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Technology Transfer and Sustainable Industrial Development for Developing Countries

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Abstract: *This paper reports on a part of work for the UNIDO initiative on technology transfer for sustainable industrial development. The proposed technology transfer framework, adapted from the East Asian late industrialisers model, identifies two categories of countries requiring support for enhancing their technological capabilities: (a) very late industrialisers ("low income" developing countries), and (b) slow industrialisers (countries with sizeable manufacturing sectors but limited success in gaining international competitiveness) 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). Very late industrialisers need support to start with Route 1 in selected sectors and upgrade through imported mature technologies. Appropriate product innovations are also possible. The slow industrialisers have more scope for increased technology transfer through Routes 2 and 3.*

1. Introduction

In the late 20th Century, industrial development and export competitiveness based on international technology transfer and learning were the major drivers of economic development, enabling a number of countries to increase their standards of living. 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 evidence shows that countries outside East Asia have been less successful in industrial development and the economic growth performance of African countries has fallen far behind other industrialising and developing countries in relative and absolute terms.

The aim of this paper is to develop a framework for enhancing the contribution of technology transfer to sustainable industrial development (SID) in countries that have been less successful in this respect so far. It reports on a part of work for the UNIDO initiative on "Technology Transfer: Assessing Needs - Promoting Action" in preparation for the *2002 World Summit on Sustainable Development (WSSD)* in Johannesburg. It focuses on the "business model" of technology transfer in which a technology transaction or collaboration takes place because both the parties (the supplier and the acquirer) perceive commercial gains.

"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" (UN Department of Public Information, 2001). The three key areas (or dimensions) are:
(a) economic growth and equity;
(b) conservation of natural resources and the environment, and
(c) social development.
The focus of UNIDO and other development agencies on the poorer developing countries (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 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 (UNIDO, Undated).

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'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 international technology transfer by a variety of methods has played an indispensable role in the acquisition of technological capability and competitiveness.

The framework for enhancing the contribution of technology transfer for SID in developing countries is based on lessons from the late industrialisers. However, it has also been necessary to stretch the lessons to make them applicable to strategies for sustainable development in the less successful industrialisers. Account has also been 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. The paper: (a) sketches the main characteristics of countries which have been less successful industrialisers so far and the main features of the business model of technology transfer applicable to them (section 2); (b) outlines the different routes for developing capability through technology transfer (sections 3, 4 and 5), and (c) concludes by summarising the main lessons and the framework indicating the enabling support required for successful technology transfer (section 6).

2. Technology transfer and the slow and very late industrialisers

The broad category "less successful industrialisers" includes substantial variations in levels of industrial experience and capabilities. For example, in Bangladesh the contribution of the manufacturing sector to GDP (manufacturing value added or MVA) 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. In the meantime, for the purpose of relating the possible contribution of technology transfer to the level of industrial development, the following two broad country models have been identified:

(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 some basic domestic consumer and food processing sectors. They could be in the "low" or "lower middle income" categories[1] (World Bank definitions). Examples include Algeria, India and South Africa. The former Eastern Block economies in transition may also exhibit many of the characteristics of slower industrialisers.

The term "slow industrialisers" has been used to reflect limited success in gaining international competitiveness and export growth. At least a part of the explanation for the slowness is that they 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 (Fisher and Reuber, 2000; Humphrey and Schmitz, 1995; Mytelka and Tesfachew, 1998, and Nadvi K, 1995).

In general, through their previous industrial experience, firms in 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 may also be attractive to foreign partners. Typically, there will also be less developed sectors 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, there is also scope for

[1] 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. The "Middle Income" category includes countries with GNI per head between US$756-US$2,995.

upgrading of the less developed sectors and the emergence of new manufacturing and service sectors, based on traditional sub-contracting and exploitation of new technologies.

The very late industrialisers are developing countries with small manufacturing sectors. Typically, they are in the World Bank "low income" or the UN Least Developed Countries (LDC) category[2] which overlap to a great extent. Most of the domestic enterprises will be small or medium sized (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 appropriate. 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 development of modern services are important. There is 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 *(see the Great Wall Machines case in Box 1)*. For sustainability, in keeping with SID, at the level of the enterprise, success could be defined as growth with profitability (or improvement in financial position if the company and sector are loss making), no adverse environmental impact (or tolerable 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.

