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TECHNOLOGY ABSORPTION AND DIFFUSION AMONG LOCAL SUPPORTING FIRMS IN THE ELECTRONICS SECTOR

Explaining the Divergence Between Penang and the Klang Valley, Malaysia*

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1. Introduction

Multinational corporations (MNCs) can play a key role in upgrading the technological competence of indigenous firms, particularly in economies that have a poor or non-existent industrial technological base. This upgrading occurs as a consequence of the transfer of technology that follows when MNCs link up with indigenous supporting firms in order to develop component parts, or to obtain inputs domestically. But what conditions favour these links and foster the transfer of technology? Clearly, the self-interest of the MNC must be a dominant consideration. Only when it is profitable to exploit the capabilities and capacities of indigenous firms will MNCs consider this option. Although this point may be self-evident, little attention has been paid to this fact. This may well account for the general tendency of those involved in policy-making and those seeking to influence policy to pressure or coerce MNCs to effect technology transfer through legislative or other means (see Fong, 1986: 195-196; and more generally, UN, 1986)[1].

Much of the thinking, even at the conceptual level, has disregarded this perspective. Most authors assumed that the rate of transfer is exogenously determined, either explicitly (for example, Krugman, 1979), or

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[1] Fong (1986: 195-96), for example, suggests: "[a] set of stringent guidelines ought to be formulated, detailing the manner of transfer for various types of technology....enterprises involving high technology could be located in the country initially as a multi-national subsidiary, but with a contractual guarantee of a quantum of staff training expenditure and *eventual take-over of management of the subsidiary by local enterprise*....The multi-nationals should also be responsible for developing the market network for export of the product." (Emphasis added.)

implicitly (Contractor, 1983; Findlay, 1978b), obviating the need to investigate conditions which may favour transfer. And even models that postulate the rate of transfer as endogenous do not link it to the self-interest of the transferor (for example, Findlay, 1978a). An important exception in this respect is Wang and Blomstrom (1992), who, however, concern themselves with a situation of limited relevance to the electronics industry in Malaysia.[2]

This paper has two objectives. First, it develops a conceptual framework which recognises explicitly the long-run self-interest of the transferor in determining the extent of transfer. The framework thus focuses on an issue of considerable interest in Malaysia: the factors that motivate a locally situated MNC to transfer technological competence to indigenous firms[3], and their implications for policy. The technological upgrading of indigenous firms is crucial with respect to the Malaysian objective of attaining the status of a fully developed economy by the year 2020, since they will constitute the foundation for eventual technological independence.

Second, the extent and nature of technology transferred by MNCs to local firms in two industrial concentrations – Penang and the Klang Valley are reviewed. An attempt is then made to assess the extent to which the insights gained from the technology transfer framework explain the differential rates of technology transfer (absorption and diffusion) noted

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[2] They look at a case where an MNC-affiliate is competing in the same market as an indigenous firm--a situation uncommon within the electronics and electrical sector in Malaysia.

[3] In this context, the transfer to indigenous firms is more relevant. These are firms that are wholly-indigenously owned or firms with majority-Malaysian ownership. The term "local firms", on the other hand, refer to both indigenous firms and firms of foreign ownership that are situated locally.

among local firms[4] in these two areas. This may serve as an indirect test of the empirical relevance of the framework.

2. Conceptual Framework[5]

The model pertains to the issue of technology transfer by an MNC, or MNC-affiliate (henceforth referred to as MNC or main firm), operating within the electronics sector. More specifically, we examine the case of transfer from an MNC located in Malaysia to indigenous firms. Typically, the control of management and policies of the MNC are closely held by the foreign owner, and, they enjoy the freedom to import components and inputs without tax or other restrictions. Thus, technology transfer can only occur in one of two ways: first, through the MNC itself fostering links with indigenous firms in an ancillary role. Second, through the provision of training to local personnel in the employ of the MNC. In the latter instance, technology is diffused to the local economy when trained indigenous workers actually leave the MNC to join indigenous firms in similar or related industries, or set up their own establishments.

The technology transferor in our setting is then the MNC, with its access to superior technology, that is willing to impart technological expertise. The recipient is a technologically backward indigenous firm with some existing capability to serve the MNC's requirements, or the potential to be developed into an ancillary firm.

For the purposes of our discussion, technology is restricted to all aspects pertaining to production, that is, production technology. The

[4] Note that local firms, whether indigenously owned or otherwise, employ largely Malaysian workers. To the extent that technology transfer is a transfer of skills or expertise to local personnel, the ownership of the firm is of limited relevance.

transfer of technology therefore refers to the extent to which increasingly sophisticated expertise associated with a given technology is passed on. In the case of technology associated with production, this would include acquiring, successively, the capabilities to independently (that is, without foreign help) operate, maintain, repair and modify the associated machinery and operations. If the further capability to perform independent R&D on both products and processes are attained, the technology absorption is complete at the level of the firm. Thus, more transfer occurs when the recipient absorbs sequentially higher levels of expertise, not with the transfer of more sophisticated technology *per se*. It also follows that the more extensive the transfer of expertise, the higher the indigenous firm's potential of becoming independent of the transferor.

