Introduction

During the last 30 years, the rapid development of Singapore’s economy has been unmatched by any other developing country. Indeed, one commentator described Singapore as:

the most successful economy in the world, even in comparison with other members of the so-called Gang of Four (Lim, 1983, p. 752).

The role played by foreign-owned capital in this economic transformation is difficult to underestimate. UNCTAD (1994) points out that Singapore, in comparison with other developing countries, is somewhat unique in its reliance on FDI for employment, investment and exports. For example, between 1986–91, foreign direct investment (FDI) as a share of gross domestic investment was 29.4 per cent, higher than any other economy in East and Southeast Asia (see Table I). Indeed, Singapore is possibly the best example in the developing world of FDI-led economic development (Huff, 1995).

Singapore’s success in attracting foreign investment is undoubtedly spectacular and its ability to exploit FDI for wider economic development may have lessons for other countries. This paper examines the material linkages between foreign-owned companies and suppliers based on the island. Backward linkages to indigenous suppliers of materials have traditionally been considered one of the main ways in which FDI develops the host economy (Hirschman, 1958). Henderson and Appelbaum (1992) claim FDI is only significant for economic transformation when it stimulates local firm production linkages and/or results in shifts to higher value-added forms of production within the subsidiaries of multinational enterprises (MNEs). Furthermore, it is generally accepted that the level of local supplier interaction is perhaps the key indicator of corporate embeddedness (Dicken et al., 1994). Another reason for the importance of linkages is the fact that linkages (i.e. supplier firms) may actually outlive the initial investment made by the MNEs, therefore contributing to long-term economic development.

Yuan and Low (1990) claim that MNEs help to nurture the local supply base in three important ways. First, they provide a market for the output of local products, especially for components and parts. Second, MNEs constitute a training ground for local engineers

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Abstract

The paper examines the role played by foreign direct investment in developing local linkages in Singapore’s electronics industry. Backward material linkages have developed as a result of two processes: the development of indigenous local suppliers, mostly within the fabricated parts sector, and foreign investment by overseas suppliers, especially in the hard disk drive sector. The economic development potential of these suppliers varies, and local suppliers in contract manufacturing offer the best hope for future indigenous growth within the supply base. Public policies targeted towards supplier development and upgrading the quality of multinationals play a significant role in facilitating local linkage development in Singapore.

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Electronics and local sourcing in Singapore

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and technicians, some of whom then form their own companies. Third, by providing product specifications to their local component suppliers, MNEs assist in upgrading the quality of local production. The last point relates to the transfer of technology which can take place during backward linkage formation. This is often deemed one of the most important aspects of MNE-supplier linkages (Mowery and Oxley, 1995) but also one of the least commonly found benefits from FDI (Kenny, 1995; Patel, 1995). Thus, it is often better to look beyond the sheer numbers of linkages and look at their intrinsic quality, especially as this relates to the long-term economic health of a region (Sklair, 1994; Turok, 1993).

Indeed, linkages which flow from branch plants may actually be becoming progressively more important. For example, increasing competition for scarce inward investment projects is placing a renewed emphasis on maximising the long-term economic spin-offs generated by inward investment (Young et al., 1994). In fact, such has been the determination to attract internationally mobile capital that MNEs are able to extract substantial concessions from host economies in return for their assembly lines (Brown et al., 1996). Regions which develop strong indigenous suppliers and subcontractors have a better chance of prospering given the continued trends in international production towards vertical disintegration: regions which neglect this imperative and continue fuelling the international bidding process for greenfield inward investment may suffer a precarious fate at the hands of powerful MNEs.

The empirical material used within this paper draws on an in-depth interview-based study of seven foreign-owned electronics manufacturers and 12 local suppliers in Singapore (see Brown, 1996)[1]. Singapore provides a useful case study of linkage development owing to its massive inflows of electronics FDI. Such has been the impact of FDI that Singapore has become a centre of excellence in the manufacture of the 3.5 inch Winchester hard disc drives (HDDs) and has been dubbed “Winchester City” in recognition of the importance this sector plays in the country’s economy (Yuan and Low, 1990).