Box 1: 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*

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
(d) market oriented.

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 are that:
(a) at every level of industrial development, there is scope for development of capability;

[2] "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.

(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.

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 and the starting point depend on the initial level of industrial development. The idea of progressing to greater capability and competitiveness in different sectors via these routes is analogous to the East Asian 'stages' approach to technological capability development discussed below (see section 6 and figure 2). However, the special circumstances of the least developed countries as well as the context of sustainability have been taken into account when devising the framework.

3. 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 during which some local companies develop capabilities in selected low-tech sectors. 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) MVA 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 top 10 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 value of manufactured exports of the top 10 countries was between US$4,000 and US$28,000, while almost one hundred countries did not record manufactured exports of more than US$5 per capita (UNIDO, Undated). 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 (Biggs and Srivastava, 1996).

Box 2: 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 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 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 to an Italian supplier of printing machines. An informal agreement was set up for the Italian firm to supply and install the machines and software for receiving designs/photographs from clients and train the operators. A royalty was paid to the Italian firm in return for technical advice and maintenance services.

The enterprise was so successful that it was difficult to keep up with the demand for T-shirt printing, most of which came from small businesses in Cape Town serving tourists. Photographs taken by tourists were e-mailed to Epping Printing, and T-shirts delivered within two days. After a year the local firm did not require the services of the Italian supplier. The machines were fairly robust, but when failures did occur, Epping 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.*

There can be adoption of improved technology induced by the entrepreneurial activities of individual firms enhanced by its diffusion in a network or cluster. An example of this is the switch from making roof tiles in traditional wooden moulds to the use of mechanical presses in Indonesia (Sandee and Rietveld, 2001). 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.

The role and nature of technology transfer
The typical motivation for technology transfer in Route 1 is 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 2)*. Wynberg Watch illustrates technology transfer for a market segment in which imported products are too expensive for some potential market segments 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.

There are also possibilities of intermediate technology innovations. These may be initiated 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, and environmentally more friendly, alternative to imported diesel pumps *(see Box 3)*. This case demonstrates the importance of management and the business model for the success of technology transfer. 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 of environmentally friendly appropriate technology transfer is the solar powered lantern and manufacturing and assembly techniques to enable local production in Africa *(see the solar lamp case in Box 4)*.

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.

Elements (a) and (f) raise 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 above assessment identifies the potential for technology transfer even at low levels of industrial development and makes a case for more attention to development of appropriate innovations possibly in collaboration with NGOs and firms with experience in this field.

In the treadle irrigation pump and the solar lantern case studies, 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. The technologies transferred are relatively low-tech and environmentally friendly and the products also make smaller claims on exhaustible resources and have lower damaging effects on the environment. This will not be the case for all technologies acquired under this route and therefore measures for ensuring environmental sustainability will be needed.

Box 3: The treadle irrigation pump in Bangladesh *

In 1979 a treadle powered suction irrigation pump was developed in northwest Bangladesh by the Rangpur Dinajpur Rural Service (RDRS). It was intended to meet 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 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 no nationwide distribution network and the short supply chain from manufacturer to user did not 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 (manufacturer, dealers, installers and customers). Its strategy involved:
- diversifying the production base by working with affiliated manufacturers throughout the country to expand the production base and foster competition;
- quality control by acting as a wholesaler, purchasing pumps from manufacturers, carrying out quality inspections, branding the pumps and selling them to a network of rural dealers;
- using a variety of commercial promotional techniques including promotion at farmers' rallies using local stories as the background to sell the pumps;
- sales and promotional training for local traders and training and supervision of installation teams;
- creating a nationwide dealer network;
- co-ordination with other organisations involved with manual irrigation pump technology leading joint promotional materials and the setting up of a credit programme, and
- access to financing informal means (friends, family and money lenders) and credit facilities extended by raw material suppliers in preference over the more cumbersome formal sources of finance (commercial banks and state banks).

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.*

Box 4: 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, 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.

At full-scale production 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 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 Williams S (2000), Let there be light!, African Business, Issue 258, October.*

4. 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 because sub-contracting arrangements include financial support from the customer or make it possible to arrange finance. The customer may also share the investment cost and assist the contracting firm through the supply of tools, equipment and training.

