Radosevic, Slavo, International Technology Transfer and 'Catch Up' in Economic Development, Edward Elgar, Cheltenham, 1999.

2. Technology and Modes of Technology Transfer

Technology and technology transfer (TT) are concepts with boundaries that we cannot clearly define. The generation and diffusion of technology are processes deeply embedded in the institutional fabric of economy and society. The forms which technology takes vary from the disembodied (patents, licences) to those embodied in machines or persons (tacit knowledge). Forms of technology transfer vary furthermore as different forms of technology can be transferred through different channels. This multiplicity of forms in which technology is embodied and transferred poses severe limitations for quantifying it and for studying its effects.

In this chapter we first discuss different understandings of technology and then review modes of technology transfer. The objective is to provide an understanding of technology and technology transfer which will form the basis for analysis and discussion in subsequent chapters.

2.1. EXPLAINING TECHNOLOGY AND TECHNOLOGY TRANSFER

Our theoretical understanding of technology and technological change defines how we view the technology transfer process. We can define technological change in many ways. Products, processes, and managerial methods embody technology, but how we understand this technology remains an important problem for economic theory. Both the classical and neo-classical theories of value and distribution take technology as given. Embodied in a product or process, technology resembles a blueprint, or kind of information, that is easily available to the producer and consumer. This view of technology is readily apparent in the growth model developed by Solow (1957). In this model, technology is information and technique that are easily reproducible and transferable.

Technology can also include knowledge about specific applications that is not easily reproducible or transferable. Both Mowery and Rosenberg (1989) and Pavitt (1985, 1993) point out that technical 'knowledge' is tacit and cumulative within individual firms. In this context, technology is part of an individual firm's 'intangibles' or 'firm-specific assets'. The firm-specific character of technology implies that technology is highly 'localized', that is, rooted in a specific institutional and organizational context (firm, network). The consequence is that there are limits to the tradability of technology. No technique is the simple summation of its reproducible elements (codified information and physical inputs). Putting these elements into practice always involves a certain degree of tacit knowledge which is not machine embodied nor codifiable and easily transferable. Thus, given sufficient variation in the relevant circumstances and sufficient elasticity in the knowledge of the ways that a particular thing may be done, in principle there are as many techniques as there are producers (Evenson and Westphal, 1995).[1] Firm-specific knowledge is rooted in firm routines and cannot be traded but only imitated through a gradual learning process with, or without, assistance (Cantwell, 1991).

By contrast, if technology is only information, it becomes 'generic' and easily transferable. Although technology creation is costly, once created it has the characteristics of public goods, that is, it can be replicated and transmitted with low marginal costs and is mobile across space. This view of technology as information appears most clearly in the model developed by Arrow (1962) to explain the allocation of resources to industrial innovation. This model shows clearly how research activity becomes perfectly codifiable and transmissible in the context of the economics of information. Models of this type recognize the problem of incentives which comes from indivisibility, inappropriability and uncertainty in the technology (Geroski, 1995). But it should be added that Arrow's model does not depend on the idea that technology is only information. Although his model considers technology as information, the intention of the model is to show the problems of allocation of innovation under uncertainty conditions, which is a problem that is also present when technology is knowledge. This becomes more apparent when transaction costs are present in the model.

Table 2.1 summarizes the differences between technology as information and technology as knowledge. While these differences reflect differences in theoretical perspectives, one may also see them as two opposite sides of the same phenomenon. March and Simon (1958) suggest that both aspects of technology coexist within the same economy and possibly within the same

1 Maybe nowhere is this understanding of technology so important as in agriculture. The experience of the 'green revolution' illustrates the consequences of a failure to pay attention to the tacit knowledge and local preferences of the farmers themselves. The result is general prescriptions for highly specific and heterogeneous problems. This conceptual misunderstanding may have quite large effects. For example, if the institutional set-up is centralized, as in the case of international agriculture research centres, it can deprive the technical system of "information (feedback) from farmers to tackle these problems, particularly those of small and impoverished farmers. But these institutions ignored the farmer himself as a source of agricultural innovation" (UNCTAD, 1996).

firm and suggest that firms rely on both sources and types of knowledge with varying mixes. The coexistence of technical information and knowledge suggests that both theory and policy need to recognize these differences, as do Romer's (1993) model and many of the evolutionary models. The process of 'interiorization' of scientific knowledge, which is generic and is potentially accessible to everyone, produces very 'localized' idiosyncratic knowledge. On the other side specialized knowledge becomes generic if there are appropriate 'adapters' (Antonelli and Perosino, 1992). The complexity, and probably the most important aspect, of a knowledge-based economy is the transformation of knowledge from its public to local form, or from its general to idiosyncratic form and vice versa. This essential feature of knowledge generation processes has been fully taken into account in studies of organizational learning (see for example Nonaka *et al.* (1996) and Nonaka (1994)). The relationship between different forms in which knowledge is embodied is an empirical question and cannot be resolved by reference to one theoretical framework.

