Foreign direct investment, technology transfer and the innovation-network model

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This article examines the evolving role of transnational corporations in the diffusion of technology both in developed and developing countries. Transnational corporations have responded to the widespread liberalization of investment and trade regimes of the developing countries with increased foreign-direct-investment flows. However, changes in the organizational structures of transnational corporations, especially with respect to their research-and-development activities, will likely make foreign direct investment a less effective means of technology diffusion than it has been in the past. Indeed, despite the deepening of international economic linkages between developed and developing countries, being driven by the activities of transnational corporations, developing countries will face new systemic impediments and policy challenges in the 1990s with regards to the acquisition and local diffusion of new technologies.

Introduction

Technological progress is the most important source of economic growth. A striking illustration of this is found in the rapid convergence of real living standards among the industrialized countries of the OECD during the 1950s and 1960s, resulting from the transmission of United States technology to Western Europe and Japan. This rapid diffusion of technological knowledge took place through four main channels; the liberalization of trade in goods embodying advanced technological know-how; the licensing of (primarily) United States technology; the United States higher-education system, which admitted large numbers of foreign students; and through foreign direct investment (FDI) by United States transnational corporations (TNCs).

This article focuses on this last mechanism, FDI, and examines the implications of changes in the nature of the global investment regime for the diffusion

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of technology both in developed and developing countries. The underlying theme of this article is that, although TNCs have responded to the widespread liberalization of investment and trade regimes in the developing countries with increased FDI flows to these, this will not necessarily contribute to the kind of technological convergence associated with increases in United States FDI to Western Europe and Japan during the early post-War period. Indeed, the factors underlying the deepening[1] process being driven by the activities of TNCs within the triad (Japan, the European Community and the United States) suggest that developing countries will face new systemic impediments and policy challenges in the 1990s with regards to the acquisition and local diffusion of new technologies. These systemic impediments relate to the particular dynamics that characterize network forms of corporate organization.

This article is organized into four main sections; the first section describes recent changes to the global investment regime; the second one outlines a conceptual framework, the "innovation-network model", which looks at the development and diffusion of new technologies within the context of the increasingly network-based international investment regime; the third explores the implications of the innovation-network model for our understanding of the role of TNCs and host-country firms in the diffusion of advanced technologies; and the last section considers the policy implications of the above analysis for host-country Governments and the broader international policy community. The concluding section summarizes the key findings of the article.

Foreign-direct-investment trends during the 1980s and early 1990s

The international investment regime was fundamentally transformed during the 1980s. Three factors characterized this transformation: first, the extraordinary increase in the volume of global FDI flows and stocks during the second half of the decade (concentrated in the triad); second, rising levels of corporate concentration in high technology global production resulting from mergers, acquisitions and network relationships, in particular strategic business alliances[2]; and third, the development and widespread application of information technologies and telematics to international corporate organization.

[1] The process by which international linkages between economies are deepened is examined in detail in UNCTAD Programme on Transnational Corporations, 1993, Chapter VII.

[2] "Concentration" refers here not just to the concentration of ownership within an industry, but also to non-equity cooperative forms of concentration which can give rise to similar distributional outcomes as the former.

Table 1 summarizes the inward and outward FDI stocks for various regions and countries for the years 1980, 1985 and 1990. Total outward FDI stocks increased by 218 per cent (more than tripled) from 1980 to 1990. Most of this increase occurred between 1985 and 1990, during which time FDI stocks increased by 142 per cent, from $516 billion to $1,644 billion. Among the most important factors underlying this rapid increase in FDI stocks were global economic growth during the latter half of the 1980s (from 2.4 per cent from 1980-1985 to 3.1 per cent from 1985-1990), rising levels of protectionism through the increased use of non-tariff barriers and procedural protectionism (abusive use of countervailing and anti-dumping duties), the depreciation of the dollar during the latter half of the decade, rapid increases in Japanese outward FDI, and the growing emphasis upon globalization and regionalization strategies by TNCs in response to rising levels of international competition (Rutter, 1992).

The global economic downturn of the late 1980s and early 1990s has been reflected in a slowdown of FDI activity in the 1990s. Global FDI flows declined in 1991 for the first time since 1982, falling from $230 billion in 1990 to $180 billion in 1991. Transnational corporations from Japan and Western Europe accounted for approximately 90 per cent of the decline, while outflows from the United States and the United Kingdom remained at their 1990s levels. Estimates for 1992 suggest that FDI flows continued to decline that year (UNCTAD Programme on Transnational Corporations, 1993, p. 13).

However, while the deepening of economic relations among the developed suggests that TNCs are now contributing to more north-south deepening. Despite the decline in overall FDI flows in 1991, flows to developing countries increased to 25 per cent of the world total, a level not reached since the early 1980s. Estimates for 1992 suggest that the developing country share of total inflows of FDI will increase further, to approximately $40 billion, or 32 per cent of the estimated world total of $126 billion (UNCTAD Programme on Transnational Corporations, 1993, p. 16).