Whether, and the extent to which, an MNC will transfer technology is viewed as its private decision based on its perceived private costs (C) arising from such transfers and benefits (B) expected from the transaction. In principle, the MNC is assumed to maximise its net benefit or net profit from the transfer.[6]

2.1 *The Costs of Transfer*

The cost of transfer may include the investment expended in developing the technology being transferred and the actual costs involved in effecting the transfer. The former is likely to be insignificant since technology being transferred to developing countries is usually of older vintage with its costs long amortised (Mansfield and Romeo, 1980). The latter refer primarily to expenditures borne by the transferor in training key

[5] This is a shortened and modified version of the framework discussed in Narayanan (1997).
[6] Costs and benefits are more accurately measured as suitability discounted flows over time. In order to capture the essence of the framework in a relatively uncluttered framework, this refinement has been ignored. This, however, does not sacrifice the basic insights to be gained from the framework.

personnel in the recipient firm, in order to increase the recipient's technological absorption.

Another relevant cost the transferor has to consider is the price of keeping ahead of the competition; in this case, the transferee. This idea, recognised by Krugman (1979) suggests that if technology transfer is effected continually without innovation keeping pace, the transferor's position may be eroded. Thus, the funds channelled to continuous innovation in order to preserve a given technological niche is an important factor to consider in deciding the extent of transfer to effect. The amount of funds devoted to continuous innovation will depend, among other factors, the size of the technological gap between the transferor and the recipient. Other things held constant, the amount of funds devoted will vary inversely with the size of the gap.[7]

It must be noted that there are some who hold the view that technological change is so rapid that even before a recipient can catch up, the transferor would have moved on to new generation of technology (Aasen et. al. 1990: 28). But this assumes that there is already a commitment to continuous innovation on the part of the transferor. Moreover, we subscribe to the view expressed by Kaplinsky (1990: 24): while developing economies may have no prospect, at an aggregate level, of moving towards the edge of world technology, some of them could compete with the best for dominance in narrow niches of technological specialisation.

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[7] Doubtless, MNCs are constantly engaged in research to keep ahead of their competitors in the developed world. Such expenditures may be sufficient to maintain their edge vis-à-vis the technology recipient as well . In such a situation, the cost of transfer may approximate zero. Even so, any continuous transfer of technology to a recipient might entail a higher level of expenditure than necessary otherwise; this is because the recipient is often privy to more sophisticated aspects of proprietary technology, relative to the transferer's competitors at large.

The concept of a technological gap and its impact on transfer has received previous attention. Following Kmenta (1967: 42-43), we postulate that the technology of the recipient is lagging behind that of the transferor by several time-periods. It is further assumed that the transferor's technology is a function of time, and grows at a constant exponential rate such that

$$D(t) = D_o e^{rt} \quad (1)$$

where D_0 is the initial stock of technology, r is the (constant) rate of growth and t is time. We postulate that the recipient's technology lags behind that of the transferor and that the length of the lag (l) is an inverse function of the rate of technology transfer (k):

$$l = l(k), \text{ where } l'(k) < 0 \quad (2)$$

The recipient's technology R(t) can be given as follows:[8]

$$R(t) = D[t - l(k)] \quad (3)$$

which simply says that the recipient's technology is at a stage where the transferor's was (l) years ago. Substituting (1) into (3),

$$R(t) = D_0 e^{r[t - l(k)]} \quad (4)$$

The above formulation assumes (for simplicity, though unrealistically) that the transferor and recipient enjoy identical rates of technological growth. This allows us to make the level of the recipient's technology a positive function of technology transfer alone.[9] Note that an increase in transfer reduces the lag between D(t) and R(t).

The technological gap (G), relative to the level of technology of the recipient, may be expressed as

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[8] This is an adaptation of one of the technological diffusion models discussed by Nelson and Phelps (1966: 69-72).

[9] In reality, the lag can be affected by the research efforts of the recipient. This is not considered explicitly because this possibility can be safely discounted at the current stage of development of Malaysian indigenous firms. A national survey in 1992 concluded that while both local and foreign firms perform little research, the MNCs in the electronics sector leads the effort (cited in UNDP/WB, 1996: 14). But the impact of R&D efforts of the recipient can be deduced easily from the framework.

$$G = [D(t) - R(t)] / R(t)$$
$$= e^{rl(k)} - 1 \qquad (5)$$

This suggests that for any given lag, an increase in (r) will widen the gap between the transferor and recipient. Alternatively, for any given rate of technological growth enjoyed by the transferor, technology transfer shortens the time lag separating the technologies of the transferor and recipient. That the gap is inversely related to transfer, given (r), is evident from the following:

$$dG/dk = rl'(k)e^{rl(k)} < 0, \text{ because } l'(k) < 0 \qquad (6)$$

It must be emphasised that although a gap is necessary for transfer to occur, the recipient cannot lag too far behind technologically; if this is the case, technology simply cannot be transferred because the indigenous firm would be incapable of absorbing it effectively.