Table 2.1. Technology as information and as firm-specific knowledge

	Information	**Firm-specific knowledge**
Unit of analysis	Technique	Capability
Characteristics of technology	Flexible/Substitutable/ Reversible/Generic/ Adaptable	Local/Cumulative/ Circumstantially specific/Path dependent
Dominant view	Static	Dynamic
Access	No problem	Limited
Concept	Transaction	Investment
Focus	Price	Spillovers, Dynamic externalities
Transfer mode	Arm's length as a norm	Various forms of knowledge transfer
Transfer costs	Negligible	High

The localized character of technical change commands the following seven characteristics: a limited range of techniques, as defined in terms of labour intensity; a limited range of complementary inputs; a limited range of pre-existing production factors; a limited range of firms; a limited range of sizes of the production process; a limited range of regions and industries in which technology is created (Antonelli and Perosino, 1992). From this it follows that localized technological change increases technological change only within a limited range of techniques, defined by the levels of factor intensity, while 'generalized' technological change enables "the global shift of all techniques represented on the map of isoquant of the neo-classical tradition" (*ibid.*, p. 21).

The localized character of technical change reduces the possibility for substitutability among firms, production processes, and inputs. The firm-specific nature of technology prevents or makes difficult and costly the transfer of technology between partners in a technology transfer contract. Limited possibilities for substitutability between production processes and inputs reduces the possibilities for choice of technique (Atkinson and Stiglitz, 1969). On the other hand, if technology is perceived as information then problems in technology transfer are reduced to an issue of incentives. Once technology is produced and property rights over it assigned it is locationally flexible – it can be transferred through markets for licences with negligible transfer cost.

We pointed out before that a technology exists as disembodied and codified technical information but also as very locally specific and embodied knowledge. In real life, the majority of problems with technology transfer stem from the localized and idiosyncratic nature of technology. That is why in the following sections we deal with aspects of technology transfer which originate from the local-specific nature of technical change.

2.1.1. Technology Transfer as an Investment

The localized character of technology has important implications for our understanding of technology transfer. Its complexity arises from the tacit knowledge which is embodied in technology, irrespective of its maturity. As Grant and Gregory (1997) show, manufacturing processes do not become more transferable as technology matures. This is primarily due to tacit knowledge which resides in operations, fault findings, process control, inspection, machine setting, equipment design, problem-solving and test equipment. A successful transfer of technology requires new investments in learning, by which tacit knowledge can be acquired. Due to the localized character of technical change any new application is a new investment, regardless of its novelty. The difference between innovation and diffusion as quite distinct processes is now misleading as numerous references in Bell and Pavitt (1993, 1993a) suggest.

Technology transfer is not merely an act of transferring proprietary information and rights to the other firm. Equally it is not a matter of transferring a piece of hardware from one location to another (Rosenberg, 1982, p. 249). Attendant services have to be provided to facilitate and effectuate the transfer. Contractor (1985) points out that rentals for services to enable technology to transfer, such as technical, managerial, marketing or R&D assistance, are an important part of technology transfer costs. Mansfield

(1975) and Teece (1977) define these costs as the costs of transmitting and absorbing all of the relevant disembodied knowledge. This definition suggests a possible distinction between technology costs (marginal cost of the technology per unit of final product) and transfer costs (marginal cost per transfer agreement) (Madeuf, 1984).

There are four types of transfer costs: costs of pre-engineering technological exchange; costs associated with transferring the process/product design and engineering; costs of R&D personnel during transfer; pre-start-up training costs and learning and debugging (Teece, 1977). However, attempts to empirically measure technology transfer costs are extremely rare. Teece (1976) suggests that the costs of transferring knowledge and competencies can be very considerable. On a sample of technology transfer projects Teece (1977) calculated that transfer costs averaged 19 per cent of the total costs of the project (with a range of 2 to 59 per cent for 26 projects). See also Mansfield *et al.* (1982).