This process of economic deepening has been accompanied by the corporate concentration of global production in several industries, especially those where research-and-development (R&D) costs are high. Data on mergers and acquisitions in the European Community reveal a 321 per cent increase in their number with respect to majority holdings between 1983 and 1989, a 382 per cent increase in the acquisitions of minority holdings during the same period, and a 180 per cent increase in the establishment of jointly-owned affiliates. Mergers and acquisitions data for the United States reveal a similar trend (OECD, 1992, p. 216).

Table 1. Inward and outward stocks of foreign direct investment by regions and countries: 1980, 1985 and 1990 (Billions of dollars and percentage)

Region / country	1990				1985				1980			
	Inward		Outward		Inward		Outward		Inward		Outward	
	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share	Value	Share
Developed countries	1328.9	81	1593.0	97	544.5	75	656.3	97	394.1	78	503.6	97
North America	504.7	31	501.2	30	247.0	34	289.7	43	134.6	27	241.8	47
United States	396.7	24	426.5	26	184.6	25	251.0	37	83.0	16	220.2	43
Canada	108.0	7	74.7	5	62.4	9	38.7	6	51.6	10	21.6	4
Europe	726.3	44	852.6	52	252.4	35	308.6	46	211.6	42	231.6	45
European Community	646.6	39	714.8	43	224.6	31	268.1	40	186.9	37	200.2	39
Other Europe	79.7	5	137.8	8	27.8	4	40.5	6	24.7	5	31.4	6
Asia	86.8	5	231.6	14	34.5	5	51.6	8	31.4	6	24.7	5
Japan	9.9	1	201.4	12	4.7	1	44.0	6	3.3	1	19.6	4
Australia and	76.9	5	30.2	2	29.8	4	7.6	1	28.1	6	5.1	1
New Zealand	..	..	..	..	..	..	..	..	..	..	..	..
Developing countries	310.0	19	51.2	3	182.6	25	21.9	3	111.2	22	13.3	3
Western Hemisphere	119.6	7	..	..	87.0	12	..	..	62.3	12	..	..
Africa	35.3	2	..	..	22.3	3	..	..	13.1	3	..	..
Asia	155.1	9	..	..	73.3	10	..	..	35.8	7	..	..
Middle East	12.0	1	..	..	6.5	1	..	..	4.3	1	..	..
Rest of Asia	143.0	9	..	..	66.8	9	..	..	31.5	6	..	..
World total	1638.9	100	1644.2	100	727.1	100	678.2	100	505.3	100	516.9	100

Source: Rutter, 1992, appendices 3 and 8.

Another indication that oligopolistic global production structures are becoming more common across industries consists in the growing concentration of market share for the largest firms in various industries. The largest ten firms in various subindustries of the electronics industry accounted for the following estimated market shares in 1987: computers — 90 per cent; telecommunications — 85 per cent; and semiconductors — 61 per cent.[3] In addition, the largest 100 TNCs (excluding financial institutions) controlled approximately $1.2 trillion worth of productive assets and accounted for roughly one third of outward FDI stocks in 1990 (UNCTAD Programme on Transnational Corporations, 1993, p. 23).[4]

Also suggestive of a trend towards greater concentration is the proliferation of strategic business alliances among TNCs, both vertically along value-added chains, such as between suppliers and users, and horizontally across value added chains for different industries, such as strategic business alliances in R&D ventures. This increased cooperation has given rise to "clusters" of firms linked by various forms of contractual and financial relationships. The nature of such interfirm cooperation will be considered more closely in the following sections.

Finally, the international investment regime has been transformed by the application of new information and telecommunications technologies to corporate organization. With the advent of these technologies, TNCs have been able to maintain globally accessible internal databases. They have also been able to manage resources and production processes across borders more effectively. These technologies have therefore served to facilitate the development of networks as well as to improve the efficiency of more traditional, vertically integrated TNCs (for a detailed account of developments in the electronics industry, see Dieter Ernst and David O'Connor, 1992).

In sum, the global investment regime has undergone a fundamental transformation during the 1980s and early 1990s. The effect of these changes has been to deepen the economic ties across the developed economies of the triad and, more recently, the economic interdependency of the advanced industrialized countries and developing countries. Given the extent to which international corporate organization has changed since the 1950s and 1960s, however, the role that TNCs will play in the diffusion of technology to developing countries is likely to be radically different from that played by these actors several decades ago in the case of European and Japanese technological convergence with the United

[3] Unfortunately, comprehensive data on global market shares across industries are not yet collected, with most of the available data on corporate concentration still limited to various national markets. See OECD, 1992, p. 222.

[4] Based upon survey data on 53 of the 100 largest companies; ibid., p. 23.