The paper begins with an overview of the development and current growth of electronics in Singapore. This is followed by a discussion of the nature of electronics production in Singapore and the level of local linkages between MNEs and suppliers. Following this, the paper assesses the nature of Singapore’s electronics supply base, focusing on a select number of key subsectors. The penultimate section examines the dynamics of linkage development in Singapore and the factors influencing linkage levels. The final section provides some brief concluding remarks.

Electronics and local sourcing in Singapore

Electronics growth

In Singapore, the electronics industry is the largest sector within manufacturing industry, accounting for 42 per cent of gross manufacturing value-added (EDB, 1994). Within the manufacturing sector as a whole, electronics accounts for about half the total output and a third of total employment. In 1996, the industry employed 128,590 people and growth was 9 per cent (see Table II). The total output for the electronics industry was S$63.2 bn in 1996 (EDB, 1997)[2]. The average gross value-added per worker in the electronics industry grew from S$94,090 in 1993 to S$132,640 in 1996 (EDB, 1994; 1997).

Although electronics as a whole experienced very rapid output growth during the last few years, the more moderate growth of the industry in 1996 was primarily a result of a slowdown in semiconductors and consumer electronics. This was partially offset by the strong growth in data storage and office automation equipment (see Table II).

The electronics industry in Singapore is classified into four main electronic sub-clusters: data storage and imaging products, 3Cs (computers, consumer electronics and communications), semiconductors and key

<table>
<thead>
<tr>
<th>Economy</th>
<th>FDI/GDI (1981-85)</th>
<th>FDI/GDI (1986-91)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong</td>
<td>10.7</td>
<td>11.4</td>
</tr>
<tr>
<td>South Korea</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Singapore</td>
<td>17.4</td>
<td>29.4</td>
</tr>
<tr>
<td>Taiwan</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Japan</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Source:UNCTAD 1994

Table I Foreign Direct Investment as a percentage share of gross domestic investment in selected East and Southeast Asian countries
modules/devices (contract manufacturing, passive components, printed circuit boards, and display devices). As shown in Table II, current growth in Singapore’s electronics industry is concentrated in the first of these clusters. The data storage sector covers products such as HDDs, tape drives, CD-ROM drives, and their related components and sub-assemblies. This sector recorded an estimated output of S$18.3 billion in 1996 and Singapore accounted for about 42 per cent of world rigid disk drive shipments in 1996 (EDB, 1997). This growth is being driven by significant investments by Seagate, Hoya Magnetics and Western Digital which have all expanded their data storage capacity in Singapore over recent years. Office automation products, such as printers, scanners and inkjet colour copiers, are also expanding rapidly. This subsector posted a record 40 per cent increase in output in 1996 and value-added increased by 35 per cent to S$2.3 billion in 1996 (EDB, 1997). This growth is being driven by significant investments by Seagate, Hoya Magnetics and Western Digital which have all expanded their data storage capacity in Singapore over recent years. Office automation products, such as printers, scanners and inkjet colour copiers, are also expanding rapidly. This subsector posted a record 40 per cent increase in output in 1996 and value-added increased by 35 per cent to S$2.3 billion in 1996 (EDB, 1997).

Table II Output of Singapore’s electronics industry by cluster

<table>
<thead>
<tr>
<th>Cluster</th>
<th>1995 output (S$ billion)</th>
<th>1996 output (S$ billion)*</th>
<th>Percentage growth rate (1995-96)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data storage and imaging products</td>
<td>Data storage</td>
<td>14.16</td>
<td>18.31</td>
</tr>
<tr>
<td></td>
<td>Office automation</td>
<td>3.82</td>
<td>5.36</td>
</tr>
<tr>
<td>3Cs</td>
<td>Computer</td>
<td>12.54</td>
<td>12.61</td>
</tr>
<tr>
<td></td>
<td>Consumer electronics</td>
<td>6.22</td>
<td>4.97</td>
</tr>
<tr>
<td></td>
<td>Communications</td>
<td>2.84</td>
<td>2.94</td>
</tr>
<tr>
<td></td>
<td>Semiconductor</td>
<td>11.74</td>
<td>12.08</td>
</tr>
<tr>
<td>Key modules and devices</td>
<td>Passive components, PCBs and display devices</td>
<td>3.41</td>
<td>3.39</td>
</tr>
<tr>
<td></td>
<td>Contract manufacturing and others</td>
<td>3.17</td>
<td>3.46</td>
</tr>
<tr>
<td>Total electronics</td>
<td>57.95</td>
<td>63.16</td>
<td>9</td>
</tr>
</tbody>
</table>

Source: EDB, 1997 *estimated

The bulk of the recent output growth has not been met with an increase in employment within the sector. Although part of this owes to increased employment throughout the supply base, the EDB (1994) claims that increased output has been attained through higher value products and greater use of automation. This (so-called) jobless growth phenomenon is mitigated somewhat by the absence of unemployment in Singapore’s labour market.