2.1.2. Technology Transfer as a Capability Transfer

If a significant part of technology is tacit and embodied in people and organizational routines, then the efficient transfer of technology means the transfer not only of technological information, but also of the capability to master that technology. Making a strong version of this point Westphal *et al.* (1985) argue that trade in technology transfers the elements but not the capabilities to provide them. The most obvious example of this distinction is technology imports to the Soviet Union, which were restricted to machinery imports and one-off licences imports (Hill and Hay, 1993). One-off import of equipment with little transfer of know-how meant that the Soviets did not subsequently acquire the capability to replicate the plant they had imported. Amman and Cooper (1982, p. 422) show that once the plant was in operation there was a strong tendency for the technology of the plant to remain more or less frozen. A Soviet case suggests that other forms of technology acquisition like learning by doing or using play an even more important role for an effective transfer of technology than technology import. Part of this trade may simply provide complementary services without any real flow of technology. Westphal *et al.* (1985) describe this kind of trade as ‘involving’ technology, rather than trade ‘in’ technology.

2.1.3. Technology Transfer and Technology Distance

The third implication of localized technical change for technology transfer is that it introduces the notion of technology distance. Evenson and Westphal (1995) suggest that this implication stems from the sensitivity of technology to differences in economic, physical and social conditions.

Does technology distance help to explain the specificities of transferring technology to developing countries? Grant and Gregory (1997) show that tacit knowledge is largely recipient independent and plays a role in transfers to both developing and developed countries. Marton (1986) answers this question by pointing to the differences in scope and magnitude between recipients of technology in developed and in developing countries. In the case of developing countries, the need of recipient firms is not only for product design but for a much broader range of technological functions, especially production know-how. The technological needs of firms in developing countries tend to be of a composite nature and cover various stages of project preparation, implementation and operation (Reddy and Zhao, 1990). The technology transferred is somewhat older (Mansfield and Romeo, 1980), and has a greater technical service component (Teece, 1976; Vickery, 1986).

When technology is localized rather than generic, international technology transfer is an investment process, with capabilities as objects of transfer. The tacit knowledge embodied in capabilities makes them inherently difficult to transfer without local investments in learning. This makes the acquisition process irreducible to explicitly traded elements in technology transfer. Technology distance between sellers and recipients not only determines the size of costs and payments, but makes technology acquisition a localized and path-dependent learning process, even when the general characteristics are publicly known and the technology mature.

2.2. MODES OF TECHNOLOGY TRANSFER

Most definitions of technology transfer do not consider the modes of transfer. Fransman (1986, p. 7) defines the international ‘transfer of technology’ as a process “whereby knowledge relating to the transformation of inputs into outputs is acquired by entities within a country (for example, firms, research institutes, etc.) from sources outside that country”.

Despite its negative inference, UNCTAD (1990) implied the existence of different modes of technology transfer when it defined it as: “the transfer of systematic knowledge for the manufacture of a product, for the application of a process or for the rendering of a service and does not extend to the transactions involving the mere sale or lease of goods”.

There are numerous dimensions which can be used to classify technology transfer. Criteria like vertical and horizontal; formal (market mediated) and informal (non-market mediated); active or passive role of foreigners; embodied and disembodied; degree of packaging; direct or indirect; institutional form (intrafirm/integration/investment, pure market, sales and intermediate forms) can illuminate different aspects of the transfer process. Also, the division of technology transfer among conventional channels such as foreign direct investments, licensing, joint ventures, franchising, marketing contracts, technical services contracts, turnkey contracts and international subcontracting, and non-conventional channels such as reverse engineering and reverse brain-drain, reveal some aspects of transfer (UNCTC, 1987).

Undoubtedly there are many different classifications which place emphasis on different aspects of the transfer process. Most attention has been devoted to the examination of formal channels of technology transfer, that is, direct foreign investments, joint ventures, licensing. These are called formal channels as technology is an explicit object of exchange.[2] The need to focus attention on non-market mediated and non-formal modes of technology transfer has been recognized for some time (Fransman, 1986). By the end of the 1980s networks as a mode of transfer between market and non-market began to gain in importance. These are embedded forms of technology transfer, i.e. transfer which is embedded in long-term relationships like subcontracting, co-operative alliances and other non-equity links. Table 2.2 shows the different types and dimensions of technology transfer. We do not comment on all its dimensions as they seem to be self-explanatory. In enumerating the various mechanisms of technology transfer, this table does not include reverse engineering, imitation and different spillovers. Their existence suggests that it is possible to acquire technology without it being transferred, while at the same time not being independently developed.

