box 3: Turnkey projects in the Kuwait electricity industry *

The Ministry of Electricity and Water (MEW) in Kuwait is responsible for the generation, operation, distribution and maintenance of electricity and water services. Currently, these utilities are entirely owned by the Kuwaiti government. MEW has no indigenous capability to develop its own technology to sustain the fast growth in demand for the services of both utilities. Consequently, it has had to acquire the necessary technologies from foreign firms. Since its foundation in 1953 MEW has established numerous relationships with highly experienced and specialized foreign firms to provide the required technology for electricity generation and desalination of seawater. All installations have been through turnkey projects. The latest project is the 2400 Megawatt Sabiya Power Plant project costing US$2.3 billion (commissioned in 2001), for which MEW contracted various foreign firms, such as Mitsubishi Heavy Industries and Hyundai Engineering and Construction. The role of MEW staff was limited to legal and administrative issues, such as the assessment of current and future demands, selection of the project's location, budget allocation and issuing the tender. The foreign firms were fully responsible for all other activities including conducting the feasibility studies, providing consultation, project design, project construction, equipment installation, commissioning, operation and maintenance

The non-participation of local staff in the technical aspects had several negative impacts. First, it did not provide any opportunity to develop local capabilities. Second, there was no motivation to boost productivity or enhance performance. The ultimate consequence is that MEW is in continuous need of foreign expertise and a very large number of expatriate engineers are employed on site to operate and maintain the equipment. Kuwait, as a relatively wealthy country capable of purchasing the required technology, has not seen the need to develop indigenous capability.

** Case data provided for Jassim Al-Fahhad, doctoral candidate at Aston Business School by the former Under Secretary of MEW, Engineer Abdullah Al-Munies.*

The focus here is on the role of technology transfer in the development of the technological capabilities of acquirers. Developing such capabilities is a long-term process with various levels of technological competences, the ability to use the technology, adapt it, stretch it and eventually to become more independent by developing, designing and selling it. Therefore, the acquiring firm is not merely a passive recipient of technology but is transformed over a period of time through the process of improving its technological capability following the acquisition (see Lall, 1992 and 1993; Bohn, 1994, and Barbosa and Vaidya, 1997). For an illustration of a company that has considerably improved its capability through acquiring technology see the *Changhong case (Box 4)*, and to see how adaptation of process technology can be necessary for transfer see the *Philips case (Box 5)*.

The ease with which an acquirer can develop technological competence based on technology transfer, depends on the transparency and ease of emulation of technology, the support it receives from the supplier and the absorptive capacity of the firm. At one extreme, the technological knowledge for manufacturing a product could be fully "explicit" in the sense that it can be acquired from a combination of written instructions, design drawings and prototypes. At the other extreme, it could be fully "tacit" knowledge which is embodied in the skills and knowledge of persons in an organisation (or even if it exists in other more tangible forms it cannot be readily acquired by others). Transfer of such knowledge typically requires closer long-term collaboration between the partners. In practice, most technologies are not at one extreme or another but include varying combinations of explicit and tacit knowledge.

Box 4: Changhong Electronics Co. *

Unlike many of China's major electronics enterprises, which are in the coastal areas or provincial capitals, Changhong Electronics Co. is in the relatively minor city of Mianyang in the inland province of Sichuan. It therefore lacks many of the advantages offered to other companies by virtue of their convenient location or special assistance and privileges provided by the Chinese government in the special economic areas. The factory was built in 1958 with help from the Soviet Union and was originally a military R&D and production establishment. However, it is probably now one of the most successful of China's electronics companies and one of the country's leading television manufacturers.

In 1973 the company started research on separation devices in connection with the development of television sets and progressed to making complete products. However, the sets it originally designed and manufactured were not suitable for large-scale assembly, so in 1985 technology more suited to mass production was imported from Japan. The first technical co-operation was with Panasonic for a 14-inch television and facilities to produce 256 sets per day. In 1987, the company again co-operated with Panasonic to build an assembly line with a capacity of 1,000 sets per day. This second co-operation with Panasonic involved a one-off payment of US$ 2 million for the technology. Since then Changhong has had the capability to design and manufacture all its own lines and every line now installed in the factory has been built in-house.

During 1990 there was another transfer co-operation with Panasonic for a TV chassis (the M11). Based on this chassis, Changhong developed its own TV with new functions and reduced costs. The technology for production of a further chassis (the TA) for 25-inch and 29-inch sets was imported from Toshiba in 1992. Since then, Changhong has been virtually self-sufficient and independent of its previous foreign technology suppliers. By 1994 the Changhong Electronics Co. was producing 1.7 million sets per annum and had captured almost 20 per cent of the Chinese market. Its total annual revenues of 2.8 billion Chinese RMB (around US$ 320 million) made it China's largest electronics company by sales revenue. Having created the capacity to produce 2 million TV sets per annum, it had the ability to further drive down prices and become a major competitor in China. It could also start looking towards foreign markets and was in a position to collaborate on new product development (e.g. for high definition TVs) on an equal footing with foreign partners.

To some extent, Changhong's success in absorbing technology from foreign companies lay in the capability it had acquired when working on military electronics applications. However, it also understood the need to improve quality, reduce cost and develop new products that appealed to increasingly discriminating Chinese consumers. As a result it is now one of the few Chinese television manufacturers whose products are considered by Chinese consumers to be comparable in quality with imported products and locally produced foreign brands. * *Case prepared by David Bennett, Aston Business School, based on interviews and visit to Changhong.*

The *Changhong case* shows that the long history of manufacturing experience and the company's own initial R&D efforts, although not commercially successful, provided a base for acquiring capabilities through a number of technology transfer collaborations which enabled the company to produce commercially successful products and become an innovator in partnership with foreign companies. The *Philips* case provides insights into the detailed operational difficulties of implementing transfer projects.

Box 5: Philips in India - adapting technology for transfer *

Philips Telecom Private Mobile Radio (PTPMR) is an autonomous division of the Philips Electronics Group. Its manufacturing site in the UK mass-produces portable and private mobile radio systems and wide-area paging devices, which the company has traditionally sold in Europe. In the mid 1990s, PTPMR identified, and decided to access, the emerging market for pagers in India. Because there were high import duties, a local-for-local production facility was planned. The product chosen for transfer was near the end of its life cycle in Europe but was ideal for the market in India, requiring only minimal redesign. The Indian government was keen for this technology to be transferred to the region and supported the project. The manufacturing process was transferred to an Indian company 40 per cent owned by Philips India, to which PTPMR had previously licensed a portable radio design.

Transfer seemed to be relatively easy. The production concept of cellular manufacturing was suited to the local situation in India and advantage could be taken of low cost labour availability. Also, the host company's existing manufacturing capability and experience of producing radio products was expected to simplify the transfer and the cultural differences were considered to have little impact on the choice of manufacturing processes. However, it was clear that some simplification of the process was necessary to allow the Indian partner to assimilate the process smoothly. The networked computer system used for shop floor control was replaced by stand-alone stations, and a barcode product identification system replaced with manual code entry. The existing test equipment had evolved some redundancy and was simplified, and a laser product-marking machine, considered too complex to maintain and too expensive, was replaced by a printed label system. A simplified MRP (Material Requirements Planning) system that provided a reduced level of functionality and flexibility system was prescribed. In terms of adaptation to suit the local climate, air filtration was prescribed to combat the high levels of airborne dust in that part of India.

Although Indian technicians had been brought to the parent company in the UK prior to the transfer and PTPMR sent a project manager to assess the host site, inexperience of technology transfer led to a number of appropriateness issues not being anticipated. The capability gap between the UK and Indian company was also underestimated, so PTPMR wrongly assumed that the partner was familiar with manufacturing practices such as efficiency improvement, TQM (total quality management), housekeeping, and customer-focus. The conclusion from this case is that PTPMR focused on product and process technology transfer to the detriment of softer issues, such as capability and understanding of the local workforce. Poor communication throughout the transfer, and the absence of a permanent representative of PTPMR in India, resulted in patchy implementation of "fixes" and a misleading picture of project progress. A more rigorous pre-transfer assessment of process appropriateness for host capabilities would have avoided some of the pitfalls encountered.

- *Based on a case described in Grant E B and Gregory M J (1997), Adapting Manufacturing Processes for International Transfer, International Journal of Operations and Production Management, Vol 17, No 10.*

Acquiring technological capability is a cumulative process in which key learning processes are part of the development and use of an acquired technology. Therefore, the accumulation of skills, experiences and technical know-how at the levels of firms, industrial sectors and countries, essential for competitiveness, takes time. The existing knowledge base is important for developing further knowledge and capabilities and new products and processes. The above observations have clear implications for the absorptive capacity of a country and its producers. Technology transfer and learning from it typically take place at the micro-level, i.e. as a part of the relationship between providing and acquiring enterprises and the learning environment and strategies of acquiring enterprises. The learning environment includes the national innovation and learning system, agencies supporting the sector and the network of suppliers, customers and competitors.

Activities formally identified as R&D are only one part of the overall process, which includes learning by doing (increasing the efficiency of production operations), learning by using (increasing efficiency by the use of advanced equipment and complex systems) and learning by interacting with suppliers and customers. In many sectors in industrialised countries, only a fraction of the technological efforts of firms is carried out in dedicated R&D facilities. From a large scale survey of European enterprises, Evangelista et al (1998) show that 50 per cent of the total innovation expenditure is embodied in plant, machinery and equipment purchased by firms. The internal technological expenditures devoted to R&D, design and trial production are 20 per cent, 10 per cent and 11 per cent respectively of the total innovation expenditure with the rest devoted to acquiring technology through patents and licences. Therefore R&D expenditures of businesses, even in industrialised countries form only a part of innovation related activities with an important contribution made by acquisition of externally developed technology.

4. Latecomer industrialisation: the role of technology in development

The high rates of economic growth in East Asia and China ("late industrialisers") have already been referred to in Section 2 and are recognised as remarkable structural transformation drawing on industrialisation *(see "Marginalization versus Prosperity: Reflections on the Development Agenda" by Carlos Magariños, September 2000)*. The following discussion refers to the earlier stages of acquisition of technological capability the late industrialisers. Their gaining of technological capability was based initially on learning to use established technology with virtually no R&D. They combined applicable technological knowledge which could be appropriated from what was publicly available with that supplied by companies from industrialised countries in technology transfer arrangements (principally through sub-contracting and licensing in the early stages).

Their progression of capabilities can be grouped into four broad categories:

(a) knowledge and skills required for the processing of production where shop floor experience and learning by doing play an important role;

(b) knowledge and skills required for investment, that is the establishment of new production facilities and the expansion and/or modernisation of existing ones;

(c) adaptive engineering and organisational adaptations required for the continuous and incremental upgrading of product design, performance features, and process technology, and

(d) the knowledge required for product and process innovation and the creation of new technology in some manufacturing industries.

It is only in the final category above that innovation and development of advanced technology capabilities take place. In the early period of rapid industrial growth, most industrial production in the Asian NICs was concentrated in consumer non-durable industries with relatively low technology requirements. Production capability was thus restricted to the efficient operation of labour intensive production processes. Firms in the Asian NICs have acquired the technological capabilities first and foremost by making judicious use of foreign technology sourcing. To acquire the needed knowledge quickly, they relied on customer firms to provide specifications and concentrated on developing the capacity to produce to specifications at low cost. Korean and Taiwanese firms used original equipment manufacturer (OEM) agreements and Singapore and second tier NICs (especially Malaysia and Thailand) relied largely on FDI as means of entry into world markets. What is crucial in these cases is how effectively a firm combines foreign technology elements with its own experience and knowledge in order to strengthen its internal capabilities.

This focus provided firms with valuable experience in mass production methods and the more successful of them were able to learn from this experience and upgrade product quality, improve production processes and efficiency, move into higher value added segments and develop own brands. The stages for the Republic of Korea are set out in Table 1. This model refers primarily to consumer products. As Amsden (1989), among others, has shown, for heavier industries such as steel, chemicals and shipbuilding, there was much greater state support and protection.

A striking feature of the early development of the Asian NICs is that they largely sought to benefit from available technological knowledge from abroad. In this sense they were "free riding" on the scientific and technological knowledge base developed by the industrialised countries. However, in order to absorb the technological and scientific knowledge, education, and especially technical education, had to be of a high level. The policy focus was on improving education and training to develop the capacity to absorb and use the imported technology efficiently.

The Republic of Korea's strategy for acquiring technological capabilities (see table 1) shows that at the early stages, the emphasis was on acquiring mature technology from abroad with virtually no R&D. The technological capability had to be combined with complementary management skills for commercial success. At later stages, dedicated R&D by enterprises and research institutes, combined with the more basis capabilities learned at the earlier stages, played an important part in developing more advanced capabilities in selected technologies. Liu and White (1997) also found that in the electronics sector in China, beyond the early stage, neither more technology imports nor more R&D alone lead to higher levels of capability and competitiveness. Firms which engaged in both technology imports and R&D did best. This finding neatly links acquisition of technological capability with technology transfer and the internal absorptive capacity emphasised by Cohen and Levinthal (1990).