The cost of transfer (C) can now be stated as the expenses incurred by the transferor to support the innovation necessary to at least maintain the technological gap (G). This cost is an inverse function of the gap.

$$C = (G), \text{ where } dC/dG < 0 \qquad (7)$$

Since the cost of transfer is a function of the technological gap and the gap, in turn, varies with the extent of technology transferred, we obtain the following cost function:

$$C = (e^{rl(k)} - 1) \qquad (8)$$

The impact on cost of a marginal increase in transfer is positive:

$$dC/dk = C'(e^{rl(k)} - 1)rl'(k)e^{rl(k)}$$
$$= C'(G)rl'(k)e^{rl(k)} > 0$$

In general, given r is constant, an increase in transfer will spur more investment in innovation and increase the cost of transfer. On the other

2.3 *Maximising the Net Benefit From Transfer*

The extent of technology transferred is an outcome of the transferor's profit maximisation decision

$$\text{Max } \Pi = B - C$$

$$\Pi = B(E(e^{rl(k)} - 1)) - C(e^{rl(k)} - 1) \quad (14)$$

Setting $d\Pi/dk$ to zero and manipulation yields

$$B'(E)E'(G)rl'(k)e^{rl(k)} = C'(G)rl'(k)e^{rl(k)} \quad (15)$$

Dividing both sides by $rl'(k)e^{rl(k)}$ gives

$$dB/dG = dC/dG \quad (16)$$

Assuming that the second-order conditions for maximisation are met, we obtain the standard maximisation rule that implies that technology transfer from the MNC to the indigenous firm will continue until the additional benefit from reducing the technology gap between the two (in the form of increased future returns to the transferor) just off-sets the additional expenditure the MNC expects to make in order to maintain the technological edge.

Manipulating equation (15) above yields

$$dB/dE = dC/dE \quad (17)$$

which conveys the same idea in terms of the impact of transfer on the technological competence of the recipient. That is, transfer will proceed until the perceived increase in the future profit stream of the transferor (the benefit) from increasing the technological capabilities of the recipient just matches the additional investment in innovation necessary to maintain the technological gap.

2.4 *Implications of the Framework*

It is evident from the framework that a passive stance on the part of the recipients (whether a firm or the state) will make technology transfer dependent on the (perceived) marginal costs and benefits of the transferor. The pace of transfer will therefore hinge on changes in exogenous forces impacting on the cost-benefit calculus of the donor. A pro-active policy stance, on the other hand, will seek to influence the MNC's cost-benefit calculus to our advantage, an approach that differs from attempts to pressure or coerce MNCs to effect transfer by imposing legal provisions.

Based on the standard *ceteris-paribus* conditions, the following predictions regarding the rate of transfer emerge from the framework. On the costs side, *given the marginal benefit schedule*, technology transfer occurs easily in circumstances where the cost (to the donor) of keeping ahead of the recipient is low. Not surprisingly therefore transfers between parent and subsidiaries may be expected to occur easily.

The framework shows that increases in the (exogenous) rate of technological growth of the transferor is likely to have a positive impact on the pace of transfer.[10] This is because rapid innovation within the MNC widens the gap between it and the recipient, thereby reducing the costs associated with such transfers. Thus, other factors remaining constant, MNCs experiencing rapid technological progress are more likely to transfer technology extensively to indigenous firms.

The framework also implies that the relatively backward nature of indigenous technology lowers the cost of transfer to the MNC. (This advantage can be further reinforced by enforcing intellectual property safeguards.) In situations where the marginal cost of transfer is zero, the

[10] A further result follows from the formulation; an increase in the rate of technological advance (r) experienced by the transferor (likely) spills-over to the recipient. This is seen by looking at the first derivative of R(t) with respect to k.

$$
\begin{aligned}
dR(t)/dk &= -rl'(k)D_0e^{r[t - l(k)]} \\
&= -rl'(k)R(t) > 0, \text{ because } l'(k) < 0
\end{aligned}
$$

This suggests that for all positive values of (r), any exogenous increase in the rate of technological progress of the transferor also raises the marginal benefit derived by the recipient, since the latter becomes an indirect beneficiary of some new knowledge gained.

MNC will transfer technology until that point where the marginal benefit from transfer is equated to zero. To ensure a more extensive (or complete) transfer of *a given technology* in such situations, policies must be in place to raise the entire marginal benefit schedule of the transferor.

The most significant insight from the framework is that any policy that seeks to reduce the cost of transfer represents, in effect, a commitment not to undermine the technological edge of the transferor in the longer term. And since this would be a non-acceptable option, *policies to encourage more extensive transfers are best focused on influencing the expected benefits of the transferor, not the costs.*

An important effort aimed at enhancing the benefit of the transferor and inducing transfer is to foster the growth and development of indigenous firms. This can be done by offering suitable financial and entrepreneurial support to new-comers and by assisting efforts to strengthen the resource and human resource bases of existing indigenous firms in the industry. A solid base of vibrant indigenous firms will provide an important incentive to MNCs seeking ties with the local economy. Such links, in turn, will enhance the prospects of direct technology inflow from MNC and eventually contribute to its diffusion when indigenous firms build up technological links between themselves. And to the extent that competition among and with indigenous firms will spur them to improve their technological capabilities, a domestically competitive environment must be fostered.