2.2.1. Foreign Direct Investments and Joint Ventures

Foreign direct investments (FDIs) are those that are made *outside* the home country of the investor, but *inside* the investing company. In national income accounts, FDI includes all flows, whether direct or through affiliates, from the investor; and includes also reinvested earnings, and net borrowings, as well as equity capital. Control over the use of resources transferred remains with the investor, giving it an effective voice in the management of the foreign firm. As Dunning (1993) notes, it consists of a *package* of assets and

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2 Here we do not make a distinction between technology transfer channels and mechanisms of technology transfer as is done in a thorough overview of this issue by Autio and Laamanen (1995) who define a technology transfer mechanism as any specific form of interaction between two or more social entities during which technology is transferred, and a technology transfer channel as the link between two or more social entities in which the various technology transfer mechanisms can be activated. However, the authors themselves recognize that “the continuous interaction can be treated as a channel and as a mechanism, depending on the time-frame and continuity of interaction” (p. 648).

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Table 2.2. Types and dimensions of technology transfer

	Type of embodiment			**Mode of transfer**			**Role of seller/partner**		
Transfer mechanism	**Capital Embod**	**Embod**	**Disembod**	**Market (explicit)**	**Network (intermd)**	**Hierarchies (implicit)**	**Active**	**Enabling**	**Passive**
Direct foreign investments	X	X	X			X	X		
Joint ventures	X	X	X			X	X		
Licensing			X	X					X
Imports of goods	X			X					X
Co-operative alliances*		X			X		X		X
Subcontracting		X			X		X	X	X
Export		X		X					X
Transfer by people		X			X			X	
Development assistance	X	X		X	X		X		

*Production sharing agreements, management and marketing contracts, service agreements, R&D consortia and other co-operative alliances, franchising, technical services contracts.

intermediate products, such as capital, technology, management skills, access to markets and entrepreneurship.

While TNCs were previously identified solely with FDI, the rise of minority-owned investments and new forms of investments during the 1970s and 1980s led to rather complex patterns of technology transfer (Oman, 1984). TNCs today engage in diversified types of relationships and arrangements of which FDIs are only a part. A range of co-operative agreements involving joint ventures, subcontracting, franchising, marketing and manufacturing are complements to traditional FDI (UNCTAD, 1997). Dunning (1993) suggests the TNCs act as transaction cost minimizers (by co-ordinating a number of separate value-adding activities) and network mobilizers (the organization of technology, not necessarily the innovator). Yet the link between FDI and technology transfer has weakened because of a multiplicity of new forms of investment, according to Lall (1992). However, it is still strong due to an increasing technology gap and the spread of FDI in newly industrializing economies (NIEs).

2.2.2. 'Disembodied' Technology as Reflected in Royalty Payments and Licence Fees

Flows of disembodied technology as reflected in payments of fees and royalties for technology largely take place within TNCs as intra-firm transfers between parent and affiliate. In 1995, some four-fifths of payments of fees and royalties for technology of US and German TNCs took place between parent firms and their foreign affiliates (UNCTAD, 1997, p. 21). According to Kumar (1993), US companies transferred 71-77 per cent of licence value through their FDI, UK companies between 31 per cent and 60 per cent, and German companies around 92 per cent in the period 1975-90. For the period 1970-85 Grosse (1989) reports that over 80 per cent of the registered payments to the US for technology sales were made by foreign affiliates of US firms. Over 60 per cent of payments to Japan originated from their own foreign affiliates (UNCTC, 1988, p. 177).

UNCTAD (1997, p. 20) estimates that global payments for disembodied technology quadrupled to an estimated $48bn between 1983 and 1995. There is some evidence which suggests that part of this may have been in transactions between unaffiliated firms. UNCTAD quotes as the only figure in support of this an increase of 175 per cent in US-sourced technology flows among unaffiliated firms between 1986 and 1995. Further support, though indirect, for this trend is a significant increase in technology alliances where exchange of disembodied technology is an important element.

Vickery (1986) estimates licensing revenue to be only 5-10 per cent of the revenue generated by intrafirm transfers.[3] Contractor (1985) estimates gross

3 Based on a royalty rate of 5 per cent of sales.

fees and royalties to be 50 to 60 per cent of the total repatriation on FDI equity holdings. The importance of intrafirm licensing is probably somewhat exaggerated as, in reality, it is to a great extent linked with repatriation of profits and transfer pricing. This also suggests that the value of disembodied flows among unaffiliated firms may be underestimated.