States. The next section therefore turns to a consideration of the dynamics that characterize the development of new technologies and their diffusion in the current global investment regime.

Technology transfer and the innovation-network model

Early models of technology transfer are based upon a linear conceptualization of the technology-development process. This process involves a flow of information upstream, beginning with basic research in laboratories and ending in the production of more technology intensive products. In these models, technology transfer and technology development are treated as distinct and separate processes. More specifically, technology transfer is conceptualized as an output that usually occurs near the end of the technology-development process (as when a new and fully developed product or process is licensed or sold).

This linear model was useful up until the late 1970s. However, the radical transformation of the international investment regime during the 1980s has given rise to the early formulations of a new model of technology development and innovation, here referred to as the innovation-network model. The key distinguishing feature of this model revolves around the symbiotic relationship between technology diffusion and technology creation.

The model identifies several of the same important nodes of activity in the innovation process as its linear predecessor. Basic research is concentrated in universities and in privately and publicly funded research institutes. The transformation of basic research into new technologies and the commercialization of these is the responsibility of firms. The innovation-network model, however, identifies numerous feedback loops within this system, as opposed to a linear transmission of information from producers of basic science to the "black box" research-and-development facilities of firms.

Feedback loops in the innovative process emphasize the importance of design[5] and the transfer sciences[6] in the development of new technologies. At the level of the firm (or group of firms in the case of a network), numerous stages typically characterize the process leading to the eventual production and

[5] The importance of technology and, more specifically, of design, to economic growth and development has increasingly been reflected in empirical attempts to endogenize technology in econometric models. This has been one of the hallmarks of the new growth theory. For an overview, see OECD, 1991, pp. 86-92.

[6] The transfer sciences include engineering, fields connected with micro-electronics, automation, robotics and computer sciences in general, fields related to chemistry, and the areas of medicine, pharmaceuticals and agronomics (OECD, 1992, p. 37).

marketing of a product.[7] Each of these stages is linked by feedback loops that serve to address problems encountered during the development process. These problems can also give rise to feedback loops linking the innovative processes taking place within a firm back to sources of basic science and, more commonly, to the transfer sciences, especially the engineering disciplines (OECD, 1992, p. 26; Teece, 1991, p. 412). In addition to the loops linking firms to the basic and transfer sciences and the internal loops characterizing the interaction between design and production within firms, loops linking producers and end-users can also play an important role.

One of the implications of the innovation-network model, with its emphasis upon feedback linkages, is that the nature of technological knowledge and the means by which it is transmitted and transformed in the network has been more closely examined. This has led to a dichotomization of technological knowledge as between its appropriable and non-appropriable components.

The innovation-network model recognizes that, in developing new technologies, research spillovers "occur when the firm developing a new idea or process cannot fully appropriate the results of its innovation" (OECD, 1992, p. 48). These spillovers have been characterized as *disembodied technology diffusion*. Competing firms capture these spillovers in a number of ways — through reverse engineering, public information about products (from ads, conferences, reports, descriptions in patents etc.), by hiring people with tacit knowledge[8], as well as through the many linkages, formal and informal, which arise through various forms of inter-firm cooperation.

While information about new products is transmitted relatively quickly through these channels, the immediate commercial potential of this information is limited for several reasons. Most spillovers are of a general nature, and therefore still require considerable innovative and design effort before they translate into a viable commercial product. Spillovers represent only that portion of the innovation developed by a given firm or group of firms which was not excludable.[9] In

[7] There are no hard and fast rules for the idenfitication of such stages, but these will generally include the initial identification of a potential market, the production of an analytic design, detailed design and testing, redesign and production, and distribution and marketing; See OECD, 1992, p. 25.

[8] "[T]echnology invariably combines codified information drawn from previous experience and formal scientific activity with uncodified knowlege, with is industry-specific, or even firm-specific, and possesses some degree of tacitness" (OECD, 1992, p. 69).

[9] "Knowledge is widely considered to be a partially excludable and non-rivalrous good" (OECD, 1992, p. 51). In other words, new knowledge can be only partially appropriated by those who develop it, and its use by one person does not limit its use by another person (non-rivaly).

other words, "certain attributes of innovation dilute its public good nature to some degree and make substantive absorption investments a prerequisite for diffusion" (OECD, 1992, p. 53). To take advantage of spillovers, therefore, firms must have some research-and-development capacity to make the partial information they acquire from the public pool of knowledge commercially significant.