The Korean approach to science and technology policy contrasts sharply with that adopted in both India and China which have long traditions of basic and applied science research, though a significant proportion of it is in military related fields (aeronautics, space and nuclear). Despite, or possibly because of, the scientific expertise and focus in China and India they have been slow to acquire proficiency in commercial applications of new technologies. This is partly because of sizeable barriers to diffusion of scientific knowledge which raise questions about the effectiveness of the institutional structure or the national innovation system in the two countries. China's success in the last two decades is based on more commercially oriented technology development.

Table 1: Typical technological capability building process: Korean model

	The process of development	**Technology imports**	**Production and R&D**
1960s-1970s	*Goal*: establishment of production base *Characteristics*: heavy dependence on imported technologies	Packaged technology: turn-key based plants Assembling technology	Knock down OEM-dominated Almost no in-house R&D
Early 1980s	*Goal:* promotion of self-reliance *Characteristics*: import substitution, localisation of parts/components production	Unpackaged technology parts/components technology Operation technology	OEM/own brand high ratio Product development
Late 1980s-1990s	*Goal:* export promotion by means of expansion of domestic market *Characteristics*: beginning of plant exports, learning advanced and core technologies	Materials-related technology Control technology Design technology High-quality product technology	OEM/own brand: low ratio Product innovation Process improvement

Source: OECD (1996) *Review of National Science and Technology Policy: Republic of Korea*, OECD, Paris.

Another possible reason is that the scientific knowledge being developed was not of the kind that could be easily commercialised. The diffusion of scientific knowledge to enterprises for exploitation is by no means an automatic process. It requires a number of relationships and appropriate incentive structures which were imperfectly formed in these economies. Birdsall and Rhee (1993), a broadly based econometric study, found no evidence of R&D contributing to economic growth in developing countries. According to the authors, the appropriate strategy for them is to catch up technologically rather than to attempt to advance the technological frontier. There may however be a case for selective R&D related to specific commercial applications *(see for example the Vietnamese 'V' Company case)*.

Box 6: The transformation of V Company in Vietnam *

In 1989 the Gun Young Trading Company Ltd of the Republic of Korea and V Company, a medium sized Vietnamese company, entered into a business arrangement involving the production of blouses and three-layer jackets. The Korean partner provided all materials and designs; the Vietnamese partner took responsibility for setting up and partially equipping an independent workshop for the venture, one that was the envy of workers at other V Company workshops. Gun Young provided specialised machinery and sent technicians to assist in organising production and to supervise production lines and quality control. The Korean experts made regular visits of 4 to 5 months each to Vietnam, training successive teams of workers. After 18 months, when V Company was reasonably confident in its performance, the visits became less frequent.

Other collaborators of V Company, unlike Gun Young, only sent their experts for short periods and at the beginning of the operation only. Under this arrangement foreign companies would send a set of sample designs to V Company, together with technical specifications, for a trial run in a workshop organised and equipped by V Company. After successful completion of the trial runs, V Company and the foreign companies signed an initial short-term contract. With the successful completion of the initial contracts (3 or 4 months) the foreign experts left and production became the sole responsibility of V Company staff. In subsequent collaboration agreements, the foreign companies supplied progressively less detailed specifications and V Company undertook, on the basis of single or partial sample design, to fill the entire order unaided, including cutting, grading and stitching. After further discussions of technical details, V Company took responsibility for further contracts, having mastered repair and maintenance functions after a short period of guidance by foreign experts.

V Company also became involved in yarn manufacture, utilising open end spinning machines that could make use of poorer quality cotton. Between 1989 and 1991, V Company had already invested US$1.75M and in 1991 it imported new equipment for dyeing, knitting and sewing from Japan, the Republic of Korea and the Taiwan Province at a cost of US$2.1M. Although it still needed some assistance from foreign partners in setting up production lines, V Company had by this time become quite proficient in carrying out most investment activities and had acquired considerable experience and confidence in its capabilities.

Together with other companies, V Company established links with domestic R&D and training institutions to seek help in solving technical and managerial problems and provide technical training to its employees. The company cooperated closely with Ho Chi Minh City Authorities in training its personnel and obtaining advice in setting up a new spinning mill that was reputed to be one of the most modern in Vietnam and became a showcase for foreign technical personnel visiting the country on study tours and a model for assisting in the design and improvement of other mills in Vietnam.

Linkages of mutual benefit were established V Company supplied yarn and raw materials to weaving companies in exchange for fabric (or in the case of the Thanh Cong Company, in exchange for technical assistance). Linkages with other companies were the result of prior contacts with management personnel of those companies who had attended the same schools or had worked together for the same employers.

** Case adapted from Ca T N and Anh L D "Technological Dynamism and R&D in the Export of Manufactures from Vietnam", in Ernst D, Ganiatsos T and Mytelka L (eds) Technological Capabilities and Export Success in Asia, Routledge, 1998.*

5. Technology transfer and the slow and very late industrialisers

One of the major objectives of this paper (see Sections 1 and 2) is to draw lessons for the poorer developing countries including LDCs on using technology transfer for improving their industrial development performance. “Developing countries” is a rather vague term which is used loosely, though the criteria for the LDCs category are more precise (see section 1 and note 1). There are also substantial variations in the levels of industrial experience and capabilities between developing countries and even within the LDCs group. For example, in Bangladesh the contribution of the manufacturing sector to GDP is about 18 per cent and revenue from garment exports make up over 52 per cent of total export revenue whereas for Cambodia and Tanzania, the share of MVA in GDP is below 7 per cent.
Precise categorisation of countries according to their levels of industrial development and capabilities is beyond the scope of this paper. We understand that the UNIDO Strategic Research and Economy Branch, in preparing the latest Industry and Development Report, is addressing some of these issues. In the meantime, for our purpose of relating the possible contribution of technology transfer to the level of industrial development, we have identified the following types of country models:

(a) slow industrialisers (including economies in transition); and
(b) very late industrialisers (which may include countries which have virtually no industries at present).

The slow industrialisers are characterised here as countries with sizeable manufacturing sectors with the contribution of manufacturing to GDP of about 15 per cent or higher and possibly a significant contribution to total exports. Typically, they will be larger countries, for example with populations in excess of 25 million, implying they have sufficiently large markets to support at least some basic consumer and food processing sectors. They could be in the low or middle-income categories. Examples include Algeria, India and South Africa. The former Eastern Block economies in transition may also exhibit many of the characteristics of slower industrialisers sketched out here.

The term “slow industrialisers” has been used to reflect limited success in gaining international competitiveness and export growth in the past. At least a part of the explanation for the slowness is that the sectors have not been able to renew their technologies within the business model as successfully as the East Asian industrialisers. The slow industrialisers may vary substantially in their recent progress. Some of them, within a more favourable policy regime and approaches from foreign firms, may have already started the process of developing their technological capabilities and competitiveness through a combination of technology transfer, collaborations with foreign firms, their own efforts and making use of their industrial networks and national innovation and learning systems.

In general, through their previous industrial experience the more established sectors may be more capable of assessing their technology needs. Because of the size of the domestic market or low-cost base they offer, they will also be more attractive to foreign partners. Depending on the sector, they could be strengthening their position within Routes 1, 2 or 3 (see below). Typically, there will also be sectors which are less developed and a large number of small enterprises engaged in formal or informal production activities. In addition to the upgrading of the established sectors, if the business conditions are favourable (economic policy and stability and availability of relevant factors), there is also scope for upgrading of the less developed sectors (see Routes 1, 2 and 3 below) and the emergence of new manufacturing and service sectors, based on traditional sub-contracting and exploitation of new technologies.

The slow industrialisers are also the countries which may have severe problems in relation to the adverse impact on the environment. Paradoxically, in this respect, they are likely to be in a similar position to the East Asian economies which, in their pursuit of the economic dimension of industrial development, paid less attention to the environmental implications. Therefore, there could be substantial scope for investment in ESTs in new investment and replacement of older industrial capacity.

The very late industrialisers are developing countries with small manufacturing sectors. Typically, they are in the World Bank "low income"[2] or the UN LDC category. Most of the domestic enterprises will be small or medium sized enterprises (SMEs) engaged in light manufacturing mainly for the domestic market. For some of these countries (for example, small island economies), industrial development may not be the appropriate route. However, for most of the others with substantial populations and inability of farming and other parts of the primary sector to contribute to economic growth, some level of industrialisation and, possibly development of modern services, is important. There is likely to be heavy representation of African countries among the very late industrialisers.

For the slow and very late industrialisers, the main lesson from the East Asian experience is that acquiring established technologies and building up technological capabilities based on their application is a good starting point. Technology is an important supply side factor. Nevertheless the success of technology transfer must be judged by the positive impact it makes on the performance of the recipient and the industrial sector and not simply by successful technical implementation of the project *(The Great Wall Machines case in Box 7 illustrates this aspect)*. For sustainability, in keeping with the SID concept (see section 2), at the level of the enterprise, success could be defined as profitable growth *(or improvement in financial position if the company and sector are loss making)*, no adverse environmental impact *(or if this is too restrictive, acceptable environmental impact)*, and contribution to socio-economic sustainability through protection and creation of employment. The available evidence from many parts of the world shows that for technology transfer to make a significant and lasting contribution to the development of capability, it must take place within a commercial orientation (Hobday, 1995, and Levy, 1994) or the business model.

In summary, technology transfer is most successful and makes the greatest impact when it is:
(a) congruent with the strategies and objectives of firms;
(b) complemented by firm-specific factors to ensure absorption, adaptation and learning;
(c) supported by related and supporting sectors, agencies and factors, and
(e) market oriented.

Different countries start from different levels of industrial development and capabilities. A framework for setting out paths for the development of industrial capability and the role of technology transfer within it for the very late and slow industrialisers is set out here. The guiding principles in setting out the framework are that:
(a) at every level of industrial development, there is scope for development of capability;
(b) the technology transfer should be for appropriate sectors and at appropriate levels;
(c) there should be commercial benefit for all parties (although this could be indirect in the case of the technology supplier); and

(d) it should take account of the incentives for the supplier to supply the technology.

Box 7: Great Wall Machines *

China Great Wall Machines (CGWM) is a small technologically based company. In 1993 it established a co-production partnership with the UK based company, Matoco who supplied technology for a best selling machining centre from its latest product range. The price paid for the technology, which included provision of training, was considered by CGWM to be high but they agreed the asking price having assessed the benefits of sharing Matoco's good reputation and capability to supply advanced technology and high quality. After three years of collaboration CGWM was able to build good quality machines but managed to sell very few of them. As a result, the added value realised by the seller and the acquirer was small, CGWM was likely to incur significant financial losses and Matoco doubted the strategic benefits from continuing to collaborate with CGWM. However, in 1996 CGWM changed its marketing strategy from selling single machines to focusing on designing production lines and started winning orders for sets of machines to be integrated into these lines. Consequently its sales of the machining centre that year were greater than those of any other CNC machine tool manufacturer in China. Not only has transfer value been greatly improved but the strategic significance of the collaboration has also been recognised by Matoco. Negotiations for a further, and closer, collaborative agreement were therefore initiated to include more transferred technology, its value reflecting the partners' mutual financial and strategic benefits.

** Case prepared by Kirit Vaidya and Zhao Hongyu, former doctoral candidate at Aston Business School, based on visits to both partners*

By virtue of the fact that the level of technological capabilities is low and suppliers of technology have not been attracted, changes in the policy environment and other enabling interventions are required. The framework attempts to identify these changes and the role of the government and international agencies in bringing them about. These factors are then linked with the possible role of UNIDO as a lead institution in technology transfer.

For the very late and slow industrialisers, there are three routes for acquiring transferred technology which meet the conditions for success outlined above. These are:

(a) technology transfer through trade and aid to strengthen indigenous production for domestic markets;

(b) technology transfer through FDI and contracting to build export oriented local companies, and

(c) technology transfer through the supply chain of capital equipment and materials to develop local sub-contracting capacity.

The appropriateness of each route depends on the level of industrial development in the country concerned. For countries at the lowest level development all three routes can be regarded as steps on the ladder towards greater industrialisation. Ultimately the objective is to achieve greater independence through development of capability and competitive advantage. The idea of progressing upwards via these routes is analogous to the East Asian 'stages' approach to technological capability development discussed earlier. However, the special circumstances of the least developed countries as well as the context of sustainability within which the UNIDO initiative is placed have been taken into account when devising the framework.

Route 1. Technology transfer through trade and aid to strengthen indigenous production for domestic markets

Initial conditions

All industrialising countries go through an early stage of import substitution and developing the capability of local companies to make alternative products. Most very late industrialisers are at an early stage of import substitution in a few sectors. Even where countries have progressed to later stages (for example the slow industrialisers), in many sectors, their industries will be competing with imports in the domestic market.

For the very late industrialisers, the industrial situation can be broadly characterised as follows.

(a) Manufacturing value added and manufactured exports per capita will be low. Growth of manufacturing exports will also typically be low signifying limited progress in improving competitiveness. In 1997 the top10 manufacturing countries had an MVA per capita of around US$ 5,000 or more, while for the bottom 10 countries it was around US$ 16 or less. In the same year the manufactured exports of the top 10 countries was between US$ 4,000 and 28,000, while almost one hundred countries did not record manufactured exports of more than US$ 5 per capita *(WSSD Industrial Source Book).* Exports are likely to be processed or semi-processed agro-products (for example cotton yarn and coffee).