At a more general level, the expected benefit from transfer (to the MNC) may be influenced positively by devoting considerable resources to upgrade the relevant skills of its human resources in the economy. These investments will have two favourable effects on the benefit function of the transferor. First, it provides the critical minimum corpus of skills necessary before technology can be transferred, even if there is a desire to do so.

Second, the value-added by firms who are the beneficiaries of the transfer to the transferors is likely to be greater, the more skilled and trained their workers are. Technical expertise given out is often enhanced by creative minds and this enhancement benefits the transferor as well, since recipient firms are in their service.[11]

It should be noted that the framework alerts us to the fact that an economy that expends considerable efforts in upgrading itself need not necessarily continue to attract technology transfers. Whereas, on the one hand, such upgrading will add to the value of services provided by indigenous firms to the transferor (and increase the benefits from transfer), such efforts, on the other hand, could also contribute to the narrowing of the technological gap between the transferor and the recipient (thus, increasing the costs of transfer). Acting singly or collectively, indigenous firms may develop the capability of undermining the position of the transferor in some market niche. The extent of transfer will then be conditioned by the relative strengths of these opposing considerations. Even so, it is intuitively evident that when indigenous firms are at a low level of technological competence (as in Malaysia), substantial increases in human resource development can be sustained without affecting the technological gap appreciably, while still making significant contributions to profitability of the transferor. Hence, diverting resources to upgrade and increase the fund of indigenous technological expertise is a good strategy to enhance transfer. Naturally, the task of developing a skill-base to enhance the absorption of technology and, eventually, generate an independent internal momentum of our own, cannot be left entirely to the indigenous firms themselves. Given that they are largely small and medium-sized enterprises (SMEs), the public sector must take an active, and even leading role in the process.

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[11] Of course, upgrading indigenous firms and investments in relevant human resources provide benefits to the economy as well, beyond those influencing the benefit schedule of the MNCs.

The market environment within which the MNC operates may also be expected to influence the perceived benefit of linking up with local suppliers and, consequently, transfer. The more competitive this operating environment is, the greater the pressure to cut costs and improve quality. This, in turn, pressures the MNC to constantly seek cheaper (but reliable) sources of inputs or support services. If indigenous firms have the potential to serve this need, the MNC will be motivated to actively forge or strengthen these links, opening the way for more extensive technology transfers. On the other hand, if the competitive pressure is lacking in the output market, the external pressures to enlist the aid of indigenous firms s may be significantly lower. In short, the framework suggests that MNCs operating in industries or subsectors subject to intense competition are more likely to transfer technology because the expected benefits from transfer are enhanced by such links.

3. Operationalising the Framework

It is quite surprising to find how much of the discussion on technology transfer proceeds without any clear concept of what it means or how it is to be measured. An entire volume on technology transfer was produced, for example, without offering a definition on what was meant by technology transfer (Chatterji, 1990). One problem is that the definition of technology itself is being widened to mean many things to many people. We now have production technology, product technology, marketing and management technology, information technology and so forth. A logical starting point is to begin with a precise statement of what type of technology transfer is being evaluated. In this paper we confine ourselves to *production technology* which refers to the expertise involved in manufacturing a given good (or input) and its related processes.

Even confining technology to production aspects, evaluating its transfer has posed a major challenge to researchers. In general, the problem has been overcome by resorting to *ad hoc* measures that serve as proxies. One frequently used measure is the number of technology transfer agreements signed formally between the transferor and the recipient (see, for example, Osman Rani, Toh and Anuwar, 1986: 18-21; Anuwar, 1992: 82-87; Lim and Anuwar, 1990: 44-45). This has two weaknesses. Firstly, these data cannot capture transfers that may have occurred in the absence of formal agreements, although this is not an uncommon phenomenon. Secondly, unless agreements are fully implemented, they do not result in transfer. Researchers must therefore go further and seek evidence of their full implementation.

Another widely-used proxy is the extent of royalties (or other fees or payments) exchanged between the transferor and recipient (Vaitsos, 1970; OECD study cited in Ernst, 1990: 291; Koko and Blomstrom, 1995: 460-461). Such data suggest, at an aggregate level, that some form of technology has changed hands but, unfortunately, offer no clue as to the extent to which it has been absorbed by the recipient. Furthermore, these data themselves may be misleading on two counts: many corporations have no precise pricing rules for technologies supplied to affiliates. And intracorporate technology payments may conceal profit repatriation aimed at evading host country taxes (Koko and Blomstrom, 1995: 460).

The import of machinery or its mere presence is sometimes assumed to reflect the transfer of embodied technology (for example, Koh, 1994: 105-106; Chee and Chan, 1982: 49-50; Fong, 1986: 73- 74; Lim and Anuwar, 1990: 45; Abibullah et al., 1995: 47-49), but this is only as good as assuming that the purchaser of a car has imbibed the technology embodied in it.

The expenditures on training (in-house or abroad) the local workforce involved in the operations of an imported technological process is perhaps a closer measure of the efforts made to transfer expertise (Natarajan and Tan, 1992: 48-50; Willmore, 1995: 531-532; Fong, 1988: 8-9)[12]. But expenditures on training need not translate to learning, just as a parent who pays the school-fee cannot assume that the child is automatically absorbing knowledge. The true test of how much has been absorbed is demonstrated only when the student can perform, unaided, the exercises expected of him or her.