The implications of the innovation-network model's emphasis upon the partial excludability of technological knowledge are profound. From a macroeconomic perspective, the complementary nature of diffusion through spillovers and the innovation process gives rise to a virtuous circle in which "...innovation leads to diffusion which in turn influences the level of innovative activity" (OECD, 1992, p. 51). However, the macro-economic benefits of spillovers identified in the innovation-network model conflict with the traditional micro-economic view of spillovers as a form of market failure. The market-failure interpretation of spillovers predicts that the level of non-appropriability and the incentive to invest in R&D will be inversely related due to the free-rider problem. Within the Fordist paradigm of corporate organization, *where the R&D activities of TNCs are largely autarkic*, the macro-economic benefits of spillovers identified in the innovation-network model therefore cannot be fully achieved.

Once network forms of corporate organization come to encompass the innovative activities of firms, however, the free-rider problem is considerably diminished. Research-and-development networks and strategic business alliances distribute, and hence lessen, the risks associated with research-and-development for the members, and they lower the capital costs of research-and-development by eliminating duplication of facilities and research. Conversely, the costs to potential free-riders of maintaining sufficient research-and-development capacity to benefit from the public pool of non-appropriable knowledge remain unchanged.

The free-rider problem is therefore not eliminated with the adoption of the innovation-network model but the overall welfare effect is positive since the lower R&D costs associated with networks and strategic alliances offsets the negative impact of free riders upon the incentive to invest in R&D. To the extent that R&D networks include leading firms in a particular industry, they also reduce the number of potential free-riders. For example, in the extreme case where all firms that stand to benefit from the development of a particular technology are included in a cooperative research-and-development alliance, the free-rider problem is eliminated.

In sum, the innovation-network model, by conceptualizing technology diffusion as an integral aspect of the innovation process as opposed to merely

being a leakage (when markets do not work) or an output (when markets do work), establishes technology diffusion as the "sine qua non condition for the development of knowledge and of the economy" (OECD, 1992, p. 50). New cooperative forms of corporate organization in turn have diminished the negative impact of free-riders upon investment incentives and have given rise to increased overall social welfare as firms have begun to pursue absolute gains in their technology-development activities and have shifted the focus of their relative gains strategies to the post R&D stages of commercial competition (e.g., low cost production and differentiation strategies based upon marketing). The innovation-network model therefore identifies the positive role played by spillovers in the development of new technologies and provides the economic and social rationale for network forms of cooperation in R&D, namely that they offset the tendency of spillovers to discourage research-and-development when firms are pursuing autarkic R&D programmes. One can now turn to a consideration of the model's implications for developing economies.

Transnational corporations from developed countries have sought to protect their ownership advantages where intellectual property rights are not strong by establishing a physical presence in these markets rather than by serving these at arms length via exports (in the case of products) or licensing (in the case of particular processes). By extending the organizational structure of the firm (or the firm's hierarchy) into foreign markets, advantages particular to a firm, such as technological know-how or proprietary designs, can be better protected. Within the context of this dynamic, the traditional debate over the contribution of TNCs to economic development has focused upon two general issues.

The first concerns the contribution of TNCs to the technological capability of their host-economies (versus the degree to which they simply come to represent technological enclaves). The second concerns the relative negotiating strengths of the two parties and, hence, the relative distribution of the welfare gains arising from the interaction between the two. Put another way, the first issue is concerned with the technical aspects of the TNC-host economy relationship (e.g., the availability of skilled labour in a host-economy, the quality of its infrastructure, the level of sophistication of the technology used by a TNC), while the second issue pertains to the economic nature of the relationship (e.g. the level of concentration in the industry in question, the level of competition among potential host-economies in terms labour costs, natural resource endowments, tax structures). The implications of the innovation-network model for both of these aspects of the TNC-host economy relationship are considered below.

The model suggests that the technical demands of technology transfer will increase as more R&D is conducted within the context of networks and strategic

alliances. Due to the increasingly cumulative nature of the knowledge underlying many new technologies, the complicated process component of research-and-development networks, and the added organizational complexity of the corporate structures being created to develop new technologies, economies seeking to adopt advanced technologies will find that the "bar has been raised" in terms of the technological and organizational requirements for effectively tapping into sources of advanced technology. For example, as telematics facilitates a deeper integration of the developed economies, and strategic alliances increasingly come to depend upon sophisticated communications networks, economies not equipped to handle the new standards (e.g., digital communications) will inevitably find it harder to tap into sources of technology.

Furthermore, under the more traditional autarkic modes of corporate organization and R&D, the innovation process is relatively linear and, by implication, relatively deterministic once the production stage has been reached. Under these conditions, host-country firms can place themselves somewhere along the value-added chain in accordance with their technological abilities and, from there, begin to absorb technology much as any other input. In this case, the interaction between a host-country firm and a TNC is largely one way in terms of the movement of knowledge. Within the context of the innovation-network model, however, the innovation process is based upon feedback loops at virtually every stage of development and production.