(b) Production will be primarily for the domestic market in sectors or market segments in which imports cannot compete effectively on price. Examples are agro-processing of domestic agricultural crops, furniture making and producing light agricultural equipment and hand tools. Even if there are imports in these categories, the domestic production offers cheap lower quality substitutes. Some of the manufacturing activities may be in informal workshops organised as crafts (for example rural furniture and tile making) and therefore may not even be formally recognised as manufacturing.

(c) Typically, there will be very limited technology transfer and low levels of technological capability partly because of lack of knowledge of the options available and partly because of lack finance and unwillingness to take risks in the face of poor commercial prospects *(for further discussion on this aspect see Biggs and Srivastava, 1996).*

The rather pessimistic situation described above is a broad generalisation. There can be adoption of improved technology induced by the entrepreneurial activities of individual firms enhanced by its diffusion in a network. An example of this is the switch from making roof tiles in traditional wooden moulds to the use of mechanical presses. Apart from the purchase of hand presses, the latter required clay mixers, which were too expensive for individual tile makers. The cluster enabled sharing of the capital cost. The remaining tile makers learned from the technical and marketing experiences of the early adopters and followed them into the adoption of the new technology. The early adopters encouraged other tile makers to make the switch to spread the cost of the clay mixing equipment and to enable members of the cluster to take on larger orders, which could then be sub-contracted out if necessary (Sandee and Rietveld, 2001).

<u>*The role and nature of technology transfer*</u>

Box 8: Cases of technology transfer in South Africa *

Wynberg Watch

Because of the crime situation in South Africa, the security industry is growing rapidly. An employee of one of the large security companies in South Africa had responsibility for installing security systems in upmarket homes in the Cape Town area. These would typically include motorised entrance gates and garages, security lighting, burglar alarms and electric fencing. The most technically complex aspect of the business was selecting the correct electronic control system. The employee saw a gap in the market for middle and lower income families and set up his own company, Wynberg Watch, while still sourcing his equipment from the same UK-based parent.

He saw the potential for several improvements in the design of the electronic circuitry and installation procedures. His redesigns were approved by the UK company. The new entrepreneur also undertook maintenance work both for his present customers and those of his previous employer. He sourced replacement parts at a much cheaper rate, and designed systems that were more appropriate to the harsher operating conditions in the poorer homes. These were installed by Wynberg Watch, which soon employed 12 staff. Partly because of the depreciation of the South African rand, importing systems and components from the UK became too expensive. With their technological expertise Wynberg Watch now design, build and install their own security systems which are only partly still based on the original UK designs.

Epping Printing

This traditional printing firm in Cape Town employed 30 printers. In order to expand his services, the owner investigated the feasibility of high quality, multi-colour printing on fabrics, and in particular, T-shirts. He identified the need for distinct, clear colour separation. His investigation led him to an Italian supplier of printing machines. An informal agreement was entered into whereby the Italian firm would supply the machines and train the operators. The Italians installed the printing machines and the software for receiving designs/photographs from clients. A royalty would be payable to the Italian firm in return for technical advice and maintenance services by the Italian firm's local representative.

The enterprise was so successful that it found it difficult to keep up with the demand for T-shirt printing, most of which came from small businesses in Cape Town serving the tourist industry. Tourists could photograph a scene, have this e-mailed to Epping Printing, and T-shirts would be delivered within two days. After a year the local firm no longer required the services of the Italians as all enquiries could be serviced by Epping Printers. The machines were fairly robust, but when failures did occur, the local company could undertake repairs.

* *Cases contributed by Ian Hipkin, formerly of the University of Cape Town, They are from projects undertaken by students in the School of Management Studies.*

The typical motivation for technology transfer in Route 1 will be to improve the acquirer's competitive position in the domestic market. This could be through reduction in costs through changes in processes or improving the quality of products. The improvement could be at the expense of domestic competitors or importers. The main emphasis will be on improving some combination of quality, reliability, delivery, flexibility, time to market and cost. The product may also be an innovation for the domestic market *(see the case examples of Wynberg Watch and Epping Printing in Box 8)*. Wynberg Watch illustrates technology transfer for a market segment in which imported products are too expensive and therefore a local substitute was developed based on the designs of the imported technology. Epping Printing is an innovative service based on imported technology. The acquirer eventually reduced dependence on the foreign technology supplier.

There are possibilities of intermediate technology innovations even at this level of development. These may be brought about by domestic entrepreneurs or by external firms or agencies. An example is the development and commercialization of the treadle irrigation pump in Bangladesh as a more efficient means of water extraction than the traditional methods and a cheaper alternative to imported diesel pumps *(see Box 9)*. This case demonstrates that development and dissemination of appropriate technology complemented by transfer of improved management methods and strategic intervention in the supply chain can ensure quality of a locally designed product, increase demand, and foster competition and affordable prices. The treadle pump now has sustained sales through a number of small, independent, enterprises, and 1.3 million pumps have been installed throughout Bangladesh.

Another example is the development of the solar powered lantern and appropriate manufacturing and assembly techniques to enable local production in Africa *(see the solar lamp case in Box 2)*.

It is clear from the above discussion that the prime actor in the process of technology transfer in Route 1 is the technology acquiring firm, which will typically be an SME. The main elements required for technology transfer are:

(a) generating motivation *(related to entrepreneurship)*;
(b) recognition of the current situation and opportunities by potential acquirers;
(c) identification of appropriate technologies by the entrepreneurs;
(d) developing the absorptive capacity;
(e) managing the transfer process, and
(f) financing.

Some of the elements identified above (especially, (a) and (f)) are general issues related to the management of SMEs. The remainder are more specific to the technology transfer process. The role of agencies in this respect would be to provide entrepreneurship training and access to information about technological opportunities. These are the typical areas in which extra effort is needed in supporting SMEs. The distinctive features resulting from this assessment are that it identifies the potential for technology transfer at low levels of industrial development and makes a case for more attention to development of appropriate innovations. This calls for strengthening capabilities in the development, manufacture and commercialisation of appropriate or intermediate technologies and products possibly in collaboration with NGOs and firms with experience in this field.

Box 9: The treadle irrigation pump in Bangladesh *

In 1979 a treadle powered suction irrigation pump was developed in northwest Bangladesh by Rangpur Dinajpur Rural Service (RDRS). It was intended to meet what was perceived as a demand for irrigation pumps that offered an alternative to the existing hand-operated swing basket or scoop methods of water extraction. The foot-operated mechanism of a treadle pump was able to extract much larger volumes of water and was easier to operate than the traditional methods. The manufacturing cost was only one tenth of the Chinese-made diesel pumps that were sold locally. The RDRS agricultural workshop in Rangpur began manufacturing the pumps in 1980 with an initial output of 600 pumps per month. To boost production RDRS helped to finance four private workshops, increasing the monthly output to 3,500. However, capacity was still limiting sales. There was also no nationwide distribution network and the short supply chain from manufacturer to user did use the promotion potential of retailers.

To assist with solving the problem of increasing production and expanding the market RDRS turned to International Development Enterprises (IDE), a non-governmental organisation based in the United States. IDE transferred the management technologies necessary to support and develop the supply chain of manufacturer, dealers, installers and customers. Its strategy involved a number of aspects:
- Diversifying the production base. IDE began working with affiliated manufacturers throughout the country to expand the production base and foster competition.
- Quality control: IDE acted as a wholesaler, purchasing pumps from the manufacturer, carrying out quality inspections, branding the pumps and selling them to a network of rural dealers.
- Promotion. As well as using a variety of commercial promotional techniques IDE promoted the pumps at farmers' rallies using local stories as the background to sell the pumps.
- Training. Links were identified and built with local traders – mostly small hardware shops – that were interested in selling pumps. IDE also trained and supervised the work of installation teams.
- Creating a dealer network. A nationwide dealer network was established to purchase pumps at wholesale prices and sell them to farmers. Ceilings were set on profit margins for both producers and retailers.
- Co-ordination. IDE helped to co-ordinate the activities of other organisations involved with manual irrigation pump technology. This led to discussions about joint promotional materials and the setting up of a credit programme.
- Access to financing was identified as the key issue for all stakeholders in the supply chain for the treadle pump. The formal sources of finance (commercial banks and state banks) were less helpful for the small manufacturers because of the collateral requirements, high interest rate and bureaucratic procedures. Informal means (friends, family and money lenders) and credit facilities extended by raw material suppliers were preferred.

In 1990/91, IDE set-up *Krishok Bandhu* (Farmer's Friend) as a brand name for marketing and sales to establish a quality benchmark and to sell pumps and other agricultural products through an exclusive network of manufacturers, dealers and installers. This subsequently became an independent limited company in 1995. In 1998, the Quality Partner Catalyst Approach was developed to increase quality consciousness among stakeholders in the supply chain, to achieve greater customer satisfaction, increased sales and a higher return on investment for all stakeholders.

** Based on a case study by International Development Enterprises, August 2000.*

A particular aspect of technology transfer in Route 1 is that it normally makes a contribution to all dimensions of sustainability. There is contribution to economic sustainability because of an increased contribution to value added achieved by the improvement of competitiveness. In general, the benefits accrue to smaller firms in the form of better financial performance and improved capability and the products benefit the poorer parts of the population. In the case studies used in this paper *(the solar lantern, Box 2, and treadle irrigation pump, Box 9, cases)* the technologies transferred are relatively low-tech and environmentally friendly and the products (the treadle pump vs. the diesel pump; the solar lantern vs. the battery torch) also make smaller claims on exhaustible resources and have lower damaging effects on the environment. This may however not be the case for all technologies acquired under this route and therefore measures for ensuring environmental sustainability may be needed.

Route 2. Technology transfer through FDI and contracting to build export oriented companies.

Initial conditions

Technology transfer using Route 2 has been a feature of the global economy in the last 30 years and is common in both industrialising and developing countries. Sub-contracting of complete products or components is used in a range of industries including manufacture of light consumer goods such as garments, sports shoes and leather goods, electronics and even commercial aircraft production. The successful industrialisers have used technology transfer via Route 2 as a part of their development strategies. In some relatively low-tech sectors (for example, garment manufacture) with increasing incomes and labour costs, the successful industrialisers have lost competitive advantage and relinquished their position to lower cost producers (Yang and Zhong, 1996, and Hobday, 1995*).* In other sectors, especially electronics, they used the capabilities acquired from sub-contracting to develop their own innovative capabilities

The conditions required for the producers in a country to attract technology investments through subcontracting are well known. When countries can offer an advantage in terms of low cost labour within a favourable policy environment, they become attractive for foreign companies looking for lower cost production bases. Usually firms looking for sub-contractors require that there are existing producers in the sector who are capable of taking on contracts. Where producers are entering into sub-contracting for the first time, they may lack the technical and management capabilities to produce in the volumes required and meet exacting quality specifications. The requirement is that there is a capability to learn and adapt rapidly.

The role and nature of technology transfer

The acquirer's objectives in entering a subcontracting arrangement are much wider than acquisition of technological capability. In the short term, the objectives are to increase sales, and especially export sales, and profits by joining the supply chain of a foreign firm with presence in foreign markets. Entering export markets is difficult for firms in developing countries because of lack of (a) familiarity with the markets and product preferences in them, (b) technological and management capability to develop products and adhere to quality specifications, and (c) an established position in the markets. In the longer term, the gains for the acquirer include upgrading of technological and management capability.

The technology acquired as a part of a sub-contracting arrangement will be relatively low-tech in international terms especially for new sub-contractors. Transfer may be through acquisition of equipment and / or know-how from the customer and / or existing upstream foreign suppliers to the sub-contractor's customer. In some sectors, there might be more complex arrangements such as licensing or co-production with greater help and close control by customer. Finance is usually not a serious obstacle issue because, where appropriate, the subcontracting arrangement contains financial support from the customer or the contractual arrangement will make it possible to arrange finance. The customer may also share the investment cost by providing FDI, often through the supply of tools, equipment and training, to assist the contracting firm to develop the necessary capacity.

In Route 2 the foreign firm will typically take the initiative and be seeking the resources in a developing country to enable production costs to be reduced. For countries new to sub-contracting, this is an obstacle because firms looking for subcontractors are likely to go to countries with which they are familiar or where other firms in their industry are located *(see Africa can compete case in Box 10).* It is however possible to make an entry into sub-contracting even if all the initial conditions do not exist *(see the Mauritius case in Box 11).*

Box 10: Africa can compete *

A study of African competitiveness in supplying garments and home products to the US presented a strong case that the US market presented a window of opportunity for African garment and crafts manufacturers. The countries studied were Kenya, Ghana, Senegal, Cote D'Ivoire and Zimbabwe.

There were two potential niches that African manufacturers could exploit, the study argued. The first was a growing market among African-Americans for African apparel and crafts. Since authenticity is almost as important as design for these consumers, and since the market, worth about US$ 190 to US$ 258 million in the mid-1990s was expected to grow to US$ 400 million over the next several years, African garment manufacturers were in a unique position to exploit this potential. The second niche was the market for low-cost apparel, where African manufacturers have the dual advantage of being quota-free and having low labour costs.