2.2.3. Technology Embodied in Import Goods, Especially in Capital Goods

One can consider technology as some unknown percentage of the value of imported goods. Among all goods, capital goods are regarded as those whose technological content is the highest. According to UNCTAD (1990) the value of capital goods imported into developing countries was $110bn in 1980-86, which was about seven times the average annual FDI and over 14 times the magnitude of technical co-operation grants.

There is a vast literature that emphasizes the strategic role played by capital goods in economic development (Mitra, 1979; Fransman, 1986a).[4] It is not clear whether the introduction of electronics has changed the role of capital goods in development. Evidence based on the Taiwanese electronics industry suggests that it is not the case. A shift in the Taiwanese electronics industry in the 1990s towards DRAMs (dynamic random access memories) suggests the limits of growth based purely on consumer electronics (Choung, 1998). Mastery of capital goods technologies remains essential for long-term growth. Also its importance should be evaluated in a specific national context.[5] However, the increasingly intangible content of new technologies certainly makes the emphasis on equipment alone outdated. What distinguishes capital goods is the variety of learning exposures and linkages upstream and downstream. However, such a degree of interaction comes only when industrial cluster is ‘deep’, which is usually the result of 20-30 years of development. Probably it is realistic to say that the importance of capital goods imports as the sole mechanism of technology transfer has decreased. However, if complemented by other channels, which are suitable for the

4 More than ten years ago Ernst (1984) concluded that only those developing countries that have an embryonic network of capital goods producers will be able to ‘catch-up’ in electronics. He identified the Philippines as a country which had a boom in chip assembly but which was unable to make further progress because of the unavailability of a capital goods base.

5 For example, Korea’s memory chip production is still heavily dependent on equipment from Japan (Choi, 1994). The costs of acquiring such capability for Korea might be prohibitive and, in the end, may have negative value-added. However, this has not prevented a highly dynamic development of this sector and its linkages with Korean industry. Porter (1990) shows that competitive advantage of nations can be created in several ways, some of which do not require a developed capital goods sector as a necessary precondition. Only in later phases of the development of national clusters do capital goods seem to be a necessary ingredient.

transfer of intangible assets (subcontracting, personnel transfer), then it functions as an indispensable channel of technology transfer.

2.2.4. Co-operative Alliances

Co-operative alliances are various forms of company co-operation which are neither arm's length relationships nor mergers and acquisitions. Their growth has been very fast during the 1980s but involved predominantly companies among Triad economies (Freeman and Hagedoorn, 1992). While the definition of FDI is relatively clear the notion of alliances is inherently difficult to define. If there is any agreement among those who have contributed to research in this area, it is in two areas. First, alliances are not majority direct investments but not arm's length relationships either. Second, the notion of alliances assumes the existence of distinctive or relatively independent agents. Although the term strategic alliances is more common we use here Dunning's (1993) term co-operative alliances, as many alliances are not strategic. Co-operative alliances are part of a spreading of network relationships among enterprises. The inability to define clearly the notion of alliances stems from two points of disagreement among analysts: first, whether alliances assume two-way technology flows, and second, whether they involve not only technology or R&D alliances but also production and marketing alliances. As pointed out by Ruigrok and Tulder (1995, p. 184) studies on "strategic alliances often assume that two partners are complementary, independent and of equal relative strength (size, financial power, etc)". Indeed, mainstream literature on alliances assumes the existence of interdependence but not dependence between partners (see Lorange and Roos, 1992). For example, UNCTAD (1996) in its definition of alliances, which are called technology partnerships, implies a two-way flow of technology and knowledge "unlike older forms of inter-firm agreements" (p. 5). Mytelka (1993) considers strategic partnerships as two-way relationships focused on joint knowledge production and sharing, as opposed to one-way technology transfer. Probably in the case of alliances focused on R&D or joint development we may assume interdependence between partners. However, this may not necessarily be the case with production or marketing alliances. In the broad meaning co-operative alliances include not only technology but also production and marketing (distribution) alliances such as procurement and fabrication agreements, service and franchising contracts. These new forms of agreements are not replacing but actually complementing and expanding traditional FDI.