Nature of production

Singapore has attracted various layers of FDI as the country developed from a low-cost production platform to a higher value-added manufacturing centre. Toh (1993) has identified three main waves of electronics foreign investment. The first wave occurred during the late 1960s when there was an influx of semiconductor firms from the USA. Firms such as National Semiconductor, Fairchild and Texas Instruments established facilities to assemble and test very simple integrated circuits (ICs) on the island. These operations were heavily focused on the labour-intensive aspects of semiconductor production. The second wave of inward investment was led by foreign-owned consumer electronics firms back when AT&T downsized production of their telephone handsets facility in Singapore and 600 people were laid off when the company relocated production to the nearby industrial park on the Indonesian island of Batam, fuelling fears that a “hollowing out” process may be taking place (Straits Times, 1994).
which began producing a wide range of products such as CTVs, clock radios, irons and audio equipment during the 1970s. The motivational force behind the third wave was the desire to establish low-cost production capacity for products such as personal computers (PCs) and HDDs.

The upgrading and development of plants has also varied. For example, Apple, which originally opened in 1981, used its facility as a printed circuit-board assembly (PCBA) operation but eventually upgraded this to include full system assembly, transferring full production of an early range of PCs to the plant in 1984. The advanced nature of Singapore's technological development is revealed by the assembly of printed circuit boards (PCBs) which is mostly undertaken by surface mount technology (SMT). The best SMT levels in Singapore are close to the state-of-the-art for volume electronics production both in the pitch of the components being assembled and in the complexity of the final assemblies (Tilley et al., 1996)[3]. Most plants interviewed typically use SMT in meeting their PCBA requirements while plants in nearby Malaysia were often used for more basic "through-hole" assembly processes.

Broadly speaking, the MNE plants visited can be divided into two key groups. The first group consists of firms in the consumer electronics industry. Such firms have a very wide array of products. JVC manufactured compact disc (CD) players and car audio equipment. Philips has an even wider product range which includes audio equipment, colour televisions (CTVs), tuners, domestic appliances such as irons and hairdryers. Indeed, with a combined turnover of £2bn, Philips is one of the largest MNEs in Singapore. The second group comprises data-processing firms (Apple, Compaq and Hewlett-Packard), undertaking the manufacture of a smaller range of products. For example, PCs are configured according to a range of criteria such as storage requirements and microprocessor capability. Firms in the latter group also experience very short product life cycles.

Most MNE plants visited have high production volumes. This derived, in part, from the markets served by the plants. Most plants in Singapore also have a market coverage extending beyond the immediate regional market. The older plants - Epson, Philips, JVC and Hewlett-Packard, for example - were established as low-cost operations in order to serve the established electronics markets in the USA and Europe. In the main, these are globally-oriented operations with production destined for various regional markets such as Europe, USA and Japan. For example, some of the CTVs manufactured by Philips also go to the Middle East, Eastern Europe and Latin America as well as the local Asian market (Philips, 1994). More recent FDI is geared towards producing for the rapidly expanding Asian regional markets. For example, the PC manufacturers Apple and Compaq currently serve the immediate Asian Pacific region.

Given that the market range covered by any given MNE subsidiary will increase the volume of production, globally-oriented plants will usually have greater input requirements than smaller regionally-oriented plants.