In sum, therefore, the proxies usually pressed into service suffer from several weaknesses. First, if technology transfer is a process, they do not tell us at what stage the transfer has reached. Second, they do not convey accurately whether or not real transfer (in the sense of the knowledge being internalised) has occurred. Third, many of the proxies measure one stage or the other of the transfer process but not its entirety.

A further limitation of many empirical studies of technology transfer is that they adopt the macro approach and are thereby tied to aggregate data. Transfer is more usefully studied by looking at the experiences of firms within an industry and accumulating firm-level experience.

In the search for a better alternative, we begin with the notion that technology transfer refers to the transfer of the capacity to understand, use and develop the technology in question (Komoda, 1986: 407). Drawing from the work of Komoda (1986) and several Japanese authors cited by him, and Baranson and Roark (1985), we have suggested elsewhere that the progress of technology transfer be measured against the extent to which three stages of the process have been accomplished: adoption, absorption and

[12] None of these studies actually used figures on training expenditures to measure transfer; they simply assume that efforts at training workers have transferred technology.

diffusion (Narayanan, 1993). This basic framework was developed and applied in several subsequent studies (for instance, Narayanan and Cheah, 1993; Narayanan, Lai and Cheah, 1994; UNDP, 1994; Narayanan, Lai and Cheah, 1997).

As applied to production technology, the process of transfer involves three stages -- adoption, absorption[13] and diffusion. While it is convenient to view them consecutively, the second and third stages frequently occur concurrently. Transfer is initiated with *adoption,* that is, a recipient agrees to adopt a given technology.

The second stage, or the *absorption* process refers to the degree to which various aspects of the given technology are internalised by the local personnel in the firm. One approach to ascertain absorption *empirically* is to pose the question as to whether the local workforce in the recipient firm can perform, *independently,* all tasks associated with a given phase of the technology question.[14] The absorption of production technology at the firm level proceeds in steps, with absorption becoming deeper as each step is accomplished. Absorption begins when the local workforce has gained independent operational skills. The three subsequent steps are attained when independent duplicative skills such as maintenance, repair and modification capabilities are mastered. Absorption of production technology at the firm-level is complete when the recipient can undertake, unaided, innovative activity to improve the production process. [15]

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[13] In the previous works using the approach, this stage was labelled "rooting". Absorption perhaps conveys better the idea of internalising technological expertise.

[14] By independence we mean that local workers are able to perform the tasks without assistance from outside parties, including the transferor.

[15] In previous discussions of the framework referred to earlier, R&D activity was not distinguished into that pertaining to processes (relevant to *production technology*) and associated with products (relevant to *product technology)*. In the present context the presence of the former indicates the final step in the absorption of production technology. This distinction was clarified in Narayanan (1995) and Narayanan and Lai (1996b).

The third or final stage of transfer -- *diffusion* occurs when technology spreads from the recipient to other firms or sectors in the economy. This can take place through various modes, such as the development of subcontracting relationships, the interaction of workers, staff turnover and mobility between firms and conscious effort. Clearly, diffusion can proceed concurrently with the absorption phase, without waiting for the latter to be fully complete at the recipient firm level. A complete empirical evaluation of diffusion will involve the study of both technological and pecuniary linkages. The former requires a reliable set of input-output data which is currently unavailable. Analysis in this paper is therefore confined to technological linkages.

4. The Data

The data used in this paper were collected as part of a larger, two-stage United Nations Development Programme-funded study on the electronics and electrical sector (hereafter referred to as the electronics sector, for convenience) in Penang and the Klang Valley (UNDP, 1994; Narayanan, Lai and Cheah, 1997).[16] Data on a total sample of 104 firms (both firms in the electronics sector and local supporting establishments) were collected. Of this, 39 were supporting establishments and we utilise the data on these in this paper.

In terms of location distribution, 15 of the 39 supporting establishments were in Penang while the rest (24) were in the Klang Valley. By ownership, 10 of the firms in Penang were Malaysian, two were Japanese-owned and the remaining three were of other foreign ownership.

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[16] These studies were collaborative efforts with several other colleagues. The first phase involved Lai Yew Wah, Cheah Kooi Guan, Abdul Fatah Che Hamat, B.N.Ghosh and Ismail

In striking contrast, 16 of the 24 supporting firms in the Klang Valley were Japanese-owned, while the remaining six were equally divided between Malaysian and other foreign owners.

These differences in the ownership of supporting firms clearly suggest that MNCs in Penang have been more successful in spawning indigenous supporting establishments relative to their counterparts in the Klang Valley.

5. Technology Transfer: Empirical Evidence

The empirical evidence is examined with respect to modes of access to technology and the extent to which technology which has been accessed has been absorbed and diffused.

5.1 Access to Technology

Table 1 shows the major modes through which supporting firms gained *access* to technology. Interestingly, in Penang, where the majority of firms was indigenously-owned, access to technology was gained while providing ancillary services (such as being subcontractors and/or doing contract or OEM manufacturing). This is consistent with the general view that indigenous firms benefit from linking up to MNCs in support roles. Firms also gained access to technology embodied in machinery and equipment purchased, with the vendors providing the initial exposure.