2.2.5. Subcontracting

Subcontracting is a technology transfer mechanism which has spread along with the spread of international sourcing of production. Although formally independent, parties in subcontracting enter into a type of 'quasi-integration'. According to UNIDO, a subcontracting relationship exists[6]

> when a firm (the principal) places an order with another firm (the subcontractor) for the manufacture of parts, components, sub-assemblies or assemblies to be incorporated into a product which the principal will sell. Such areas may include the treatment, processing or finishing materials or parts by the subcontractor at the principal's request.

Subcontracting as a channel of technology transfer is unevenly spread. It is most developed in East Asian countries, comparatively less developed in Latin America and is increasingly expanding in Eastern Europe.

Subcontracting is a broad term encompassing several types of relationships. Outward processing is a type of subcontracting where goods from country A can be temporarily exported to country B in order to undergo processing operations. Usually these operations are released from import or export duties.

There is also an important distinction between 'normal' subcontracting and original equipment manufacturer (OEM) arrangements. Under subcontracting arrangements the client has to buy ordered products or components and support their production. An OEM produces finished goods that are sold under another company's name (UNCTAD, 1995, p. 209). The foreign firm markets the product under its own brand name and through its own distribution channels thereby capturing the large post-manufacturing value-added. OEM sometimes involves the foreign partner in the selection of capital equipment, the training of managers, engineers and factory workers. The arrangement usually involves a close technological relationship between the firms. Hobday (1993) shows in the case of East Asian firms that OEM arrangements are an important 'training school' for local firms in which production and design techniques are absorbed.

The highest form of subcontracting is the own design and manufacture arrangement (ODM). Under ODM firms design and manufacture a range of products with little or no assistance from the overseas purchaser. The buyer then purchases the goods it requires and sells them under its own brand name (Hobday, 1993, p. 24).

When a subcontractor attains the financial and marketing capacity to sell products under its own name it becomes an OBM (own brand manufacturer).

Although subcontracting is an extremely important channel of technology transfer, analysts have neglected it. This is due to the implicit character of technology transfer in subcontracting relationships where technology is not an explicit object of exchange. Also in trade statistics most types of

6 Cited in Germidis, 1980. See Germidis for several other definitions and see Section 5.5 for further discussion on this definition.

subcontracting appear as normal trade and thus it is not recognizable as a distinctively different channel of technology transfer.

2.2.6. Export

Foreign markets are a source of demand as well as a source of learning through close relationships to foreign buyers. This latter aspect – buyers as a source of knowledge – is not yet fully recognized. The experience of East Asian countries shows that information, requirements and knowledge transfers, although by-products of trade, are very valuable sources for the seller (Westphal *et al.*, 1985). The information acquired from foreign buyers is a focusing device and free consultancy for improving production capability. Close, long-term buyer-seller relationships provide information on international markets and market segments, product specifications, and on appropriate production methods (Egan and Mody, 1990).

The quantity and quality of knowledge transferred is a function of buyer–seller communication. The measurement of technology knowledge that is transferred in this way is probably impossible. Among different sources of knowledge foreign buyers are usually ranked very high by enterprises from developing countries. For the example of Korea see Westphal *et al.* (1981). However, the relative importance does not tell us anything about the volume of value of this transfer. One indication of knowledge transfer is the organizational context and length of relationship. The extent to which the seller will transform the learning potential of this channel into a source of active learning depends on its capacity to absorb knowledge and further inputs that it receives from markets/buyers.

2.2.7. Transferring Technology by People (Brain Drain, Brain Gain, Visits and Exchanges), Trade Journals and Exhibitions

Economic historians have shown the importance of the movement of people as a key mechanism for technology transfer during the industrialization of Europe and the US. However, the possibilities for systematic insights into the role of this technology transfer in the contemporary development of developing countries are limited. The measurement of migrations of researchers and engineers, and understanding of their contributions to their home countries produce little beyond anecdotal evidence.

The growth of highly dynamic Asian economies has shown the virtues of the ‘brain drain’ – which until recently was seen as an exclusively negative phenomenon. The transformation of ‘brain drain’ into a ‘brain gain’ (return) and into development of close contacts with ex-patriots (‘brain bank’) emphasizes the importance of technology transfer through people. This phenomenon has reached such an extent that the technological sophistication of electronics sectors in East Asia cannot be explained by conventional technology transfer mechanisms but mainly by 'reverse engineering' and 'reverse brain drain' (Meyer-Stamer, 1990).