It has been observed that the supplier infrastructure tends to be weak in most developing countries, often leading to a high degree of vertical integration (Kaplinsky, 1995). Sklair (1994) notes that this sometimes leads to MNE procurement requirements being met internally vis-à-vis intracorporate sourcing; however, it would appear that foreign-owned companies located in Singapore do not face these problems. The levels of vertical disintegration within Singapore are similar to those found throughout the developed world: the average figure of material needs externalised for the sample of firms interviewed ranged between 70-80 per cent. The levels of intracorporate sourcing, although not fully established, did not appear to be a major feature of MNE sourcing plans. These factors would suggest that supply factors do not, per se, constrain the nature of electronics production in Singapore. Hewlett-Packard's large operation in Singapore has only two SM T lines in-house and sources the rest of its PCBA production from local suppliers. Vertical disintegration on this scale is thought to offer substantial supply opportunities for local suppliers.

Local sourcing
During the 1970s researchers analysing the electronics industry in Singapore found low levels of local linkages: There are few input linkages to the rest of the economy and local material content tends to be low because of an inadequate local supporting industry (Pang and Lim, 1977, p. 61).
Higher levels of linkages were detected in the electronics industry during the early 1980s with case study evidence suggesting moderately high levels of local sourcing by foreign-owned firms (Pang and Lim, 1982). More recently, studies show that foreign firms are successfully stimulating local suppliers, generating a substantial number of spin-offs as employees of MNEs became successful entrepreneurs, often becoming suppliers to their former employees (Lim and Pang, 1991; Tan, 1990). Some claim that Singapore has developed to such an extent that its electronics industry is the:

Southeast Asian “star” when it comes to linkage formation (Henderson, 1994, p. 275-6).

Although there is some evidence to suggest that electronics sourcing is quite high (EDB, 1995; Hobday, 1995), current knowledge regarding linkages in Singapore’s electronics industry remains limited. Aggregate sourcing figures from Singapore’s electronics industry indicate that a number of firms have indeed taken advantage of these supply opportunities. An unpublished survey conducted by the EDB of 119 electronics MNEs located in Singapore revealed that local sourcing amounted to 37 per cent (EBD, 1995).

Although this includes expenditure on semiconductors, this figure suggests that local sourcing in Singapore is significant. Company-specific sourcing information now available also confirms that sourcing in Singapore is indeed substantial, especially in the consumer electronics sector (see Brown, 1996).

On the whole, MNEs in Singapore appear to source roughly the same types of materials locally (Brown, 1996). Table III reveals that the types of materials sourced by three PC manufacturers are broadly similar. Consumer electronics plants and domestic appliances also source similar types of materials locally. For example, JVC claims that it locally sources PCBs, plastic injection mouldings, metal parts, some ICs and transistors. In common with some MNEs in Singapore, the company meets all its PCBBA needs internally. High-end ICs still come from Japan, however. Owing to the sensitive nature of the information, obtaining details on sourcing outwith Singapore was problematic, but one PC manufacturer claimed that the key components not sourced locally were obtained from Japan (LCDs), Malaysia (keyboards) and Taiwan (PCBs).

Table III Examples of materials sourced locally by data-processing firms in Singapore

<table>
<thead>
<tr>
<th>Apple</th>
<th>Compaq</th>
<th>Hewlett Packard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet metal enclosures</td>
<td>Precision sheet metal moulding</td>
<td>Sheet metal parts</td>
</tr>
<tr>
<td>Plastic parts</td>
<td>Plastic injection moulding</td>
<td>Printed circuit boards</td>
</tr>
<tr>
<td>Hard disk drives</td>
<td>Hard disk drives</td>
<td>Power supplies</td>
</tr>
<tr>
<td>Printed material</td>
<td>Printed circuit boards</td>
<td>Plastic parts</td>
</tr>
<tr>
<td>PCBBA</td>
<td></td>
<td>PCBA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard disk drives</td>
</tr>
</tbody>
</table>

Source: Brown, 1996
Note: * The Table excludes semiconductors bought locally

Technology and unavailability of supply were often cited as the key factors prohibiting greater localised supply. This was particularly the case for specialist supply items such as customised ICs or application-specific integrated circuits ASICs and LCDs which mostly come from Japan. Some companies claim they would source certain items locally if they could be obtained within Singapore. Proprietary technology, used in items such as laser reading equipment, was one such barrier to greater local sourcing in the consumer electronics industry. Often such items were supplied directly on behalf of the parent organisation, as was the case with JVC. Some very low cost items (crystals, resistors, capacitors, oscillators etc.) previously sourced in Singapore, were now being sourced in nearby, lower cost locations such as Malaysia, Indonesia and Thailand.