The picture is quite different in the Klang Valley. Bearing in mind that the majority of the supporting firms were foreign-owned, it is not

Omar. The second phase was undertaken with Lai Yew Wah and Cheah Kooi Guan. Both phases were co-ordinated by Dato' Chet Singh.

surprising to find that the technology came from parent plants (abroad) or through the purchases of plant and equipment from abroad. Firms reporting access to technology through subcontracting links with local MNCs represent only a small proportion of the total. In the case of the three Malaysian supporting firms, they depended largely on purchases of machinery and equipment and through assistance from firms they served (data not shown).

In sum, given the fact that MNCs in Penang have fostered wider links with indigenous firms, access to technology to supporting firms has come largely by way of spill-overs. In the Klang Valley, various factors (to be discussed later) inhibited the forging of links between MNCs and indigenous firms. This has resulted in an inflow of foreign supporting firms that bring their technology with them. Diffusion of this technological expertise to the local economy will only occur once Malaysian workers in these firms have assimilated or absorbed the skills.

Table 1: Access to Technology for Local Supporting Firms

Mode of Access	Penang (%)	Klang Valley (%)
Subcontracting	64.3	20.8
Contract Manufact./OEM	50.0	12.5
Machinery/Equipment	57.1	79.2
Parent Company	-	75.0
Attachment	14.3	16.7
Other	-	33.0

Notes: Penang Sample = 15 firms; Klang Valley Sample = 24.
Multiple responses were allowed.

5.2 Adoption and Absorption

Technology is adopted when a firm installs imported machinery and its related processes. All firms in our sample are therefore adopters since they utilise imported machinery and the technology embodied in them. It should be noted that proxies commonly used to indicate technology transfer such as the import of machinery and/or the installation of imported equipment indicate only that the *first phase of transfer* has occurred (within our framework discussed previously).

Indisputable evidence of technology transfer (at the firm-level) is obtained when local workers in the recipient firms carry out the associated functions without foreign-assistance. The progress in this respect is mirrored in Table 2.

Two observations common to both areas may be noted. First, the proportion of firms where indigenous workers have mastered a given phase of production technology varies inversely with the complexity of skills involved in that phase. There was a higher proportion of firms where local personnel have mastered operational skills, relative to those where more complex skills (like maintenance, repair/modification or R&D) have been attained. Second, evidence of independent R&D capabilities was very thin in both samples.

Table 2: Stage of Technology Absorption in Local Supporting Firms

Extent of Absorption	**Operations**	**Maintenance**	**Repair/Modify**	**R&D**
Penang	13 (86.7)	9 (60.0)	8 (53.3)	3 (20.0)
Klang Valley	14 (58.3)	6 (25.0)	4 (16.7)	1 (4.2)

Note: Penang sample = 15 firms; Klang Valley sample = 24 firms.

Comparing the level of technology absorption by local workers in firms within the two areas, progress in the Klang Valley lags considerably behind that in Penang. And, in general, this disparity becomes wider as the absorption of more complex skills are considered. To illustrate, whereas Malaysian workers were able to fully man the operational stage of production technology in 58 percent of the supporting firm sample in Klang Valley, the comparable figure was 87 percent for Penang. Independent maintenance capabilities, on the other hand, was acquired by Malaysians in only 25 percent of the Klang Valley supporting firms, as opposed to 60 percent of their Penang counterparts.

In terms of our transfer framework, while all firms in both areas have passed the first stage of transfer (adoption), progress in the second stage of absorption is markedly different between supporting firms in Penang relative to those in the Klang Valley. While more than half the firms in Penang have moved to the third and fourth steps of technology absorption (repair/modification skills), the majority of the firms in the Klang Valley is still at the first stage of absorption.

5.3 Diffusion

An important mode of technology diffusion is via the links built up between the original technology recipient (the supporting firm) and other local firms that serve it in various capacities. The extent to which supporting firms source their inputs locally is one measure of the progress of diffusion.[17]

It is clear that although local sourcing by supporting firms is still at an infancy stage, it is more visible in Penang than in the Klang Valley (see

[17]A full evaluation of linkages and, thus, diffusion, requires deatailed input-output data. Such data are not available, at least in published form.

Table 3). While 46 percent of the firms in the former sourced more than half their input requirements locally, the comparable figure in the latter was just 13 percent.

The lower level of local sourcing by supporting firms in the Klang Valley may be partly explained by the fact that Japanese-owned supporting firms predominate here.[18] The greater tendency of Japanese firms to source inputs from their own suppliers (in Japan) or elsewhere has been documented (Guyton, 1994; Narayanan and Lai, 1996a).

Another reason for the lower reliance on local sourcing in the Klang Valley may be due to reservations regarding the suppliers themselves. A significant majority (63 percent) of the supporting firms in the Klang Valley found their local suppliers inadequate, although 12 out of the 15 complainants (or 80 percent) were Japanese-owned supporting firms. In other words, about 43 percent of all Japanese supporting firms registered difficulties with local suppliers, relative to 22 percent of indigenously-owned supporting firms and 7 percent of the firms owned by other foreign nationals.