However, if African manufacturers expected to sell increasingly to the American market they had to be prepared to supply US wholesale buyers on their terms. Too often a lack of information on their own production costs (leading to poor price negotiations), financing problems and other constraints led to unproductive relationships.

* *From Biggs T, Moody G, van Leeuween, J and White, E (1994) Africa can compete: export opportunities and challenges for garments and home products in the U.S. market, World Bank Discussion Paper WDP242 (Africa Technical Department series), World Bank, Washington.*

An important obstacle is sometimes the economic policies of the government in the host country, which may cancel out the advantage of lower labour costs. These could be macroeconomic policies which lead to an uncompetitive currency or regulation of trade which imposes high costs on importing inputs and exporting outputs. The potential sub-contractors need to be aware of the need to upgrade their capabilities in order to meet the exacting standards on quality, timeliness, costs and adaptability. As noted above, the initiative in establishing sub-contracting relationships is usually with the customers, so for new entrants, support is required to promote opportunities to potential customers.

There is a view that Route 2 is not appropriate for acquiring technology because of the low level of capability it provides. However, the evidence from the late industrialisers shows that as well as providing access to export markets it develops technical and managerial capabilities at the early stages of industrialisation, although a strategy for developing more advanced capabilities in selected sectors would be needed to take Route 2 beyond simple sub-contracting to the stage where companies become independent exporters in their own right.

It is also argued that the gains from Route 2 could be very short-lived with the customers moving rapidly out if the business environment changes. In the short term this is an incentive for policy makers to ensure that the country remains attractive to investment in the form of contracting. In the longer term, increase in labour costs with increasing incomes will lead to some sub-contracting moving out of a country. Some movement is inevitable and even in the industrialised countries, where sub-contracting is still common, there are losses and gains as customers change their sources of supply.

Box 11: Exporting from Mauritius *

The Export Processing Zone (EPZ) in Mauritius was initiated in early 1971 in response to the country's economic difficulties during the 1960s. There was over-reliance on the sugar industry, especially for export earnings, rapidly increasing population and high level of unemployment.

The basic idea of the Export Processing Zones Act was to provide a package of fiscal concessions and other benefits that would attract overseas manufacturing firms with established markets to locate the labour-intensive parts of their activities in Mauritius. The incentive package included a tax holiday, the option to repatriate profits and duty exemptions on imports of machinery, equipment and raw materials. These distortions were thought to be necessary to attract investors to a country with limited industrial reputation and experience.

An important local innovation was that the EPZ was not to be limited to a geographically restricted area. A limited zone would have required additional investment in factory buildings and infrastructure developments, which would have increased costs, delayed developments and prevented existing firms from taking advantage of the EPZ without relocating.

The EPZ has transformed the Mauritian economy which grew by an average annual 5.9 per cent between 1973 and 1999. Since 1982, output of the EPZ has grown by 19 per cent a year, on average, employment by 24 per cent, and exports by 11 per cent. The export-processing zone accounts for 26 per cent of GDP, 36 per cent of employment, 19 per cent of capital stock, and 66 per cent of exports. Moreover, a growth-accounting analysis demonstrates the exceptional productivity of the zone. During 1983-99, total factor productivity growth in the export-processing zone averaged about 3.5 per cent a year, compared with 1.4 per cent in the economy as a whole. In the 1990s, productivity growth in the export-processing zone was remarkable, averaging 5.4 per cent a year.

**Source: Finance & Development, 38(422-25), December 2001, IMF.*

A further argument which induces pessimism with respect to the potential for acquiring capability through Route 2 for both the slow and the very late industrialisers is that some large countries such as China, with very low labour costs and an abundant labour supply, have established themselves in sub-contracting in a large range of sectors. This is clearly an obstacle. However, there could be some scope for specialisation, for example in ethnic products from Africa *(see the Africa can compete case in Box 10)* or products utilising local raw materials, which might reduce head-on competition on cost with large countries with a large pool of low cost labour.

Route 3. Technology transfer through the supply chain of capital equipment and materials to develop local sub-contracting capacity.

Initial conditions

This also involves sub-contracting but for foreign firms, or joint ventures with foreign firms, manufacturing or assembling within the host country. The sub-contracting arrangements in Route 3 will be for components and sub-assemblies rather than complete products. As for Route 2, firms require some related industrial experience, although the economic conditions should be conducive to local manufacture instead of importing. Local content rules are often a reason for sub-contracting. Under WTO's Trade Related Investment Measures (TRIMs) minimum local content requirements will not be permitted in future but there will still be the incentive for customers to sub-contract locally on the basis of cost, to retain goodwill in the host country and as part of offset agreements to win orders. Initially, local procurement is likely to be limited in scope and for less advanced components. Later increases in scope and more advanced production requirements will come about if the initial arrangements are successful and the sub-contractors develop their capabilities.

The role and nature of technology transfer

Like Route 2, the acquirer's objectives in entering a sub-contracting arrangement with the customer are much wider than upgrading technological capability. In the short term, the objectives are to increase sales and profits by joining the supply chain of a foreign firm. In the longer term, the benefits are a continuing business relationship with the customer and development of technological capabilities for pursing other opportunities. A difference with Route 2 is that the supplier is less likely to be dependent on a single customer. Firms in, for example, the automotive or electronics sector supply chain may commonly be producing for a number of different customers. For this reason, and because there is an objective on the part of customers to source locally, they are less vulnerable than firms in Route 2.

In broad terms, the nature of the technology transferred will be similar in level to that in Route 2 i.e. relatively low-tech in international terms, especially for new sub-contractors. However, there are often greater opportunities with Route 3 to move quickly up the technology ladder as the customer sub-contracts more advanced components to suppliers that have demonstrated the capability to absorb and master the transferred technology. The acquisition of technology may be from the customer and / or existing upstream foreign suppliers to the customer through purchase of equipment. In some sectors, there might be more complex arrangements such as licensing or co-production with more help and close control by the customer. Finance is also less of an issue because the subcontracting arrangement might itself contain financial support from the customer or the contractual arrangement will make it possible to arrange finance.

The benefits to the customer (and also the technology supplier if this is not the customer) are that it localises the supply chain of capital equipment and materials with possible cost advantages. Technology may also be supplied by the upstream suppliers of products, components and manufacturing technology to enable the local sub-contracting arrangement. By agreeing to transfer technology, they retain or strengthen their relationship with the customers and possibly develop a low cost export base by collaborating with the new local sub-contractor *(see Wuxi-Walter case in Box 12).*

Box 12: Wuxi-Walter – a German tool manufacturer in China *

Wuxi-Walter makes carbide cutting tools with replaceable inserts. It was formed as a joint venture in 1996 between a German partner (Walter), and a high-speed steel tool manufacturer based in the city of Wuxi in Eastern China. The Chinese partner contributed the building, some Chinese machines used for production and provided all the production personnel. The German partner, Walter, put in the imported machines, software and cash. When the company was established six Chinese staff were trained in Germany for 5 months as part of the agreement.

The reason Walter entered into a joint venture was that it was having difficulty selling into the Chinese market. Its products were expensive compared with those of its main European competitors who already had operations in China. The price of tools in China is approx. 40 to 50 per cent lower than in Germany.

The main customers for the cutters are in the automotive industry. Initially the tools were sold mainly to automotive manufacturers in China with some exports to the Taiwan Province and the Republic of Korea (only around 5 per cent). Originally just 9 people were employed on production and 40 people in sales. Now there are 100 employees of which approximately 40 are related directly or indirectly to production approximately 60 per cent of Walter's tools sold in the Asia Pacific Region are manufactured in China and within the next 3 years this is planned to increase to 90 per cent.

** Case prepared by David Bennett and Kirit Vaidya, Aston Business School, based on interviews and visit to Wuxi-Walter.*

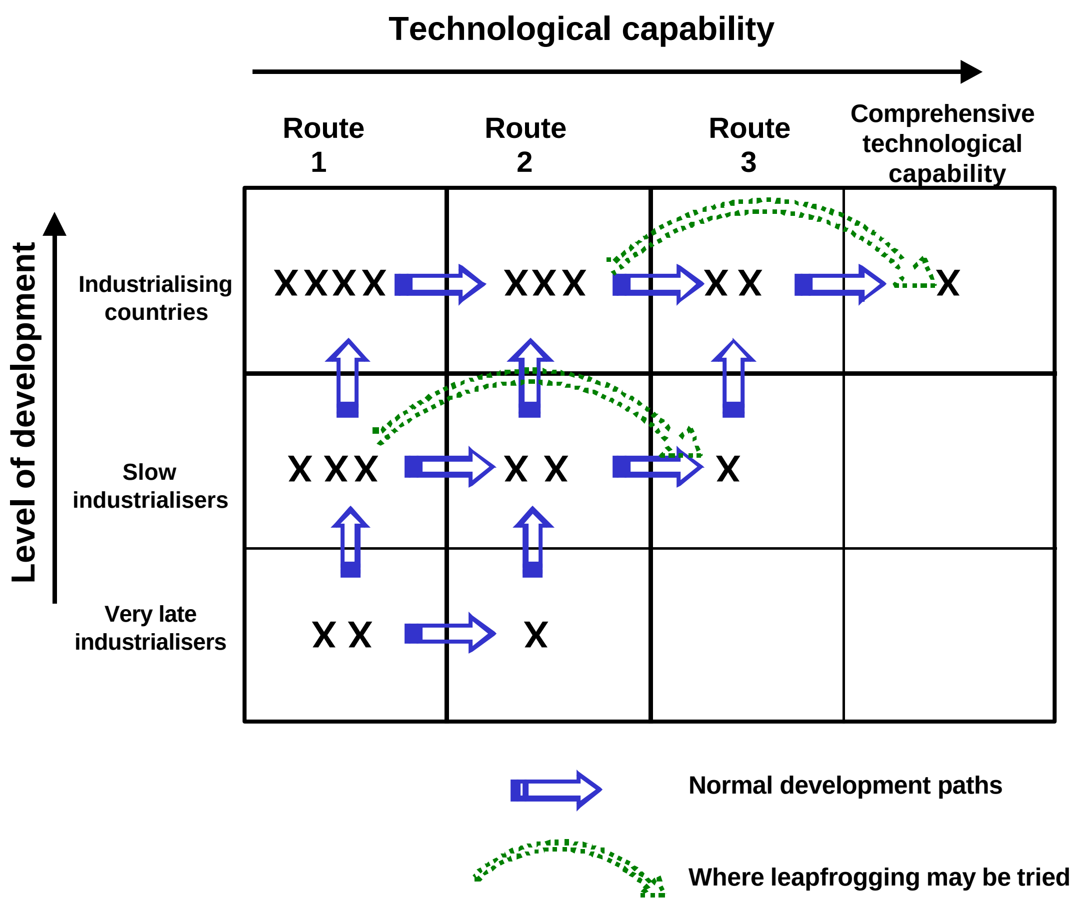
Some of the obstacles and gaps to be bridged are similar to those for export oriented sub-contracting. For example, government economic policies have to be favourable. The emphasis is more on domestic market attractiveness than the costs of exporting. Potential sub-contractors need to be aware of the exacting technical standards that are applied by foreign subsidiary customers or foreign joint ventures. In addition, they will also need to learn the complementary managerial technologies such as JIT (just in time), TQM (total quality management) and ERP (Enterprise Resource Planning) to enable the customer to manage the supply chain effectively. One of the factors that a foreign company will take into account when deciding to locate in a country is the potential of setting up a local supply chain.

In both Routes 2 and 3, the relationship with foreign firms is likely to continue with more advanced technology being transferred at later stages. For example, when the cost of making sports shoes in the Taiwan Province and in the Republic of Korea increased because of increased incomes and labour costs in those countries, Nike maintained its relationship with their experienced Korean and Taiwanese contractors who continued to make the more advanced shoes and materials. The Korean and Taiwanese contractors also set up subsidiaries in lower wage countries (for example, China, Thailand and more recently Vietnam (Donaghu and Barff, 1990).

Over time, in some industries, the relationship between the acquirer and the supplier may become more equal and, for the acquirer, one of partnership rather then dependence as its capability strengthens. The capability acquired will also be transferable and can be applied in developing relationships with other customers or towards producing own products. Further development of capabilities requires national strategies, which include establishment of dedicated research institutes in selected sectors and support for clusters and innovation networks.

Figure 2 shows the relationship between the three routes described in this section and the relevant levels of country development for which each route is appropriate. The figure shows the paths that can be followed as countries climb the ladder of development until they achieve the comprehensive technological capability associated with industrialising countries. It also shows where there are possibilities of 'leapfrogging', for example where China's township enterprises have moved from products from the domestic market (through Route 1) to supplying Sino-foreign joint ventures in the automotive industry (Route 3), or where the Republic of Korea's electronics component manufacturers have moved from sub-contracting (Route 2) to developing their own large-scale memory chips (comprehensive technological capability).