Singapore’s supply base

An overview

Although the electronics industry in Singapore is dominated by foreign-owned firms, the industry is currently supported by about 1,500 companies providing a wide variety of component parts (Chia, 1995). The ownership of most supply areas is a mixture of foreign and local. Locally-owned suppliers are to be found in a number of supply areas: PCBBA, PCBs, plastic injection moulding, sheet metal parts, mould makers, die-casting and packaging etc. On the face of it, most of these conform to the traditional bulky low added-value formula commonly found in branch plant economies, but there are some suppliers who have developed beyond this categorisation. Foreign suppliers moved to Singapore to support the production needs of...
the end-product manufacturers which located there during the 1970s. These firms tend to dominate the contract manufacturing and higher value-added precision engineering sectors where local entrepreneurial experience is more limited.

Possibly the most important subsector of the electronics supply base is the HDD industry. During the early 1980s nearly all the major HDD firms (Seagate, Conner, Western Digital and Maxtor) established manufacturing capacity in Singapore. Singapore’s experience of manufacturing cameras and related optical equipment was one of the reasons the firms chose Singapore as a low-cost production location (Rodan, 1989). In sectoral terms, the HDD industry is perhaps the most important subsector in Singapore’s electronics industry. For example, the HDD sector in Singapore accounts for about 42 per cent of world rigid disk drive production in 1996 (EBD, 1997). Employing over 25,000 people, the sector accounts for about 22 per cent of total value added in the electronics industry (EBD, 1994).

Some of the MNEs operating in this sector have upgraded their operations and transferred important design work to their plants in Singapore. For example, Conner’s plant in Singapore has become its key manufacturing centre for this product and has used the plant’s resources to transfer technology to other Conner subsidiaries in Scotland and Malaysia (Hobday, 1995).

The existence of this subsector has important linkage effects. Most of the PC firms in Singapore source some of their HDDs locally (Apple, Compaq and Hewlett-Packard). For example, Apple claims that once disk drives are subtracted from its local material spend, its local sourcing figure falls by 50 per cent. Having this supply sector reduces the need for large quantities of imported disk drives, and it also makes the electronics cluster a better integrated sectoral unit. Further, the development of a strong and dynamic aluminium die-casting sector has resulted from the growth of the HDD industry in Singapore. Two local companies, Uisco and Wearnes, supply the main players within the HDD industry and cumulatively employ over 1,000 people. It has also greatly benefited the growth of the connector industry, another foreign-owned industry with a sizeable presence in Singapore. Connector manufacturing involves key precision engineering technology and is dominated by US firms: AMP, Molex and Methode. Backward linkages would appear to be a positive benefit from this type of linkage-intensive industry.

According to Hobday (1994), the huge HDD manufacturer (employing some 12,000 people), Seagate, played an instrumental role in this process, and, by 1991, most of Seagate’s material needs were purchased locally. In turn this induced other HDD firms to locate on the island, leading to even more component suppliers. The 1980s witnessed a significant upgrading of the HDD local support industry (Hobday, 1994). These backward linkages further illustrate the HDD industry’s overall importance in Singapore’s electronics industry.

The display devices sector is also substantial and comprises cathode ray tubes (CRTs), LCDs and computer display tubes (CDTs). Annual capacity of CRTs is 9.5 million units per year; a figure representing 6 per cent of global CRT production (EBD, 1994). This sector is currently witnessing strong growth, particularly in large CRTs. The sizeable output is mainly attributable to two plants: Hitachi and Sony. Hitachi’s plant also has some capability in display devices which are used in PC monitors. This concentration of such a large output by two companies illustrates the importance of large oligopolistic firms within the CRT industry. It is not known how much of the output from these plants remains in Singapore.

It is interesting to note that local firms have managed to break into leading-edge LCD technology. Singapore has two indigenous LCD manufacturers (PCI and Vikay Industrial) which make basic display products used in cellular phones, photocopy machines and navigation systems. Although these firms manufacture lower value display products than the large MNEs mentioned above, they represent a relatively sophisticated technology for local suppliers. This sector also leads to forward linkages within the local electronics industry. PCI makes LCDs for Philips in Singapore and Vikay manufactures and markets LCD products throughout the world but retains its headquarters in Singapore.