This increased dynamism does not raise the organizational demands placed upon host-country firms that seek to benefit from equipment embodied technological diffusion. As buyers of the technology intensive products of TNCs, these firms interact with TNCs at arms length (through the market). However, for host-country firms seeking to establish deeper linkages with TNCs through either equity- or non-equity based alliances (e.g., joint ventures or non-equity strategic business alliances, respectively) the innovation-network implies that greater demands will be placed upon the host-country firms involved. Since the innovation process is increasingly characterized by feed-back loops at the different stages of design and production, the organization and communication costs to all participants in the network, including host-country firms, are raised.

Turning to the issue of the relative bargaining powers of TNCs and host-country Governments and firms, the innovation-network model does not, in and of itself, suggest any worsening of the position of developing countries. As long as firms do not extend their cooperation beyond research-and-development efforts, developing countries should benefit from the increased technological output of networks and the competitive efforts of TNCs to sell their new technologies in global markets.

This being said, however, the available data do indicate increasing corporate concentration in key high technology industries of the global economy. Since the distribution of welfare benefits from equipment embodied technological diffusion is tied to the pricing of technology intensive intermediate goods and the ability of suppliers to capture the social surplus associated with the adoption of these new technologies, the welfare impact of equipment embodied technological diffusion is directly related to the degree of competition that characterizes the market in which technology intensive goods are sold. If supplier industries are highly concentrated, the expected textbook-pricing patterns will roughly prevail and a larger portion of the social surplus will accrue to producers than to consumers. The heightened corporate concentration described in earlier, therefore, indicates that the welfare dynamics associated with equipment embodied technology diffusion have witnessed a worsening of the developing country position.

This section has outlined the main features of the new thinking on innovation and technology development that has accompanied the move from autarkic to network forms of research-and-development activity by TNCs. For the developed economies, the innovation-network model links the motivation behind technology networks to the dual nature of knowledge spillovers which, at the macro level, are central to technological advancement but at the micro level can act as a disincentive to invest in research-and-development in the absence of cooperation.

The innovation-network model also holds significant implications for developing countries. The main issue concerns the increased organizational and technological thresholds that host economies and firms must overcome if they are to participate directly in the value-adding activities of networks. If they cannot develop these abilities they will, to a greater extent, be forced to deal through markets (instead of linking into the value-added networks of TNCs) for new technologies. Since the negotiating position of developing countries relative to TNCs has deteriorated during the 1980s where equipment ebodied technology diffusion is concerned, the impediments to host-country firm participation in the value-added networks of TNCs, described above, become all the more significant.

The role of transnational corporations and host-country firms in technology diffusion

The first section identified a substantial increase in the FDI activities of TNCs during the 1980s which represented a deepening of economic ties between the developed economies of the triad. It also showed that, although global FDI activity slowed considerably in the early 1990s, FDI flows to developing countries continued to increase, suggesting that the deepening process has more recently

come to encompass many economies that were largely peripheralized during the 1980s. The preceding section then outlined the basic features of the innovation-network model which identifies the role played by spillovers in the development of new technologies and the rationale for network forms of cooperation in research-and-development. The innovation-network model also suggests, however, that a traditionally significant channel for the diffusion of technology to developing countries, the interaction of TNCs and host-country firms in value-added activities, might become less effective if host-country firms cannot adjust to the higher organizational and technological requirements of participation in the new corporate structures associated with the development of new technologies.

This section therefore considers more closely the evolving roles of TNCs and host-country firms in the international diffusion of technology. Transnational corporations have long been viewed as the most important link for the transmission of innovations from technologically more advanced to technologically less advanced countries (e.g. Quinn, 1969; Dunning, 1993). Indeed, for most developing countries (as well as for small, open advanced economies), diffusion generally plays a much more important role than domestic research-and-development towards technological advancement (Antonelli, 1986, Antonelli et al., 1989). The process of diffusion, however, does not end with the TNC. While TNCs, through their foreign affiliates, serve as the primary channel of innovations from the developed to the developing countries, the welfare gains to the latter of adopting new technologies depend upon the extent to which these innovations are diffused locally. The role of host-country firms is central in this regard.[10]

One of features of the previous technology regime was the dominance of United States TNCs and technology in the international economy. In stylized terms, these were usually large, vertically integrated firms that concentrated most of their innovative activities in the United States (OECD, 1992, p. 102). The main goal of TNCs is to profit[11] from their innovations and proprietary

[10] It should be noted that much more research and information is available on the diffusion of process innovations than is available on the diffusion of organizational innovations — this despite a growing awareness of the co-dependent relationship between these two types of innovation. The diffusion of process innovations is now generally perceived to be complemented by the diffusion of organizational innovations and in certain industries, such as telecommunications and telematics, the line between these forms of innovation actually begins to blur.