Figure 2: Paths to development and increasing technological capability



Developing the role of small entrepreneurial exporters

The focus of this paper is on the role of technology transfer. However, for this to lead to development of technological capabilities, conducive government policies and effective learning strategies and the ability to learn are required at the level of enterprises. According to Mytelka and Tesfachew (1998), the policies for encouraging foreign investment used by a number of African countries did not develop local capabilities. Trade policy instruments and fiscal and monetary policies were by and large geared to reducing the commercial risks to foreign investors and protecting their profits. The type of investment that was encouraged tended to be capital intensive and intended to replicate technologies and products from industrialised countries. In Kenya, Langdon (1989) found that development of capability through learning was limited in foreign owned and joint venture firms but smaller family firms were found to have engaged in learning by doing, made different choices with regard to inputs and machinery and equipment and been able to cut costs. The main explanation appeared to be the protection of FDI firms and the need for the smaller enterprises to be entrepreneurial to remain competitive.

In the three routes developed above, continuing collaborative relationship with the technology suppliers is an important method of developing capability. This assumes that the foreign partner benefits from this relationship and often the foreign partner has an interest it the acquirer developing capability and share the benefit with the partner (in the form of better products and lower costs). The exception is when the acquirer threatens to become a competitor. At the early stages of developing capability, the acquirer will typically be more dependent on the supplier. However, with greater capability, the firm will also gain the ability to learn from other sources such as publicly available information, reverse engineering and hiring specialist consultants.

The other route for developing capability is working within clusters of local enterprises to benefit from the sharing of knowledge, mutually beneficial learning from suppliers, customers and even competitors and sharing the cost of some resources. The role of clusters and networks in learning and related policy implications has been well documented (for example, see Humphrey and Schmitz, 1995, Nadvi, 1995 and Fisher and Reuber, 2000). For clusters and networks to retain their ability to learn and innovate, they need to be outward looking and open. Technology transfer which provides one of the external stimuli for clusters could make an important contribution to their learning and innovation. Identifying actual and potential clusters and enabling them to identify appropriate technologies and develop links with technology suppliers is an important role for policy.

The above discussion has identified a number of important roles for government and international agencies as enablers of appropriate technology transfer and the development of broader conditions required.

(a) The first is to make an assessment of the current competitive position and state of technological capability of the existing industrial sectors and identification of actual or potential clusters. These will depend crucially on the level of development of the country.

(b) Given the existing level of capability, the next task is to identify the most appropriate technological upgrading and the potential for development of new products. This identification is a crucial but difficult process which should not be imposed by a government agency.

(c) With regard to the problems, aspirations and possible opportunities, the input should be from the firms or the industry association representing them.

(d) With respect to possible solutions and opportunities, input will be required from foreign firms in the same or related sectors and institutes and other organizations involved in developing appropriate technologies. Although firms in the same sector may be unwilling to participate because of concerns about competition, this may be less of an issue in the domestic market development route. In the other routes, the main external participants will not be competitors and so the potential for conflict is less.

Foreign investment promotion agencies with a widened scope may be the most appropriate agencies. However, in order to develop in this direction, in most countries they will need a substantial amount of assistance from external agencies such UNIDO. There will also be a role for the Africa-Asia Investment and Technology Promotion Centre (AAITPC) and similar agencies in promoting and facilitating South-South technology transfer.

Virtually all studies of technology transfer and development of technological capability emphasise the importance of (a) macroeconomic policies (b) the broader institutional aspects such as the effective implementation of policies, and (c) a technically skilled and proficient labour force (for example, see Mytelka and Tesfachew, 1998). Clearly these aspects are beyond the scope of short-term strategies for technology transfer. However, they are crucial for the development of technological capabilities and many countries require support in achieving these conditions.

The prospects for bucking the conventional stages model

The slow and the very late industrialisers find it discouraging to contemplate slow acquisition of capability in the stages model, with step by step build up from the present state. With the rapid development of new technologies and the quickening pace of technological development, there is even more concern about the widening gap in technological and economic development, between the developing and developed countries.

The possibility of technological leapfrogging as a means of bridging this gap is often raised. The notion of leapfrogging can be considered at a number of different levels. It could be at the level of the country where the conventional evolution of countries is to move progressively through the phases of pre-industrialisation (with mainly a primarily sector based on agriculture and other extractive activities), industrialisation (with the secondary sector based on manufacturing making the largest contribution to GDP) and post industrialisation (a tertiary sector based on service activities dominating). Within the industrialisation phase, the more successful industrialisers started with mature technologies and progressively moved to more advanced technologies in selected sectors.

Some countries have attempted to leapfrog from mature to advanced sectors and technologies through heavy investment in science and technology and acquisition of foreign technology. In the past 15 years, the growth of China's manufacturing sector has been amongst the fastest in the world. It has also had ambitions to leapfrog from mature to advanced sectors. The available evidence (Bennett, Liu, Parker, Steward and Vaidya, 1999) shows that China's export volume and comparative advantage are still primarily in labour intensive low technology industries such as garments, toys and sports goods, watches and clocks and travel goods. However, China has a large and growing broadly medium-tech electronics sector which provides it with a base for developing into advanced technology areas. Its initial capability has been attained through acquisition of technology to assemble TVs and other consumer electronics products. However, FDI, technology transfer and the base of experience have enabled the more capable firms to move into more advanced technology sectors. Telecommunications equipment is another advanced technology sector in which China is acquiring technological capability, largely through collaborative ventures with foreign investors.

The development of the Republic of Korea's capabilities which has been studied by many authors and discussed in section 4 demonstrates that 'leapfrogging' to higher levels of capability cannot be achieved without a country having gathered sufficient momentum through learning complemented by dedicated R&D *(see Box 13 on the Republic of Korea's progression).* This may appear to be a discouraging message for latecomers. It is also argued that the slow developers and the very late industrialisers are at a disadvantage in competing with the newly industrialised and industrialising countries. However, they also have the advantage of learning from the earlier industrialisers. The evidence shows that if the policy and factor conditions are not an obstacle, with a combination of appropriate technology transfer and learning, rapid progress can be made. As Figure 3 shows, the successful industrialisers have progressed from mature sectors to more advanced sectors and the later industrialisers have made more rapid progress. The NIEs in the figure refer to the so-called Asian tigers (The Republic of Korea, Taiwan Province of China, Hong Kong SAR and Singapore) while the ASEAN-4 are Malaysia, Thailand, Philippines and Indonesia.

Box 13: Republic of Korea: Changing trends in technology transfer *

In the Republic of Korea, modern technology development and/or technology transfer began only in the early 1960s. Old industrial equipment and facilities from developed countries were imported on a turnkey basis through foreign aid or loan programmes. At that time, the Republic of Korea's production technology was at the level of facility operation or simple manufacturing with unskilled or semi-skilled labour. Most training was dependent on foreign experts. In the 1970s Korean industries began to import foreign technologies, even though they were mainly in the declining stage, through licensing agreements. Between the late 1970s and early 1980s, the Korean economy abruptly took off. Two decades in assimilating imported technologies and its own capacity building of imitative technology development made Korean industries look for maturing technologies through licensing agreements rather then on a turnkey basis. Developed countries then initiated technology protectionism policies against the Republic of Korea due to fear of the boomerang effect. From the late 1980s, cases of patent right disputes with developed countries increased drastically, indicating that the Republic of Korea had entered the competition phase in some industrial areas. This also meant that the Republic of Korea will face more aggressive attitudes from foreign technology donors in the future.

There is no golden rule for technology transfer. It is an act of local and dynamic characteristics, and therefore the Korean experience in the past three decades of economic development and technology transfer may be looked upon as a special case. Technology development was gradual rather than a leapfrogging process until the Republic of Korea had gathered enough momentum (or technological capacity) to make a quantum leap. This fact must be remembered in promoting environmentally sustainable development and transfer programmes (see Table). In the specific case of technology transfer within the power sector, especially in cogeneration technology, Lee and Kim (1993), analysed the progressive relationship between the mechanism of technology transfer and five strategic stages of capacity building. The success of indigenisation of foreign technology in the Republic of Korea was attributed by them to institutional alliances between the government, public corporations, R&D institutes universities, and the private sector, all aimed toward integrated capacity building.

Trends in Technology Transfer in the Republic of Korea

Decade	Major Industry	Core workforce	Scope of Technology	Technology Transfer Mechanism
1950	Agriculture	Simple labour	Pre-modern	-
1960	Handicrafts	Skilled labour	Declining	Turnkey and project
1970	Light industries	Skilled technicians	Declining and maturing	Licensing (partly)
1980	Heavy industries	Engineers	Maturing	Licensing
1990	High-tech industries	Engineers and scientists	Growing	Licensing and Joint venture

Lee H and Kim J (1993) The Role of Technology Transfer in Abating $C0_2$ Emissions: The Case of the Republic of Korea, Journal of the Asia Energy Institute, June, 119-151

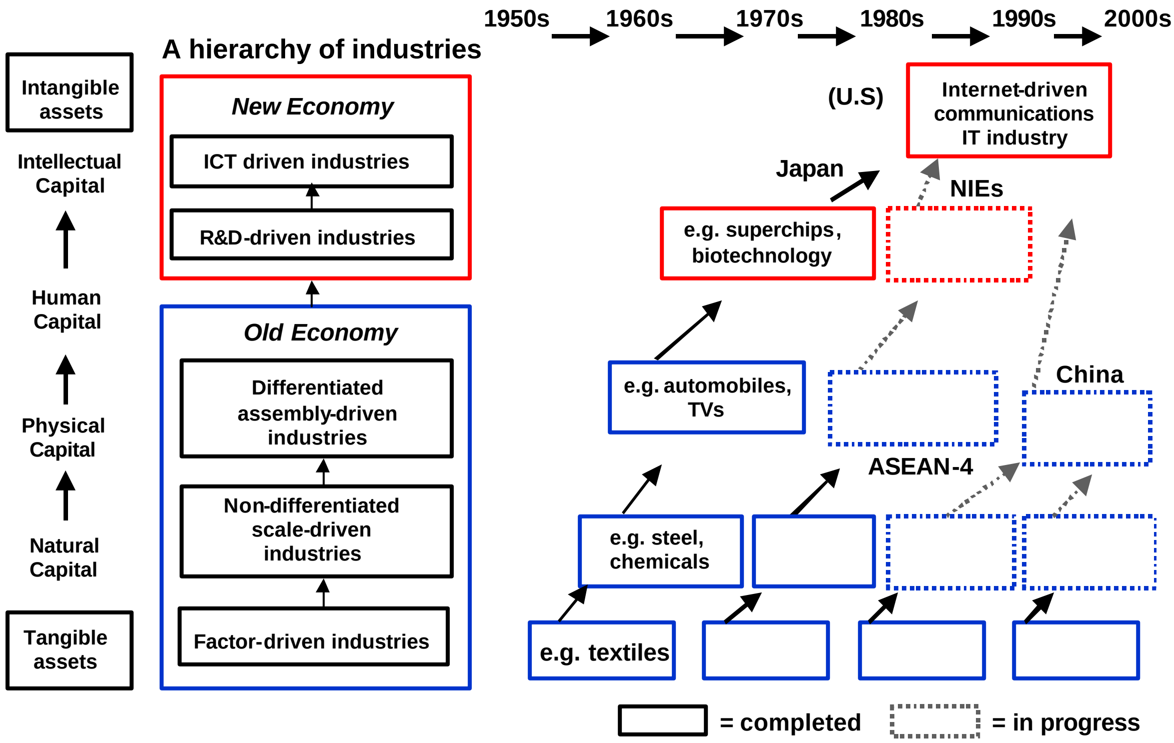
- *From Choi H-S, The Transfer and Development of Environmentally Sound Technology, in Green Productivity: In Pursuit of Better Quality of Life, Asian Productivity Organization, Tokyo, 1997.*

There are prospects for leapfrogging in that later industrialisers do not necessarily have to follow precisely the same path and the same technologies within the sectors. Heavy industries such as steel and chemicals will also not be appropriate for most small to medium size industrialisers.

Most cases of leapfrogging in fact relate to activities in the services sector. Common 'low-tech' examples are in the tourism, hotels and leisure industry, where it has been possible to capitalise on a country's location, weather and labour resources complemented by investment, importing management skills and learning from them. More recent examples of leapfrogging in the service sector are in 'higher-tech' software development and lower-tech 'back office' functions (such as call centres). They depend on a good technological infrastructure (e.g. telecommunications system), but this can often be acquired from foreign countries on a turnkey basis. The fact that the infrastructure exists does not mean they have a capability in replicating and developing it; the main capability is in using the infrastructure to provide services that add value. In addition, such leapfrogging, especially for relatively high-tech activities such as software development, requires availability of technically trained personnel.

New technologies, and especially Information and Communication Technologies (ICTs), raise concerns about the "digital divide". The primary contributions of ICTs for productive activities are (a) reduction in the cost of acquiring information and communication, (b) widening the scope of information acquired, and (c) thereby to increase the ability to enhance knowledge. With respect to ICT technology, it is essential to make a distinction between using the technology and developing a capability in producing and enhancing it. Acquiring the capacity to make advances in this technology is likely to be beyond the scope of most developing countries because of the characteristics of the ever increasing complexity of new applications and integration between software and hardware (Steinmueller, 2001). There could be possibilities of manufacturing the less advanced ICT hardware but this also requires technical skills which would have to be learned.