Singapore also has a sizeable semiconductor industry. In fact, there are now 30 semiconductor MNEs in Singapore (EBD, 1994), cumulatively employing 16,000 people (EBD, 1992). Traditionally these investments were concentrated in the lower value areas of
semiconductor production such as assembly and testing. Recently some have moved into the more advanced stages of production such as wafer fabrication, the core manufacturing technology involved in semiconductor manufacturing. In 1984 SG S-T homsen became the first firm to establish fabrication capabilities in Singapore (H obday, 1994). According to H enderson (1994) most M N E s are producing semiconductors in the more advanced areas of production (e.g. 16 megabyte D R A M s and some microprocessors).

Subsectors, firms and development potential

In order to develop a fuller appreciation of the dynamics of linkage formation in Singapore, we shall now examine a limited number of subsectors within the supply base in greater depth[4]. It is important to note that suppliers within different subsectors of Singapore's electronics industry form a wide variety of relationships with local and non-local end users. Broadly speaking, there were three different types of suppliers analysed during the study:

(1) component manufacturers;
(2) contract manufacturers;
(3) hard disk-drive suppliers.

The first category manufacture basic supply items such as sheet metal enclosures, P C B s and plastic injection mouldings. The second group of suppliers were contract manufacturers who mostly undertake P C B A as their core business activity. The third group are high value suppliers manufacturing hard disk drives which are modular storage products used mostly, but not exclusively, for the P C industry.

On the whole, the highest technology suppliers were drawn from the contract manufacturing and H D D sectors, relates to the level of technological competency and capital investment which are required to commence production in these supply activities. Often it was the cost of production rather than the lack of proprietary technology which prevented this type of supply activity. In particular, the high costs of S M T can act as a deterrent to firms moving into P C B A. Nevertheless, the barriers to entry in the P C B A or contract manufacturing subsector would appear to be somewhat lower than those in the H D D sector, one of the reasons why the H D D sector is dominated by large M N E s. At the same time, component makers are found in abundant supply in Singapore owing to low barriers to entry which are faced by this type of supply activity. Low barriers to entry can have the knock-on effect of leading to market saturation and poor profit margins for firms competing in the sector.

Another factor differentiating supply areas was the fact that higher value supply items such as H D D s are generally not made by end-product manufacturers to the same extent as some other supply activities (e.g. P C B A). M N E s in the electronics industry often have their own internal P C B A capabilities which are supplemented with the use of contract manufacturers on a capacity basis. Once again, the downside of this means that some suppliers in the P C B A supply sector are used for short periods. Similarly, component makers such as plastic injection moulders are often used in conjunction with the continuation of internal production at the end user, as was the case with Philips and Meiki Plastics in Singapore. This helps to explain why firms manufacturing integrated higher value supply items (such as H D D firms) can obtain more equitable supply relationships with their customers.

One of the main differences which marked out the H D D industry was the size and global nature of producers in this sector. The P C B A sector also features a high degree of foreign ownership (e.g. A vex, Flextronics and S C I). This is in stark contrast with firms from the component manufacturing sector. Indeed, the firms studied in this sector were all locally owned. Large foreign-owned suppliers obviously have a number of advantages over smaller locally-owned suppliers. For example, capital investment, technology levels, and market reach can all be enhanced by the size and multinational nature of a supplier. In turn this can increase technical and managerial competency levels when linking up with buyers, especially on a global level.

Considerable variation existed between suppliers according to their overall growth potential and ability to maximise supply opportunities in all three supply areas. Thus, in addition to these basic factors differentiating the groups of firms outlined above, there were also substantial differences within each subsector which are now outlined.

The component manufacturing sector

Although most firms in this supply area were locally-owned sheet metal companies or
plastic moulders, the differences between firms within the component sector were substantial. More specialist and foreign-owned firms were also examined in this industry grouping. For example, a local precision rubber manufacturer, San Teh, makes rubber keypads for the PC and telecommunications industries. Similarly, Showa Plastics was a Japanese-owned company which moved to Singapore to take advantage of the supply opportunities which were being created by the burgeoning consumer electronics industry.