[11] As strategic actors operating in less than perfectly competitive markets, TNCs are not limited to maximizing profits as their sole objective. They may choose to puruse strategies that do not maximize profits since they are not operating at the margin in a neoclassical sense. For example, they may choose instead to pursue increased market share, to make investments that serve to block competitors in particular markets, and to make investments that serve as "windows" in particular markets.

knowledge. Internalization theory dichotomizes the means by which TNCs capture the rents from their proprietary knowledge as between arms-length transactions involving only exports and the internalization of markets into the hierarchy of the firm by means of FDI.

One of the most effective channels through which TNCs transfer innovations and technology to less technologically advanced economies is through their foreign affiliates (UNCTAD Programme on Transnational Corporations, 1993, p. 176). The reason that such internal transfers are effective is that the process can take place under one administrative roof. Through centralized coordination, a TNC is better able to deal with the various externalities usually associated with the transfer of technology, especially learning externalities. The size advantage of large TNCs has therefore long been recognized as being an important factor in facilitating technology transfer (Dunning, 1993; Tilton, 1971).

Given the complex nature of technology and technological knowledge, in particular its level of tacitness, foreign affiliates are well placed to take advantage of technological innovations developed elsewhere within a TNC. In particular, foreign affiliates can benefit from a TNC's technicians and researchers, the presence of complementary equipment, software, and internal communication networks, and from the availability of numerous secondary innovations that are complementary to the main innovation being adopted by the affiliate (Antonelli, 1991). Foreign affiliates can also serve to overcome learning externalities in a host economy by hiring local technicians and workers. One study of the diffusion of advanced telecommunications technology in sixteen countries, for example, found that diffusion of innovations was faster in countries where the ratio of employment by United States affiliates to total employment was higher (Antonelli, 1986).

The resources of TNCs are also important insofar as they serve to capture economies of scope in diffusion. Most innovations are developed in conjunction with other innovations in related fields. The adoption of a package of innovations is therefore often required to maximize the gains from adoption. This, however, entails additional costs, both in terms of the total purchase price as well as in terms of organizational costs, which distinguish the replacement of a single process from the replacement of a whole production system. Therefore, only large firms, and TNCs in particular, have the resources to deal effectively with economies of scope associated with diffusion. Indeed, TNCs often explicitly seek to internalize economies of scope by means of strategic horizontal integration into areas characterized by technological developments complementary to those in which the firm already enjoys proprietary advantages. In the case of the adoption of shuttleless looms, for example, the simultaneous adoption of

innovations in synthetic fibres and open-end spinning rotors were integral to the process of technological upgrading (Antonelli, 1992).

Related to the notion of economies of scope in diffusion is the concept of network externalities which relate to the particular characteristics of a given product which cause the costs of adoption to decrease as the product (and, in particular, the standard it represents) comes into increasingly wide use. In this case, the monopolistic or oligopolistic position of TNCs can serve to accelerate diffusion insofar as ambiguity over standards and fragmented markets can be avoided. Here, a clear distinction needs to be made between the costs of purchase of new technologies and the costs of adoption. If uncertainty exists over standards, and a market is characterized by a lack of a clear leader in this regard, diffusion will be delayed. Firms will defer the risk associated with making a commitment to a technology which might not be on the technological trajectory finally decided upon by the market. This is especially the case in the telecommunications industry, where large networks and high levels of inter-relatedness of the technologies involved with the activities in other industries naturally gives rise to cautionary approaches (for early work on network externalities, see David, 1985).

The main advantages of TNCs in the transfer of technology are therefore twofold. First, due to their size and the resources they command, they are able to overcome various externalities, particularly learning externalities and network externalities. Second, through the establishment of foreign affiliates, TNCs have sought to internalize many of the costs associated with the organization of international production and the communication of ideas. As such, they are well equipped to transfer new ideas to technologically less advanced markets through their affiliates. However, and as explained in the previous section, the diffusion of advanced technology and innovations developed by TNCs, as well as by R&D networks and high technology consortia, to the less technologically advanced economies increasingly runs the risk of being impeded by the rising investment thresholds for research-and-development which have given rise to systemic forms of entry deterrence. This has especially been the case in such industries as pharmaceuticals and micro-electronics.

Economies of scope in technological diffusion and innovation have given rise to the transition from multi-product to multi-technology firms (Ernst and O'Connor, 1992, p. 263). This dynamic has given rise to systems of innovation, involving cooperation among advanced firms specializing in inter-related technologies. These systems, while useful for technological advance, have been based uniquely in the triad, and constitute one example of systemic forms of entry deterrence. Heightened levels of R&D cooperation among technologically advanced firms has been characterized not only by high levels of tacit knowl-

edge but also by important organizational innovations necessary for the coordination of such networks. Linkages between these high technology networks and firms in less technologically advanced countries are very uncommon.