Organizational innovations, because of their high tacit component, are transferable mainly through this channel (Kaplinsky and Hoffman, 1992). Many organizational changes, Japanese management techniques being an important part, are now codified and accessible through publicly available literature and the consultancy market. However, their transfer is most effective when combined with transfer through visits (learning through visiting). US technical assistance to postwar Europe via the Marshall Plan is the best example of how effective this channel can be.

2.2.8. Technical Assistance and Co-operation

Although similar to technology transfer by people this channel has its own specific financial, public/private elements and institutional arrangements. Probably because of its institutional specificity, on average it has not been very effective. It seems that the aid system failed to provide sufficient investment in human resource capacities while overspending on capital equipment (OECD, 1992). However, in value terms this is still an important channel of technology transfer. A good coupling of official development aid and FDI has been recently noticed in the case of Japan (see Hiroka, 1995).

2.3. PROBLEMS IN QUANTIFYING TECHNOLOGY TRANSFER

There are three main problems in the quantification of technology flows. First, technology itself is not easily identifiable. Statistics monitor the most explicit forms of technology effects such as R&D, patents and licences. The technology content of FDI can only be indirectly estimated through intra-firm licences. Trade indices such as unit prices are based on an assumption that higher unit price denotes higher technological content. Recently innovation surveys within the EU have become a tool to capture technological activities which are of a non-R&D character. However, all this still leaves a large 'stock' of technological knowledge which is embodied in enterprises and their networks and is unmeasurable. Second, technology flows through different channels where technology is embodied in diverse forms. This diversity prevents comparison of flows along different channels. Third, it is difficult to separate the technical from the transactional elements and costs in technology transfer.

Technology as knowledge has *technical* and *transactional* elements, the former relating to product characteristics and physical processes, and the latter to social arrangements (various kinds of market and contractual arrangements) through which knowledge is transmitted (Westphal *et al.*, 1985). The very process of transfer involves transactional elements (costs, skills needed to perform transfer) as well as specific institutional set-ups. The transactional elements influence the measurement of transferred technologies. Very often they are inseparable from what is being transferred – i.e. the technology itself. Except in cases where the object of transfer is a patent or another form of disembodied knowledge, it is difficult to identify the magnitude of technology transfer. In the case of informal channels, such as subcontracting, it is almost impossible to separate trade in components and products from technology transfer.

Even if better data are collected, Pavitt (1985) points out that the problem of putting different channels together on a common measure of volume and value remains (see also table 1 in Barnett *et al.*, 1993, for the evidence in this respect). Because of the tacit component in much of technology, it is unlikely that we will ever have good approximations of the technology component transferred through different channels.

Systematic data exist only for FDI and trade. Data on licences are available only for a few developing countries. The evidence on the size of technology transfer through other channels is anecdotal. In short, there is little that can be said on the relative magnitude of technology flows among different channels. A relationship between FDI and licensing is the only one where comparisons seem possible. Kumar (1993) and the UN (1993) provide data which suggest that:

- during the early post-war period, to the mid-1960s, FDI was the main mode of technology transfer;
- from the mid-1960s until the mid-1980s non-equity arrangements, especially arm’s length licensing, was the main channel; and
- by the end of the 1980s FDI again became the most important channel of technology transfer.

In view of our previous discussion these generalizations should be taken as very rough simplifications. They do not take into account a rise in different forms of co-operative alliances from the beginning of the 1980s which complemented the rise in FDI. Also, they do not take into account the rising role of subcontracting as a technology transfer channel since the mid-1970s.

2.4. CONCLUSION

In this chapter we discussed different notions of technology transfer and different channels of technology transfer. The complexity of technology and the ensuing difficulties in approximating different types of technology flows are pervasive. Hence, it is very unlikely to be possible to quantify and compare different types of flows on a common basis. This implies that the analysis of technology transfer should be eclectic in order to cope with the multidimensionality of technology. The necessity of a multi-faceted analysis will become obvious in forthcoming chapters.

Among different types of technology transfer, the 1980s have pointed to the increasing importance of network types of organizational forms (subcontracting and alliances) where technology is embedded in inter-firm relationships, and where technology transfer is possible, though not guaranteed, due to the enabling role of the partner/seller. However, this does not mean that the old modes (FDI, licensing) have lost their importance. Effective technology transfer is not a matter of identifying one or two best channels but it is the result of a combination of appropriate modes which are highly dependent on industry, technology, and the level of a country's development.