Figure 3: Accelerated stages of industrial development of successful industrialisers



Adapted from T Ozawa, S Castello and R J Phillips (2001) "The Internet revolution, the "McLuhan" stage of catch-up, and institutional reforms in Asia" Journal of Economic Issues, Vol. 35, No.2.

Developing the capability to use the technology is of vital importance for the contribution it makes to solving some of the basic problems of education, health and poverty (Vergnes, 2001). Development of scientific knowledge by research and higher education institutions in developing countries is hindered by the high cost of accessing the available literature (Ming-te Lu, 2001). Developing capability in ICT, extending its use in education and improving access to international scientific knowledge are important for developing the basic capabilities needed for longer term industrial development. Although providing assistance for this rather broad transfer of capability and knowledge is not directly within UNIDO's remit, other agencies partnering UNIDO could make a contribution.

6. Technology transfer, trade and TRIPS

There is an important link between technology transfer, acquisition of technological capability and trade, especially at the early stage of industrial development. As Figure 2 shows, the objective is to develop comprehensive technological capability and become a competitive exporter. Technology transfer under Route 2 in this paper shows this link most clearly. In this route, based on the principle of mutual benefit (for the supplier and acquirer), the suppliers of the technology (or firms facilitating supply) are also the customers, firms seeking low-cost production locations. Therefore a corollary of technology transfer is increased trade of benefit to the technology supplier and the acquirer. There are wider benefits to the acquiring firm which gains access to world markets and the capability to produce to international standards.

The trade link is less direct in the other two routes. Nevertheless, in Route 1, the enhanced capability could be the first step to exporting. For new products, such as the solar lantern or the treadle pump, there could be opportunities for exporting to other developing countries. Route 3 is primarily for domestic supply but in this case also, the capability developed in serving a foreign firm can be transferred to exporting.

TRIPs has become a bone of contention between industrialised and developing countries and we were asked to look at the issues it raises for technology transfer because of the intellectual property vested in the technology transferred. As a principle, protection of intellectual property is based on sound reasoning. However, producers from developing countries have the most to gain from better protection of intellectual property (The Economist, 2001). Producers from developed countries want protection of intellectual property (which includes proprietary knowledge, brand names and trade marks as well as artistic property and literary works) against misappropriation. The intention is to provide an incentive to carry out research and development for further innovations. The problem for developing countries is that the cost of implementing intellectual property rules is high with very little direct benefit to governments in the short-term (although there are benefits for present or future owners of intellectual property in developing countries).

Another concern for developing countries is the high cost of patented products which has come into prominence in connection with the high prices of proprietary drugs. However, in the first instance, this issue is about the use of patented drugs and not the development of capability to produce and develop them. Some of the more capable pharmaceutical firms in developing countries have the ability to replicate them, presumably by infringing intellectual property rights. TRIPs would make this more difficult in the future.

In industrialised countries, patent protection for pharmaceutical products is granted for specified periods of time to enable companies to earn a high return as a reward for their R&D efforts. Beyond this period, copying is permitted. There are also competition policy authorities to prevent exploitation of market power. Adjusting the time limit on patent protection (which would have to be within the context of international negotiations) and strengthening competition policy and its implementation could improve the situation somewhat. If the pricing of drugs is considered to be an important humanitarian issue, one possible solution (though beyond the scope of this brief) could be a special fund from aid for subsidising the purchase of selected drugs if this is thought to be sufficiently high priority and an agency to assess whether a drug could be included.

It has been suggested (The Economist, 2001) that within a bargaining framework, developing countries agreed to comply with TRIPs in the expectation of concessions from developed countries on agricultural products and textiles but these have not been forthcoming. For industrial technology transfer, while there are concerns about the protection of intellectual property vested in the technology, they can usually be managed within the transfer arrangements. The supplier typically enters into a transfer arrangement with the expectation of some gain from it. Therefore the possible loss of control over the proprietary knowledge has to be balanced against the gains from the transfer in the form of royalties (in the case of licensing) and profits (in the case of a joint venture).

A study 20 European firms in diverse sectors (including high-tech sectors such as telecommunications) transferring medium and high level technologies found that nearly 80 per cent of the companies stated that the protection of their intellectual property was not adequate in China (Bennett, Liu, Parker, Steward and Vaidya, 2001). They dealt with the situation by withholding some key parts of the technology. However they also expected the Chinese acquirers of technology to learn and catch up and 90 per cent stated that their strategy was to maintain their lead through own R&D.

Other measures regulating trade and related aspects under the WTO have important implications for the prospects for developing technological capabilities through technology transfer. For example under Trade Related Investment Measures (TRIMs) minimum local content requirements are not permitted. A number of other measures discriminating in favour of the domestic sector (for example, public procurement, domestic subsidies and high tariffs against imports) which were used to a greater or lesser extent by the Republic of Korea and the Taiwan Province are not permitted now and therefore there has to be greater reliance on comparative advantage based on industry conditions and economic policies.

7. UNIDO and technology transfer

Review of activities and initiatives

This section provides a brief overview of the overall scope of UNIDO’s technology transfer related activities, the technology transfer strategy of the Industrial Promotion and Technology Branch, the institutional infrastructure for operationalising the strategy and UNIDO’s environmental sustainability agenda and transfer of ESTs. Based on the discussion and conceptual framework introduced in the previous sections, it also comments on the strategic and operational aspects as a lead to the conclusions and recommendations in section 8.

Under the reform of UNIDO and its Business Plan adopted in December 1997 its activities are now grouped into two areas of concentration: (a) strengthening of industrial capacities, and (b) cleaner and sustainable industrial development *(UNIDO Medium-Term Programme Framework 2002-2005, note by the Director-General, General Conference, Ninth session)*. In both these areas technology transfer has an important contribution to make in developing the capabilities of developing countries. UNIDO has also identified (a) LDCs, especially in Africa, (b) agro-industries, and (c) small and medium sized-enterprises, as requiring the most attention.

Among UNIDO' s 8 service modules, one specifically specialises in Industrial Technology Promotion ("Investment and Technology Promotion") and that has been referred to in this paper as the business model. However, others either have a role to play in technology transfer or have an interest at the policy level. They are; "Industrial Governance and Statistics", "Quality and Productivity", "Small Business Development", "Agro-Industries", "Industrial Energy and Kyoto Protocol", "Montreal Protocol" and "Environment Management".

This implies that most of the branches in UNIDO play some role in technology transfer. However, the Industrial Promotion and Technology Branch has a brief which addresses most directly the transfer of technology to the LDCs, including the transfer of managerial technologies relating to quality and productivity. Also closely involved with the needs initiative for WSSD and transfer of ESTs is the Cleaner Production and Environmental Management Branch with its "Cleaner Production" service module.

According to the Industrial Promotion and Technology Branch, technology promotion and investment promotion are intrinsically linked in its "Investment and Technology Promotion Programme" which comprises institutional capacity building and advisory services to promote investment and technology flows and facilitate business alliances *(Quality, Technology and Investment Branch "UNIDO and its role in transfer of technology: Contribution for the expert meeting on international arrangements for the transfer of technology", Geneva, 27-29 June, 2001).*

The guiding principles for the strategy (summarised from the document referred to above) are:

(a) Investment and technology should not be seen in isolation but as contributors to the process of improving competitiveness at the enterprise level and sustainable growth at the national level.

(b) The strategy should include extension services to enterprises, and especially to SMEs, because of their inability to manage the technological acquisition and innovation process by themselves.

(c) The strategy should involve consistent international cooperation to learn from the industrialised and more advanced developing countries.

(d) Within a country, the strategy should involve and articulate various key players in the national innovation system (for example, R&D and academic institutions, technology centres and development financing organisations).

The institutional capacity building services aim to establish and / or strengthen (a) national Investment Promotion Agencies (IPAs), (b) technology centres and technology support institutions to assist enterprises with the assessment and transfer of new and appropriate technologies, and (c) Subcontracting and Partnership Exchanges (SPXs) to support SMEs in their development of business relationships and build up their technical and management capabilities. Advisory services are provided to the investment and technology institutions in developing countries and economies in transition to assist them in formulating and appraising business proposals, searching for international partners and locating sources of funds.

The programme supports promotion of investment and business partnerships and development of technological capabilities through the networks of Investment and Technology Promotion Offices (ITPOs), Investment Promotion Units (IPUs) and the Africa-Asia Investment and Technology Promotion Centre supported by UNIDO Exchange. In addition, the programme maintains linkages with International Technology Centres which provide advanced technological inputs where necessary. The activities and initiatives are briefly described in Box 14.

The brief description of UNIDO's technology transfer operations and the institutional infrastructure supporting them shows that the overall strategic objectives and infrastructure are well thought out. In particular, the focus on relating investment promotion and technology acquisition to developing capability and competitiveness at the enterprise level and sustainable national economic growth (strategic guideline (a)) is sound and fits in with the business model of technology transfer developed in the earlier sections. The tools and training materials are also comprehensive and impressive.

However, our discussion and framework in the earlier sections identifies the need for some reorientation in UNIDO's technology transfer strategy and activities with regard to the slow and the very late industrialisers. We comment on the strategic guidelines (b) to (d) before considering the institutional infrastructure and activities.

Strategic guiding principle (b) is in keeping with the first guiding principle. It also fits in with the assessment in section 5, which identifies the inability of firms to develop their technological capabilities within the business model of technology transfer as the main problem and justification for devising support strategies. However, decisions on targeting sectors and determining the appropriate type of extension are difficult, requiring comprehensive studies of sectors. Effective extension services are also expensive to provide and therefore there are resource implications.

On guiding principle (c), there are clearly general lessons to be learned by the very late and slow industrialisers, especially from the late industrialisers on how they developed their capabilities from basic levels with the help of technology transfer combined with technical training and learning. More specific lessons for sectors and especially development of effective technical training in the appropriate sectors would be highly valuable forms of technical assistance.

Guiding principle (c) highlights the importance of developing national innovation systems. This is a highly desirable outcome but it emerges over time as a consequence of mutually reinforcing relationships between firms and other institutions. It is difficult to achieve in the short-term, especially in the very late industrialisers which start with very low levels of industrial development and supporting institutions. For these countries, in the early stages of industrial development, the emphasis should be on learning rather than innovation and therefore initiating the development of national learning systems might be more appropriate. Within such systems, technical training institutions and technology centres dealing with basic appropriate technology would play an important role. With respect to technology transfer, an important element of the learning system would be identification of appropriate technologies for licensing and support for firms in gaining competence in them, within the business model of technology transfer.

In the slow industrialisers, there may be more potential for developing R&D institutions, but based on the lessons of the late industrialisers, at the early stages, the emphasis should be on learning and adaptation of available technologies, rather than R&D and innovation. This may require reorientation of existing national innovation and learning system in some countries if, for example, R&D efforts are not closely related to the needs of firms and sectors with development potential.

Box 14: UNIDO: Principal investment and technology transfer activities and initiatives

UNIDO has a number of specific activities and initiatives relating to investment and technology transfer. The main ones are listed here.

Investment and Technology Promotion Offices (ITPOs)
The ITPO's, described as "one stop shops" for UNIDO's investment promotion and technology transfer services, are responsible for dissemination of investment information, identifying and promoting investment opportunities, providing training in promotional techniques, and matching project sponsors with potential foreign investors. Currently there are thirteen ITPO's, mostly in industrialised countries. There are also Investment Promotion Units (IPUs) in Egypt, Jordan, Morocco, Tunisia and Uganda.

International Technology Centres (ITCs)
ITCs focus on the industrial application and commercialisation of new technologies and innovations. They are therefore mainly concerned with the 'vertical' transfer of technology (i.e. R&D to production) rather than 'horizontal' transfer (i.e. transfer of established technologies between countries).

Africa-Asia Investment and Technology Promotion Centre (AAITPC)
The objective of AAITPC is to promote technology and investment flows from Asia to Africa within a framework of South-South Cooperation. Asian countries participating are China, India, Japan, Malaysia and Thailand. African participants are the Ivory Coast, Ghana, Mozambique, Senegal, Tanzania, Uganda and Zimbabwe.

Subcontracting and Partnership Exchanges (SPXs)
SPXs are technical information, promotion and matchmaking centres for industrial subcontracting and partnership between main-contractors, suppliers and sub-contractors. UNIDO provides technical assistance to developing counties for establishing and operating SPXs. It recommends legal statutes and standard terms of reference for their establishment.

UNIDO Exchange
UNIDO Exchange is a software tool to disseminate knowledge and promote business and technology opportunities. Its aim is to "bridge the digital divide" between the developed world and the majority of the developing world which requires access to electronic business and technological opportunities.

Technology Foresight
Technology Foresight and Monitoring provide inputs for formulating technology policies and strategies, which guide the development of technological infrastructure, support for innovation, and assistance in technology transfer and management. Foresight is a new concept in UNIDO (and has only recently gained popularity in Europe, the USA and Japan).

Continuous Improvement and Quality Management
An important aspect of the technology transfer is that it involves learning, which by implication means the transfer of managerial technologies as well as hardware and software.

SME Clusters and Networks Programme
The Small and Medium Enterprises Branch has developed an approach to help government and the private sector to co-operate in the design and implementation of programmes to promote the organisation and development of clusters / networks of SMEs. The approach has been introduced in a number of countries, mainly in Latin America, but also in North Africa and South and Southeast Asia.