Host-country firms have traditionally needed to be large to adopt effectively new innovations. In cases where innovations are being acquired through actual products or descriptions based on patents, host-country firms must possess the substantial resources necessary to carry out backwards engineering. If a particular innovation is licensed to a host-country firm, some internal innovative capacity, if only in design, is necessary to deal with the tacit component of the innovation being licensed. The innovation-network model, however, points to the need for host-country firms to also develop flexibility. Transnational corporations from developed countries will be looking increasingly at host-country firms not as downstream buyers and users of new technologies but as participants in a system in which the diffusion of the technology cannot be easily unbundled from its development.

The economies of scale and scope involved in the development and transfer of innovations also point to the potential benefits of cooperation among host-country firms to accelerate technology diffusion. Cooperation among firms can serve to overcome many of the common barriers to technological diffusion. The cost of adoption of a new technology is always much higher than the cost of purchase (which is actually a subset of the cost of adoption). The cost of adoption, as described by Christiano Antonelli, is affected by the following five factors (Antonelli, 1991):

- the availability of information about the technology from other users;
- the availability of trained skilled manpower;
- the availability of technical assistance and maintenance;
- the availability of complementary equipment and software;
- the availability of complementary innovations, both technological and organizational.

In less technologically advanced economies, all of these factors are likely to be relatively scarce and, hence, the cost of adopting a new technology is fairly high. Cooperation among firms and the pooling of resources will lower adoption costs in the same way as high investment thresholds in R&D have been overcome by technologically advanced firms through cooperation.

Host-country firms can become even more effective in the diffusion of new technologies with the help of appropriate regulation aimed at overcoming net-

work-related uncertainty. By regulating the adoption by domestic firms of new technologies in such a way that innovations are only allowed to be adopted by one leading domestic firm (considered best suited to developing the innovation for local market conditions) the ambiguity surrounding standards and possible incremental innovations which has been shown to slow diffusion is avoided. For example, this type of staggered entry policy has been highly successful in encouraging the rapid diffusion of synthetic fibre technology in Japan (Ozawa, 1980).

The exclusion of host-country firms from the cooperative R&D networks is the most serious problem faced by developing economies. With regards to the electronics sector, Dieter Ernst and David O'Connor noted that "access to international technology networks has been beyond the reach of most electronics companies in NIEs" (Ernst and O'Connor, 1992, p. 265). It is important to distinguish innovation capacity from diffusion capacity in assessing the potential impact of this problem. The traditional interpretations of technology diffusion, most of which are based upon Raymond Vernon's product life-cycle model, assume that diffusion capacity and innovation capacity are inextricably related, such that economies that are highly innovative are assumed to be able to diffuse technology more quickly than economies lacking innovative capacity. Indeed, this relationship has been supported by extensive empirical studies of the post-war period in the United States, and remains valid in most instances today.

However, recent studies of certain industries, in particular the telecommunications industry, have indicated that a considerable gap can exist between diffusion and innovation capacity, and that such gaps have important policy implications (Soete, 1991). Technological backwardness can give rise to the potential for technological leap-frogging since the costs to developing countries of adopting new technologies can be much lower than they are in the innovating countries. Where innovating countries have committed themselves to a particular technological trajectory determined by previous infrastructural investments, high replacement costs mitigate against the rapid the adoption of new technologies.

As Moses Abramovitz has suggested, a country that adopts new technologies sees both the technological and the chronological age of its capital stock decrease, which in turn can lead to considerable gains in productivity (Abramovitz, 1991). Therefore, the concentration of innovative capacity among firms in certain industries from industrialized countries need not impede the rapid technological progress of technologically developing countries. Leapfrogging, however, does not hold much promise for host-country firms, since it implies the need for system-wide change (for example, investing in fibre optics does not make sense until the whole system is based upon fibre optics) along the lines of the "Big Push" thinking in early development economics (e.g. Nurske, 1953; Rosenstein-Rodan, 1943).

Another option for host-country firms is suggested by the experience of the new biotechnology firms during the late 1970s and 1980s. The new biotechnology firms are relatively small, innovative firms whose activities have centered around specialized R&D niches in areas considered high-risk by the pharmaceutical giants. The new biotechnology firms developed a complementary relationship with large pharmaceutical companies which, contrary to expectations, did not squeeze the new biotechnology firms out, but entered into cooperative arrangements with these and supported their activities through research contracts. The advantages of the new biotechnology firms seem to have been based in the development in the 1970s of basic genetic science (which allowed for sophisticated product development without huge capital outlays) and the closer contacts which the new biotechnology firms enjoyed with the university research community. For large pharmaceutical companies, the new biotechnology firms offered a window into developments in basic science in the universities, relatively low risk means of carrying out research in areas of questionable commercial merit, and a way of tentatively branching out without having to disrupt well established in-house research projects and teams (Sharp, 1990, p. 103).