Table 3: Local Sourcing of Inputs by Local Supporting Firms

% Local Inputs	% Penang Firms	% Klang Valley Firms
0	-	33.3
0-24	38.5	-
1-25	-	37.5
25-50	15.4	-
26-50	-	16.7
> 50	46.2	12.5

[18] In Penang as a whole, 14 of the 16 plastics supporting firms enumerated in the PDC Directory (1992a) had completely indigenous ownership while the remaining two had a substantial indigenous majority ownership. Similarly, among metal supporting firms, 32 of the 37 firms enumerated were fully, indigenously-owned and three had majority Malaysian ownership (PDC, 1992b). Recall that in the Penang sample, 10 of the 14 firms were Malaysian-owned.

Most dissatisfaction revolved around the quality of local inputs (67 percent of the complainants) and the lack of reliability with respect to deliveries (53 percent). Interestingly enough, Japanese supporting firms complained on both accounts while both indigenous and other firms were more concerned about the reliability factor (Table 4).

Of course, sourcing inputs from local suppliers is not equivalent to using *domestically-produced* inputs. This is because local supplier-firms frequently import at least some of the materials that they supply directly to their client-firms. Another problem is that local supplier-firms themselves rely largely on imported inputs to produce their final output. Unfortunately, we do not have the data to check on the extent of these phenomena.

Table 4: Complaints of Local Supporting Firms Regarding Local Suppliers

Complaint	Price	Quality	Delivery	Other	Numbers Complaining
Japanese	3 (25.0)	9 (75.0)	5 (75.0)	2 (16.7)	12 (80.0)
Other Foreign	1 (100.0)	-	1 (100.0)	-	1 (16.7)
Local	1 (50.0)	1 (100.0)	2 (50.0)	1 (13.3)	2 (50.0)
Total	5 (33.3)	10 (66.7)	8 (53.3)	3 (20.0)	15 (100.0)

Note: Figures in brackets are proportion of complaining firms registering each type of complaint. Multiple responses permitted.

There is also no significant evidence of supporting firms in the Klang Valley spawning links with other indigenous firms or attempting to pass technology through these or other links. In fact, only three of the 24 supporting firms claimed to have transferred technology (of any sort) to indigenous firms.

In sharp contrast to the Klang Valley, (indigenous) supporting firms in Penang who were original recipients of technological expertise from MNCs, have spawned second and third tier local suppliers of their own. And 12 of the 15 firms in our sample claimed to have transferred technology to other indigenous firms.

In a detailed study of the linkages between seven electronics sector firms and nine indigenous machine tool firms in Penang, Rasiah (1994) found that the latter, in turn, fostered the growth of second and third-tier suppliers through subcontracting relationships. The first-tier vendors (those who had the first links with the electronic sector firms) have, in time, chosen to specialise in certain functions, and passed on some of their previous tasks to second-tier machine-tool firms whom they now nurture. These second-tier firms have gone on to spawn their own third-tier subcontracting firms, giving them simpler tasks like parts fabrications which are no longer profitable for the former. In this way, not only has the number of machine tool firms increased but there has also been a greater degree of specialisation among them. These findings suggest a wider diffusion of technology through the agency of first-tier firms to smaller firms servicing them. The findings of this study have been corroborated by other observers as well (for example, Lim, 1992: 33; Teh, 1989).

An important development that provided the impetus for MNCs to link up with local firms was the intense competition that characterised the world electronics environment (and, particularly, the "chip" market) in the mid-1980s. This pressured MNCs to seek ways to cut costs and attain precision levels beyond those possible by manual processes alone (see Kamal and Young, 1989; Rasiah, 1989; Narayanan and Rasiah, 1992). As a consequence, the process of automation was hastened and flexible production systems (such as the Just-in-Time technique) were introduced in local subsidiaries. The latter, among other things, required that machines be components firms the latter has a bigger nucleus of firm in the consumer electronics subsector where technology change has been markedly slower.

Technology transfer and its subsequent diffusion requires a larger, sympathetic network than the goodwill built between the parties that are immediately involved. This network includes public agencies that are supportive of technology transfer and demonstrate it through thoughtful and enlightened policies in favour of it. It encompasses public programmes and governance mechanisms and procedures that promote transfer and diffusion (see Freeman, 1987; Nelson, 1993; Mowery and Oxley, 1995; Rasiah, 1995). Such institutional support, in terms of the conceptual model, increases the expected benefits from transfer.

In this respect, the local supporting firms in Penang have been historically more fortunate than those located in the Klang Valley. The state leadership, right when electronics was first introduced in the 1970s, was extremely committed to ensuring its success. Penang was in the midst of an unemployment crisis which was not helped by the removal of its Free Port status. Wooing the labour-intensive, export-oriented electronic assembly operations that were beginning to seek sites in Southeast Asia was made a priority and the (Chinese) Chief Minister of the state took a personal interest in promoting the electronic industry. In the words of the then Managing Director of National Semiconductor, the first semiconductor firm to be set up in Penang in 1971 (Hill, 1989: 138):

> These overall Malaysian advantages were leveraged in Penang because the Chief Minister was and is very pro-active, or in more general terms, a good salesman of the state and country. He essentially went knocking on doors in California and was able to convince quite a few companies that this was a good place to be in.

serious impediment since Taiwanese firms of even more recent vintage have progressed further in the transfer process (see Narayanan and Lai, 1996a).