Training, tools and methodologies
UNIDO carries out a wide ranging training programme to support investment promotion and appraisal, design of feasibility studies, technological capability assessment, technology management and transfer and transfer, quality management and standardisation. A number of tools and methodologies on these subjects are also available in the form of manuals, software and training packages.

UNIDO's environmental sustainability agenda and technology transfer

Since UNIDO was set-up there have been a number of developments relating to the sustainability agenda that have caused it to reassess its functions and services. The main ones include:

(a) the Montreal Protocol on Substances that Deplete the Ozone Layer (agreed in 1987 and subsequently adjusted or amended);
(b) the United Nations Conference on Environment and Development (UNCED): the Earth Summit (1992), giving rise to Agenda 21, and
(c) the Kyoto Protocol on limiting emissions of carbon dioxide and other greenhouse gases (1997)

As a result of these and other developments in the sustainability agenda, UNIDO introduced new service initiatives and created new branches (the Montreal Protocol Branch and the Industrial Energy-Efficiency Branch, which embraces the former Kyoto Protocol and Industrial Energy-Efficiency Branches). The Montreal Protocol Branch offers skills in technology transfer, mainly relating to end-products, that can assist the acquisition of clean non-ozone depleting substances and related plant, equipment and processes. It can help with obtaining rights and licences, procuring equipment, and the upgrading of products and processes, as well as conservation and maintenance. The Industrial Energy-Efficiency Branch lists among its activities help with transferring technology for environmentally sustainable energy production, as well as technical assistance, training and awareness building programmes for industry.

The branch of UNIDO that has a pivotal role in promoting and assisting the transfer of environmentally sound technological processes is the Cleaner Production and Environmental Management Branch. Its approach to pollution control and reduction embraces both preventive as well as treatment (e.g. end-of-pipe) solutions. Its technology transfer activities include help in creating and building up the capabilities of countries and industries to evaluate, transfer and install cleaner technology and techniques. Some specific services and outputs from the branch are:
(a) support (in collaboration with UNEP) in establishing National Cleaner Production Centres (currently there are around twenty in the developing and transitional countries of Latin America, Africa, Europe and Asia);
(b) creation of a Knowledge Network for Industrial Technology Transfer (KNITT), consisting of inter-linked national networks to support the application of relevant knowledge to identifying and implementing Clean Development Mechanism (CDM) projects, and
(c) for the Johannesburg Summit on Sustainable Development, a project to assess the uptake of ESTs in selected developing countries.

It has long been acknowledged that transferring environmentally sound technology from developed to developing countries is necessary to reduce greenhouse gas emissions in countries undergoing industrialization. Within the framework of negotiations on protection of the environment organised by the UN, there have been strong commitments to the transfer of ESTs. Under Article 4.1 of the UNFCCC (1992), parties were urged to "promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases." (Grubb, Koch, Munson, Sullivan, and Thomson, 1993, pp 64-65.)

Article 4.5 also stated that "Annex I (mainly industrialised countries) parties shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other parties, particularly developing country parties."

A similar approach was adopted in Agenda 21 in which Chapter 34 stated that:
"technology transfer should be encouraged on favourable terms, including on concessional and preferential terms, as mutually agreed, taking into account the need to protect intellectual property rights as well as the special needs of developing countries for the implementation of Agenda 21". (Grubb, Koch, Munson, Sullivan, and Thomson, 1993, pp 144-145.)

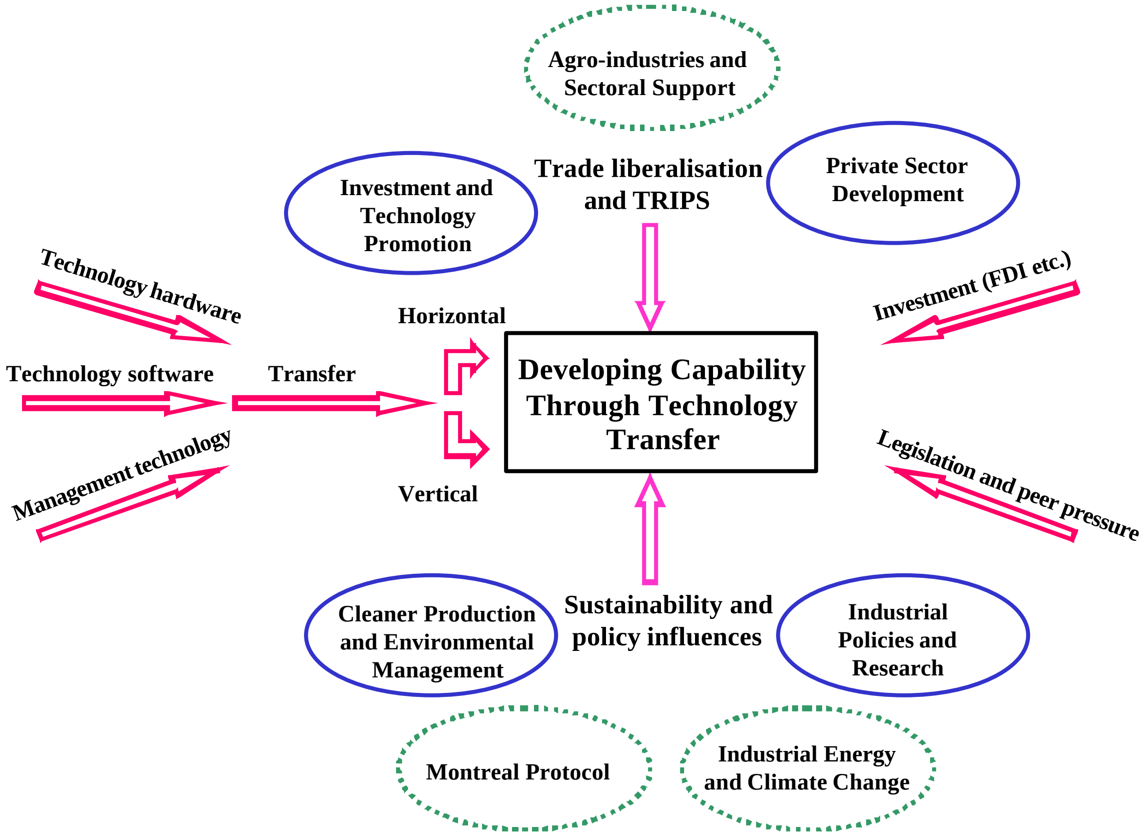
In practice, very little has been achieved under these agreements and technology transfer has been associated with some of the most bitter disagreements between developed and developing countries in climate change negotiations. Developing countries demand increased efforts by developed countries on technology transfer while the latter argue that most of the relevant technology is proprietary knowledge owned by businesses and therefore governments cannot transfer it. Businesses who own the technologies consider the issue of transfer within the business model, weighing the benefits of protecting the technology against the possible benefits and costs of transferring it.

The conflicting positions show the sharp difference between the business and political bargaining models of technology transfer. Resolution of this impasse requires (a) a proper understanding of the nature of the technology transfer process and (b) an incentive structure for the transfer of technology by firms who own it (Forsyth, 1999). On the former, as this paper has shown, it is necessary to understand that technology is not a commodity that can be transferred as a whole and in usable form through a transaction. There are different levels of capability and acquiring them could take substantial amounts of time and effort by both the supplier and acquirer.

The creation of an incentive structure by firms to transfer technology could be one approach to resolving the conflict between the business and political bargaining models of technology transfer with respect to ESTs. The incentive structure could be used in conjunction with the Clean Development Mechanism (CDM) which was created as a part of the Kyoto Protocol in 1997 as a flexible mechanism to promote climate-related investment in non-Annex I countries. However, the CDM does not yet have guidelines or incentives for technology transfer or private sector participation.
Two possible mechanisms for creating the incentives for technology transfer are: (a) tradable credits for companies and (b) a clearing house or bank for technologies.

Companies transferring ESTs (rather than national governments in the case of emission control at present) could be credited for the environmental and / or development effect of the transfer. The credits could then be traded or used for making tax payments. For this mechanism to work effectively and without abuse, the valuation of the technology being transferred based on its contribution to environmental or development objectives is required and crucially, governments have to agree to accept the credits in tax payment. Effective and strong governance by national agencies or the CDM executive is also required.

Figure 4: Technology transfer related issues and UNIDO services



The second approach offers owners of technology to "deposit" it in a clearing house (or a technology bank). This would be in return for a payment for the technology thus providing a relatively fast return for the company. The clearing house would then disseminate the technology. This and similar ideas have some promise but they also raise some important issues to be resolved. These include the valuing of technology, whether the clearing house would be international and the basis for funding the process. This is clearly an area in which further research is required. Any agreements will also have to be internationally negotiated.

Figure 4 provides an overview of the involvement of UNIDO's branches in technology transfer. It indicates those branches of UNIDO (in the solid ellipses) that are most concerned with the implementation, sustainability and policies relating to technology transfer and mainly concerned with the influences of trade liberalisation and TRIPs. The branches less directly concerned with policy issues but with involvement in technology transfer are shown in dotted ellipses.

8. Conclusions and recommendations for a path for future action

Overview of the framework

With regard to the World Summit on Sustainable Development, it appears that UNIDO's mandate and the services it offers make it very well suited to play a key role on technology transfer (see section 7). Previous sections have developed a number of elements that make up the possible framework for UNIDO's initiative on technology transfer. Many of the elements of the framework identified are already being undertaken by UNIDO and therefore our approach has been to relate these to the requirements of the countries which have been less successful in acquiring technological capabilities and competitiveness so far.

Figure 5: Technology transfer, policy context and supporting institutions

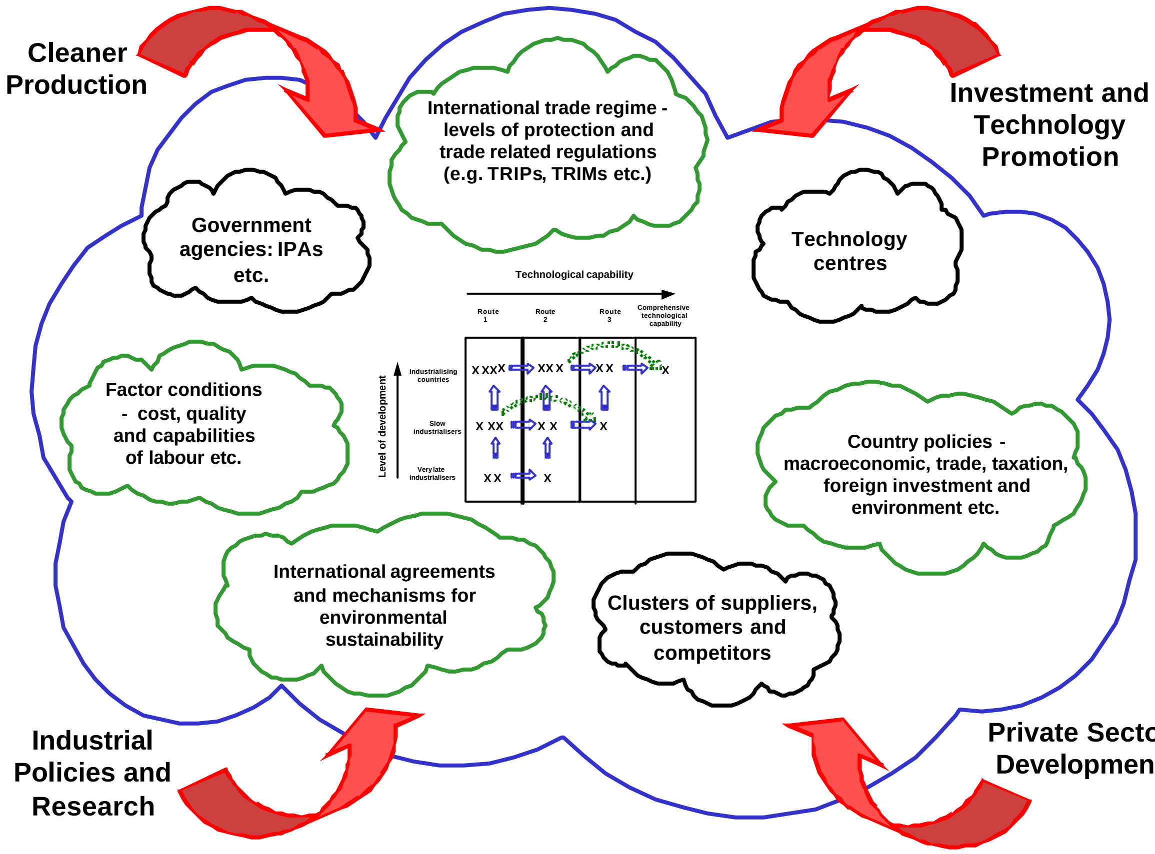


Figure 5 shows the three technology transfer routes at the core of the framework. In section 5, these were identified as routes having realistic chances of success because (a) they were appropriate for the levels of initial capabilities in the countries and (b) commercial incentives for the technology supplier and provider either existed or could be created. As the figure shows, the context of the relationship includes:

(a) country policies (macroeconomic, trade, taxation, foreign investment and environment);
(b) factor conditions (including the cost, quality and capabilities of labour);
(c) the international trade regime (including levels of protection and trade related regulations such as TRIPs and TRIMs), and
(d) international agreements and mechanisms for environmental sustainability.