In Route 2 the foreign firm typically takes the initiative in seeking out suitable locations and sub-contractors to reduce production costs. 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 5)*. 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 6)*.

Box 5: 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 progress beyond Route 2.

It is also argued that the gains from Route 2 could be short-lived with 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. The successful late industrialisers have upgraded to higher levels of capability and entered new sectors (see section 6 below).

Box 6: 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 Export Processing Zones Act provided a package of fiscal concessions and other benefits to attract foreign manufacturers 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 EPZs averaged 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 is scope for specialisation, for example in ethnic products from Africa *(see the Africa can compete case in Box 5)* or products utilising local raw materials, which might reduce head-on competition on cost with large countries with large pools of low cost labour.

5. 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), this protection for domestic firms is restricted but there are still incentives 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 to changes in sourcing by customers than firms in Route 2.

In broad terms, the nature of the technology transferred is 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 for more advanced components from suppliers who demonstrate the capability to absorb and master the transferred technology. The acquisition of technology may be from the customer and/or existing upstream foreign suppliers 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 within sub-contracting, as for Route 2.

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. 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. 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.

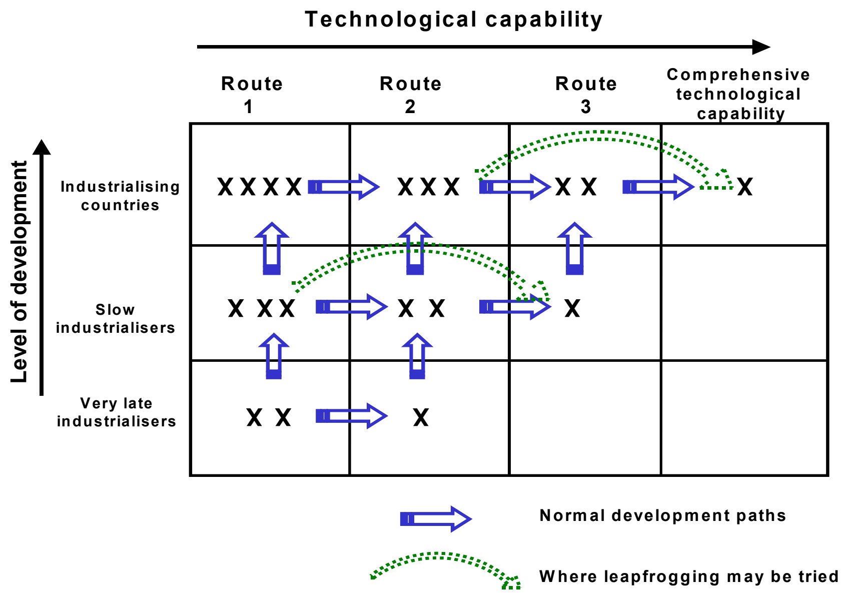
In both Routes 2 and 3, the relationship with foreign firms is likely to continue with more advanced technology being transferred at later stages. For example, when the cost of making sports shoes in Taiwan and Korea increased because of increased incomes and labour costs in those countries, Nike maintained 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 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.

6. An overview of the three routes and framework for enabling support

Figure 1 shows the relationship between the three routes described in previous sections and the relevant levels of country development for which each route is appropriate. It also shows where there are possibilities of 'leapfrogging', for example where China's township enterprises have moved from producing for the domestic market (Route 1) to supplying Sino-foreign joint ventures in the automotive industry (Route 3), or where Korea's electronics component manufacturers have moved from sub-contracting (Route 2) to developing their own large-scale memory chips (comprehensive technological capability).

Figure 1: Paths to development and increasing technological capability



The slow and the very late industrialisers find it discouraging to contemplate slow acquisition of capability, 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 also 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 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. 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 Korea's capabilities which has been studied by many authors 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 7 on Korea's progression)*. The slow and 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 2 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 (South Korea, Taiwan Province of China, Hong Kong SAR and Singapore) while the ASEAN-4 are Malaysia, Thailand, Philippines and Indonesia.