The commitment of the Chief Minister was reflected in the efforts of the state economic development corporation (SEDC), known as the Penang Development Corporation (PDC), of which he was also the Chairperson. The PDC took a pro-active stance in wooing and overseeing industrial development in the state and ensuring that it developed linkages with the state economy. [20]

If the state leadership in Penang was singularly moved to ensure that the electronics industry took root and grew, the state leadership in Selangor (within which the Klang Valley was then located) was preoccupied with other concerns. The early 1970s and much of the 1980 marked the enthusiastic implementation of the New Economic Policy (NEP), committed to "restructuring society".[21] This task was spearheaded by the public sector and a plethora of public institutions was created for this purpose. And unfortunately, the early enthusiasm of seeing the NEP succeed might have spread thin the attention of the largely Malay leadership as they focused on many fronts including ensuring that Malay employment quotas were being met.

Another implication of the conceptual framework is that, other things remaining constant, technology transfer is facilitated (that is, the expected benefit from transfer is increased) when there exists local firms capable (or with the potential) of serving in ancillary roles. Again, this requirement was met more completely in Penang than in the Klang Valley.[22] Not only were

[20] Similar points are also made by Rasiah (1996)

[21] Malaysia is made up of Malays and other indigenous groups (collectively called the *Bumiputera*) and those of immigrant descent such as the Chinese and Indians. The remarkable, but lopsided development since independence in 1957, saw the politically dominant Malays being virtually shut out from commerce and industry where the Chinese held sway. This unequal distribution of wealth and economic opportunity triggered the race riots of 1969 and the promulgation of the New Economic Policy (NEP) that vowed to restructure the economy so that race was no longer identifiable with economic function.

there local firms involved in low-precision parts fabrication activities, but the physical "smallness" of Penang facilitated contact and co-ordination. An added factor was the common ethnic (Chinese) background of the representatives of the foreign MNCs and the owners of local firms. In fact, Rasiah (1994) notes that seven of the ten owners of local machine tool firms in his study had past employment experience with the MNCs they now serve.

The ethnic factor also operated in other ways to boost the co-ordinated push to forge ties between the MNCs and local firms in Penang. The state leadership was ethnically Chinese, as was the entrepreneurial class that led and financed most of the local industrial and commercial activity in the state. And the PDC, although headed by a non-Chinese administrative head, was sufficiently staffed with key personnel who were Chinese. They therefore found no conflict in interests between their assigned task of fostering links between the MNCs and existing local firms that were almost all Chinese-owned and run.

In sharp contrast, the SEDC (state economic development corporation), the counterpart of the PDC in Selangor, was Malay-led, and staffed predominantly by Malays. Undoubtedly, officers manning the SEDC faced a dilemma: fostering and strengthening indigenous firms, so vital for technology-absorption and diffusion, meant nurturing Chinese capital -- already perceived as having a strangle-hold over the domestic economy. This was seen as running contrary to the spirit of the NEP. Not surprisingly, therefore, while much energy was expended in attracting and retaining multinationals, the related effort to develop indigenous (Chinese) ancillary firms was seriously lacking. In fact, the authorities remained ambivalent

[22] Recall that our framework suggests that strong, technologically capable indigenous firms may also increase the cost of transferring technology by narrowing the gap between the transferer and the recipient. However, as argued previously, when the level of technology of

when Japanese and Taiwanese-based multinationals circumvented the lack of local supplier firms by bringing in support firms owned by their own nationals. [23] And in the case of the Japanese, the ambivalent stance of the officials coincided with the reservations of the former in dealing with local suppliers at the expense of Japanese suppliers from within their own business network. The way was open for an inflow of foreign-based supplier firms setting up operations domestically which raised the anxieties of local supplier firms struggling to establish themselves.[24]

Finally, the framework suggests that the easily availability of skilled human resources facilitate transfer by impacting favourably on the transferor's benefit calculus. Penang undoubtedly attracted a larger corpus of trained and skilled personnel, relative to the Klang Valley, simply because these were to be found among the non-Malays (more specifically, the Chinese) who might have preferred (in their view, at least) the less stifling career prospects in Penang. In the 1970s and 1980s, Malay representation in the engineering and technical professions was low relative to the Chinese. For example, 71 percent of all registered engineers in 1980 was Chinese, as compared to only 19 percent Malays. And while Malays made up 54 percent of all professional and technical workers in 1985, nearly two-thirds were teachers and nurses (Malaysia, 1986: 104-105). Moreover, Malays professionals displayed a marked preference for serving in the public sector with its general career stability.

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the recipient firm is substantially behind that of the transferer (as in this case), the expected increase in benefit will easily outweigh the increase in the cost.

[23] More generally, it has been noted of that period that "..local manufacturing capital had minimal support from the state." At times the state even seemed to "undermine the power of local capital by strengthening the position of foreign capital the manufacturing sector." (Mohd. Nazari, 1995: 21)

[24] See, for example, the complaint by the Federation of Malaysian Foundrey and Engineering Industries in the *Business Times* (12 March, 1993). See also Lim (1992: 31).

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