What the experience of the new biotechnology firms suggests is that there is a place for smaller firms in the development of new technologies, even in a global economy dominated by large firms and even larger networks. This proposition is also supported by the experience of some firms in the electronics industry where research-and-development networks have been most prevalent. Where firms in the newly industrialized economies have been able to develop clear firm-specific advantages, they have often been able to establish partnerships with larger OECD firms. Among the firm-specific advantages of the host-country firms that have given rise to these linkages are "access to finance; access to the pools of cheap scientists, engineers and designers...and access to national research-and-development subsidies, government procurement markets and national/regional collaborative projects" (Ernst and O'Connor, 1992, p. 256).

Policy implications of the innovation-network model for host-country governments

Governments of developing countries throughout Asia and Latin America sought to increase the technological sophistication of their economies beginning by removing barriers to FDI during the 1980s. This widespread liberalization has been characterized by the following two themes:

- Ownership restrictions limiting foreign interests to minority holdings have been replaced with provisions allowing majority and often full

ownership in all but a few of the most sensitive industries. Some distortionary measures continue to characterize legislation pertaining to FDI, especially the application of performance requirements. However, the overall trend during the 1980s has been characterized by, first, greater openness towards foreign investors and, more recently, greater neutrality as between domestic and foreign investors. Furthermore, foreign exchange controls and restrictions upon remittances have generally been relaxed.

- Intellectual property protection remains a contentious issue in north-south relations, and a particularly tricky question from a policy perspective given the double-edged nature of the problem. If, as has often been the case in the Asia-Pacific region, intellectual property protection is lax or non-existent by Western standards, foreign TNCs will be more reluctant to enter into technology-sharing agreements. If, on the other hand, intellectual property protection is too stringent, diffusion will be retarded. The general trend during the 1980s has been towards the gradual adoption of more stringent intellectual property legislation in most newly industrialized economies.

The attempts by Governments of developing countries to attract FDI have clearly succeeded (recall that the overall slowdown in FDI flows during the 1990s has been accompanied by increases to developing economies). However, as previous sections have argued, success in attracting FDI is no longer a guarantee that technology transfer will take place. And while host-country firms will continue to be key actors in the diffusion process and will have to make considerable adjustments if diffusion is to continue, Governments of developing countries must also adjust their policies to the new global research-and-development regime.

Governments of developing countries should focus upon the following three areas in formulating policies aimed at improving the absorptive capacity of their economies within the context of the widespread adoption of the innovation-network model by TNCs: (1) the impact of Government policy upon domestic corporate structure; (2) the impact of Government policy upon the relationships between host-country firms and TNCs; and (3) the impact of Government policy upon indigenous innovative capacity.

Research into the relationship between overall corporate structure and the innovative capacity of economies suggests that, within any given national economy, a balance between large and small firms is desirable. Small and medium sized firms are, as a general rule, more versatile and responsive to changing market conditions than are larger firms. Larger firms, however, enjoy economies of scale in

all facets of their operations, from marketing to R&D. It is especially their ability to sustain in-house R&D programmes, and hence their ability to tie-in to advanced international technology networks, that makes the presence of large firms an important ingredient in national competitiveness and technological advancement. Government policy should therefore aim, in the first instance, at not biasing corporate structure strongly towards either small or large firms (either through tax regulations or subsidies). Moreover, Governments can more actively seek to redress imbalances in the economy between small and large firms by the strategic distribution of Government procurement contracts. Where the information needs of small and medium-sized firms are not overly firm-specific, Governments can also play a role by "making available information which might reduce search costs... and creating a policy environment in which technology flows freely" (Ernst and O'Connor, 1992, p. 106).

The second broad area in which the Government can play a useful role in supporting the technological advancement of local firms lies in its ability to control and regulate economic relations between domestic firms and TNCs — more specifically, by giving domestic firms greater leverage in their negotiations for more advanced technologies in international markets. In this regard, policy can influence technology diffusion and absorption in two ways: first, through infant-industry policies and, second, through policies that trade access to the domestic market for advanced technology from foreign firms.

By protecting infant industries, indigenous innovative capacity can be developed. The well documented drawbacks of infant-industry support and protection bear repeating — all too often, protected infants have grown up to become spoilt and incompetent adults. This result, however, is due to the failure on the part of Governments to establish (and stick to) strict phase-out schedules for protection, not the protection itself. Furthermore, a growing body of evidence suggests that a certain threshold of technological competence needs to be achieved before firms can benefit from interacting with advanced international technology networks. In their study of newly industrialized economies, Ernst and O'Connor found that "strong economic arguments apply for the selective protection of key industries at an early stage, in order to consolidate learning effects and industry linkages" (Ernst and O'Connor, 1989, p. 15).

Governments can also have a positive impact upon domestic absorptive capacity by using market access as a lever to encourage technologically advanced foreign firms to share knowledge and information with domestic firms. Obviously, the effectiveness of this policy is a function of the size of the domestic market, the rate at which the market is growing and the extent to which the prospective host-Government accurately understands the value of the

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