Box 7: Korea: Changing trends in technology transfer *

In Korea, modern technology transfer began in the early 1960s. Old industrial equipment and facilities from developed countries were imported on a turnkey basis through foreign aid or loan programmes. Initially, Korea's production technology was at the level of facility operation or simple manufacturing based on domestic unskilled or semi-skilled labour. In the 1970s Korean industries began to import mature foreign technologies through licensing agreements.

Between the late 1970s and early 1980s, the Korean economy took off, based on two decades of assimilating imported technologies and its own capacity building of imitative technology. Developed countries then initiated technology protectionism policies against Korea due to fear of the boomerang effect. From the late 1980s, cases of patent right disputes with developed countries increased drastically, indicating that Korea had entered the competition phase in some industrial areas. This also meant that Korea will face more aggressive attitudes from foreign technology suppliers.

There is no golden rule for technology transfer. It depends on local and dynamic characteristics, and therefore the Korean experience in the past three decades may be looked upon as a special case. Technology development was gradual rather than a leapfrogging process until Korea had gathered enough momentum (or technological capacity) to make a quantum leap. The success of indigenisation of foreign technology in Korea was attributed by Lee and Kim (1993) to institutional alliances between the government, public corporations, R&D institutes universities, and the private sector, all aimed toward integrated capacity building.

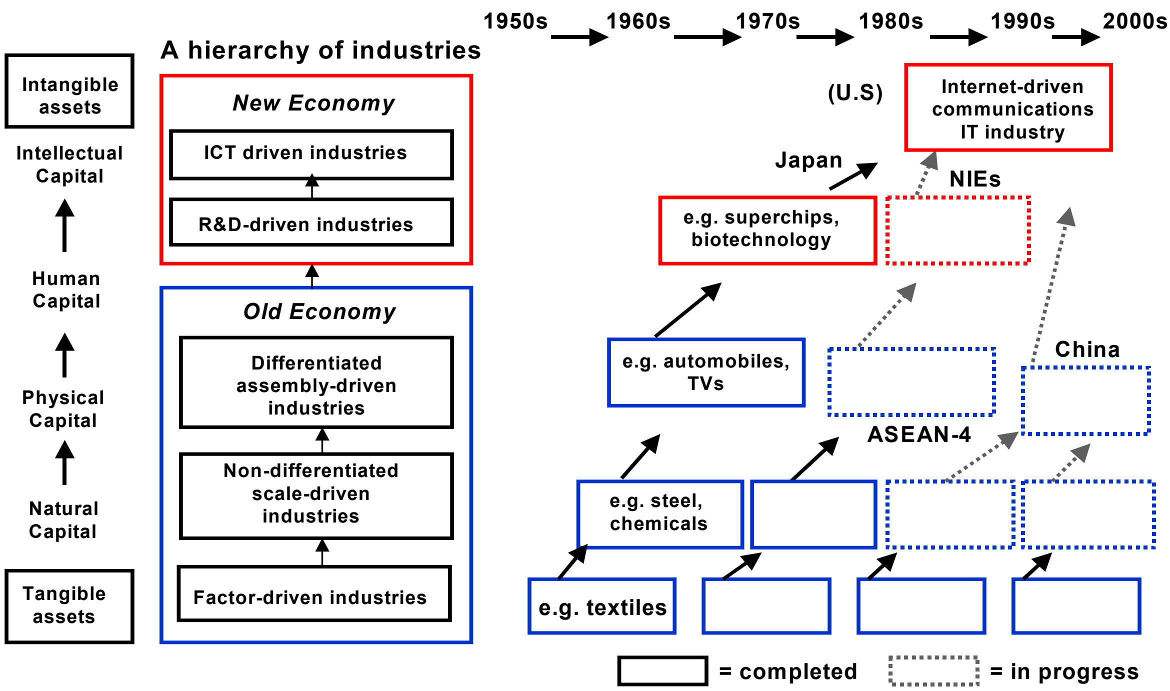
Trends in Technology Transfer in Korea

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.*

Figure 2: 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.

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.

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.

With respect to supporting the process of technology transfer, Table 1 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 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.

Table 1: 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 development agencies	- 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 - training and support for transfer arrangements and negotiations	- assistance with identifying the most promising industries and enterprises - making foreign investors aware of opportunities - training and support for transfer arrangements and negotiations

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 South 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 6). 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).

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