The commercial incentive to acquire technology partly depends on market conditions, which in Route 1 are affected by government economic policies, performance of the economy, the international trade regime and the level of protection from international competition. In Route 2, economic policies, the trade regime as well as factor conditions (i.e. the cost of labour) will affect the attraction of the country as a location for contracting and through it the acquisition of technology. Technology transfer under Route 3 will depend on domestic market conditions and factor conditions as well as the capabilities of the relevant industry sector.

The technical effectiveness of the transfer process will depend on factor conditions (i.e. technical skills of employees, the technical and management capabilities of acquiring firms, access to adequate finance and accommodating government policies. The agreements and mechanisms for environmental sustainability may affect the type of technology acquired and may increase the transfer of ESTs if there are effective regulations or adequate incentives for such transfers.

Development of higher level technological capabilities based on transfers will initially depend on the abilities of the technology acquiring firm and the relationship with the supplier. However, further development and innovation, especially for SMEs will depend on the supportive environment, which includes government agencies, technology centres, finance providers as well as the cluster of suppliers, customers and competitors.

Failures in creating commercial incentives, technical implementation of technology transfer or creating capabilities based on the transfer could all have contributed to the poor take up of imported technology by firms in the slow and very late industrialisers. UNIDO cannot directly affect government economic policies, the international trade regime or the agreements on the protection of the environment. However it can develop policy guidelines based on its own expertise and research and attempt to influence policy makers at the national and international levels. Within the context of national policies and international regulations and agreements, UNIDO's role is to support government agencies in identifying the obstacles against technology transfer and development of capability and play an enabling role in promising sectors.

UNIDO's technology transfer roles can be put into the following two categories:
(a) to support the process of technology transfer and technological capability development at the national level within the business model, and
(b) to develop international policy initiatives (by itself or in collaboration with others) to deal with the trade and environment issues which have adverse effects on technology transfer in the very late and slow industrialisers.

Table 2: Technology transfer routes: Identifying the gaps and possible means of bridging them

	Route 1 **Trade and aid to strengthen indigenous production for domestic markets**	**Route 2** **FDI and contracting to develop export oriented firms**	**Route 3** **Supply chain of foreign investors to develop local sub-contracting capacity**
Implications for type of technology and transfer arrangements	- low-tech in international terms - initiative to be taken by domestic firm - acquisition mainly by purchasing technology or licensing with more or less help by provider - benefit to provider – immediate financial return on mature technology with low risk	- low-tech in international terms - initiative in the hands of customer - acquisition from customer and / or existing upstream foreign suppliers to the customer e.g. through licensing, JV, co-production agreements with more help and control by customer than in Route 1 - benefit to customer – cost advantage	- generally low-tech products and components (in international terms) - initiative in the hands of foreign firm (the customer), though government may impose local content rules (restricted under WTO) - acquisition from customer and / or existing upstream foreign suppliers to the customer e.g. through licensing, JV, co-production agreements with more help by provider - benefit to customer as provider – localises supply chain with possible cost advantages, complying with government rules
Gaps to be bridged (with external assistance)	- recognition of current situation and opportunities by potential acquirers - identifying appropriate technologies - developing the absorptive capacity - managing the transfer process - financing	- offering opportunities to potential foreign partners (manufacturers and brand owners) - speed of absorption and adaptation - capability to operate the technology and meet exacting standards, for example on quality, timeliness, costs - managing the transfer process	- offering opportunities to foreign firms investing in the country - capability to operate the technology (hardware and software) to meet customer specifications - capability to learn the complementary managerial technologies (JIT, TQM, ERP) to meet exacting standards on quality, timeliness and costs
Possible ways of bridging the gaps and the role of UNIDO	- assistance with identifying the most promising industries and enterprises - assistance with selecting appropriate technologies and suppliers - training and support for transfer arrangements and negotiations - working with national investment promotion agencies and banks on financial support for sound projects	- assistance with identifying the most promising industries and enterprises - making potential foreign partners and brand owners aware of opportunities (e.g. through SPXs) - training and support for transfer arrangements and negotiations	- assistance with identifying the most promising industries and enterprises - making foreign investors aware of opportunities (e.g. through SPXs) - training and support for transfer arrangements and negotiations

With respect to supporting the process of technology transfer, Table 2 summarises the features of technology transfer through Routes 1 to 3, the gaps preventing technology transfer from taking place and the possible ways of bridging the gaps and the role UNIDO can play. The gaps identified in Table 2 are self-explanatory and the possible ways of bridging them also appear to be obvious. The aim here is not to provide state support to selected sectors and firms, but to enable the sectors showing the greatest promise, based on market prospects and technological capability, to acquire technology.

For example, under Route 1, these could be sectors in which domestic firms offer a significant amount of competition to importers (indicated by market share). Through trade associations, domestic firms would be made aware of the possibilities of technology upgrading and management training, provided avenues for contacts with technology suppliers (including appropriate technology product developers) and required to apply for finance (if needed) based on feasibility studies. Under Routes 2 and 3, the focus would be on developing the contracting capabilities of domestic firms in selected sectors through training.

Development of technological capabilities based on technology transfer at the firm level depends on the firm's initial capabilities and relationship with the technology supplier. Figure 3 also shows the importance of support from within the country, especially from technology centres and the cluster of suppliers, customers and competitors. A further role for the cluster is to stimulate mutual learning by firms in the sector and related sectors. The interaction between technology transfer and internal processes means that each country's trajectory of technology and industrial development will be different. Leapfrogging and developing into new directions therefore become possibilities with the development of capabilities in different sectors.

The emphasis on the conditions required for technology transfer to make a contribution to industrial development (including the need to develop capabilities progressively) is daunting. Nevertheless, examples of a number of countries show that success is possible. Sometimes dramatic changes can be induced by a combination of policy changes, effective governance and the influence of foreign investment and technology transfer combined with domestic learning strategies. China's industrial performance after the initiation of the "Open Door" policy in 1979 is an example of this. There are others examples of countries whose economic and industrial development prospects were written off by social scientists who have been proved wrong. As late as the mid-1960s the Republic of Korea was written off as a country which could not industrialise because of the cultural bias against industry inherent in Korean Confuscianism (Choi, J, 1966, quoted in Morawetz, 1981). A more recent unexpected economic success, though more modest with respect to technological capability, is Mauritius (see Box 11). The Nobel Prize winning economist James Meade prophesied in the early 1960s that Mauritius's development prospects were poor—that Mauritius was a strong candidate for failure, with its heavy economic dependence on one crop (sugar), vulnerability to terms of trade shocks, rapid population growth, and potential for ethnic tensions (Subramanian 2001).

There are disadvantages for the very late and slow industrialisers (especially in the trade regime and against countries which have developed strong competitive advantages). But they also have the advantages of learning and use of new technologies which could enable them to develop their own development trajectories based on using technology transfer in the context of sound policies and supportive institutions.

Recommendations

Based on the general conclusions above and previous discussion of UNIDO's role in technology transfer in the previous section, the following specific recommendations have been identified. In line with the distinction between (a) supporting technology transfer and (b) developing policy initiatives, the role(s) that each recommendation is related to is indicated.

1. Given the range of technology transfer related activities and involvement of a number of branches, for the development of the technology transfer initiative, policy coordination and implementation, UNIDO should consider forming a task force with representation across its branches. The main representation would be from the Industrial Promotion and Technology Branch, the Cleaner Production and Environmental Management Branch, the Small and Medium Enterprises Branch and the Strategic Research and Economy Branch. Links should be created between the task force and the Montreal Protocol Branch, the Industrial Energy-Efficiency Branch and the Agro-Industries and Sectoral Support Branch *(support and international policy initiative roles)*.

2. The paper has focused on UNIDO's role in technology transfer to the very late and slow industrialisers. UNIDO has something to offer to all countries within its mandate but different packages to assist technology transfer need to be constructed depending on the country's level of development. All of them will require identification of sectors which have the potential for benefiting from technology transfer within the business model, assessment of existing technological capabilities, support for identifying suitable technologies and suppliers and setting up transfer arrangements. These requirements could be addressed within the framework of the existing Integrated Programmes *(support role)*.

3. Some reorientation of the support role is needed to address the needs of the very late industrialisers and the less developed sectors in the slow industrialisers. This could be addressed by:
   (a) setting up Technology Centres (international and national) with the focus on research, development and adaptation of intermediate products and technologies (with some of the international centres being set up in the very late industrialisers), and
   (b) creation of an international network of institutes, agencies and other interested parties working on development and application of intermediate technologies *(support role)*.

4. To balance the focus on appropriate products and technologies which are suited to (a) the current capabilities of many producers and (b) demand conditions in many of the very late and slow industrialisers, the initiative should include increasing access to and training in new technologies (especially in ICT). The purpose would be to develop longer term capabilities for leapfrogging through development of new activities sectors. Since such an initiative would not fit entirely within the remit of UNIDO, it may require collaboration with other agencies within the UN system (e.g. UNESCO) or outside it *(support role)*.

5. UNIDO should take the initiative in expanding the scope of the Africa-Asia Investment and Technology Promotion Centre (AAITPC) to include more African countries and in extending its role to develop closer business links between Asian and African businesses and the transfer of technologies at the appropriate levels *(support and international policy initiative roles).*

6. The orientation towards the very late industrialisers and the less developed sectors in the slow industrialisers has the potential of making a significant contribution to the social and equity aspects of sustainability and would enable UNIDO to make a strong case for donor support. Many donors are also likely to assist in this direction because they recognise the imbalances in the present status quo on international trade and trade related reforms (for example TRIPs and TRIMs favour industrialised countries but industrialised countries have been slow in reducing barriers against agricultural and agro-processed products which would benefit developing countries) *(support and international policy initiative roles).*

7. Specific technology transfer related areas in which industrialised countries could provide financial support and technical assistance are *(support role)*:
   (a) acquiring non-proprietary scientific, technological and business knowledge;
   (b) access to and training in new technologies;
   (c) developing national business related technology strategies;
   (d) identifying appropriate technologies for acquisition, and
   (e) developing appropriate technologies.

8. To emphasise the practical orientation of the initiative, a pilot technology transfer project based on the framework outlined in this paper could be designed for implementation in at least one very late and at least one slow industrialiser and donor funding sought. The aim would be to learn from the experience and create demonstrator effects *(support role).*

9. In the recommendations made above, it is implicitly assumed that the principle of environmental soundness balanced with development objectives and other aspects of sustainability would be observed in any technology transfer. In addition, UNIDO should take the initiative in proposing an international agreement which requires the bundling of an agreed level of environmental soundness into all the technology (hardware and software) exported, thereby enabling the developing country importers to free ride on regulations and their implementation in the industrialised countries and other exporters *(international policy initiative role).*

10. There are likely to be objections to recommendation 9 from industrialising country exporters who do not have access to environmentally sound technologies. Transfer of ESTs is a highly contentious issue on which the intent to transfer such technologies has been stated but actual transfer is limited because the agreements on intent did not take account of the business model within which technology transfer takes place. The UNIDO initiative should propose implementation of flexible mechanisms such as transferable credits or technology clearing houses for the transfer of ESTs *(international policy initiative role).*

11. Imbalances in the current status quo on trade and trade related agreements has already been mentioned. Negotiations are currently in progress as a part of the Doha Agenda under WTO *(see <www.wto.org>)*. UNIDO should take the initiative (in collaboration with UNCTAD and WTO) on reduction in the protection by industrialised countries of agro-processed products which are the predominant industrial exports from the very late industrialisers *(international policy initiative role)*.

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12. A wide range of issues related to technology transfer to developing countries have been considered in this paper and the recommendations are also wide ranging. A single paper cannot do justice to all the issues and further research is needed on a number of them before firm conclusions and policy prescriptions can be arrived at. One of UNIDO's roles is policy oriented research and some of the areas which are in the greatest need of further investigation are *(support and international policy initiative roles)*:
    (a) approaches to identifying appropriate sectors for technology transfer initiatives;
    (b) local participation in identifying priorities;
    (c) appropriate technology and related R&D;
    (d) role of ICT and other technologies and leapfrogging, and
    (e) the role of Cleaner Production Centres in very late industrialisers.

Notes

1. "Least developed countries" (LDCs) is a UN classification of countries based on three criteria:
   - (a) a low-income criterion of gross domestic product (GDP) per head (three-year average) below US$ 900 (though there is a higher threshold for graduation out of the LDC category);
   - (b) a human resource weakness criterion based on indicators of health, nutrition, education and adult literacy, and
   - (c) an economic vulnerability criterion based on instability of agricultural production and exports, diversification of production and exports and size of the population.

   There are 49 countries (34 African countries) in this category, containing 10 per cent of the world population and generating 0.5 per cent of the world GNP.

2. The World Bank "Low Income" category includes countries with GNI (Gross National Income per head less than US$755. There are 63 countries in this category with 37 of them in Africa.

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Printed in Austria
V.02-54935–June 2002–500

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