Firm size seemed to have a knock-on effect on their overall capabilities. Larger suppliers were often publicly owned with access to greater amounts of capital to finance expenditure on new capital investment. Larger firms also had the capacity to invest in the latest type of machinery whereas smaller suppliers had to forgo this and substitute technology for different supply qualities such as low cost or responsiveness (i.e. short lead times). The difference between Amtek Engineering and Stamping Industries is illustrative in this instance. Whereas Amtek had considerable resources to invest in the latest computer numerical controlled (CNC) and laser cutting equipment, Stamping had one CNC machine. Unlike Amtek, this prevented Stamping from being able to offer customers additional services such as prototyping. In turn, Amtek was able to become involved with MNEs at an early stage of new product development and offer some design input into the pre-production phase of product development, increasing its chances of inclusion in new products developed by the customer. Stamping meanwhile was more reactive and generally used as a short-term (low cost) capacity supplier.

Likewise, larger suppliers appeared to pursue different objectives and focus on different types of markets. For example, Amtek and San Teh were large enough to compete for business outside Singapore. San Teh claims that as little as 10 per cent of its production stays within Singapore. In addition to this, some of the larger local suppliers also had overseas production capabilities. Both Amtek and San Teh both had overseas operations. Conversely, some smaller suppliers were heavily dependent on the local market. Meiki Plastics has two customers which together account for 90 per cent of its output. One of these customers, Philips, accounts for a staggering 70 per cent of this total. This type of dependency sometimes can lead to a negative outcome which results in a very one-way relationship (see Turok, 1993). Although Showa Plastics are heavily dependent on one customer, Sanyo, it had used this relationship to develop linkages with other Japanese firms in Singapore. This reflects how Japanese suppliers use their relationships with buyers at home to advance their subsidiaries abroad.

The contract manufacturing sector
All firms within this sectoral grouping of suppliers have the same core central business – PCBA. This industry subsector employs nearly 14,000 people and constitutes a sizeable proportion of the supply base (EDB, 1994). The importance of this supply sector goes beyond these substantial employment figures. For example, some PCBA firms also undertake original equipment manufacture (OEM) supply arrangements for MNEs which often involves PCBA suppliers assembling complete products for end users.

As with the component manufacturers, considerable variation exists between suppliers in this sector. Usually, suppliers took two different approaches to their business. First, some firms provided additional services such as design/prototyping and procurement as a means of adding value to their basic supply service. It was hoped that these additional functions would increase their chances of winning new business. Second, others were more limited in the type of service they could offer a buyer and typically competed on cost, essentially acting as capacity suppliers for MNEs on an ad hoc basis.

Admittedly, this dichotomy is somewhat crude, but it does indicate the type of strategic differences between suppliers within this segment of the supply base. Only one PCBA examined, PCI, could offer design and procurement outlined in the first scenario. In addition to the design support with PCBA layout and the procurement of material needs, PCI could offer buyers their own raw materials such as bare PCBs and LCDs. Other PCBA firms, such as Venture, could only offer limited design support.

Characteristic of the second approach, firms such as Next Technology and Richgold Industries did not provide any form of ancillary service to their customers. Primarily these firms competed on cost. Next Technology did this by moving its production to nearby Malaysia to attain lower unit labour costs.
while focusing on the US power supply market to avoid competition with large PCBA firms in Singapore. This market strategy was undertaken to avoid the intense competition which exists in Singapore’s PCBA sector. Richgold, on the other hand, remained heavily geared towards the local electronics industry, acting as a capacity supplier. Although Richgold supplies local MNEs on a just-in-time (JIT) basis, it does not manufacture on a JIT basis. This offers MNEs a flexible way of managing cyclical production schedules without incurring any additional inventory holding costs.

PCBA firms engaged in this sector also differ according to the type of OEM facilities they could offer buyers. This type of supply arrangement has important positive features for the long-term development of the firms within the electronics industry. Some PCBA manufacturers in Singapore, which initially began production on an OEM basis, have now gone on to establish their own brand names. For example, the Singapore-based OEM producers IPC and Wearnes now produce personal computers for markets throughout the world and sell under their own brand names (Yuan, 1994), illustrating the importance of this supply sector as a platform for expansion into end-product manufacturing.

Some firms were issued materials which were then manufactured according to the exact specifications laid down by the buyer. Relying on MNEs for components is seen as one of the main disadvantages of the OEM system (Hobday, 1995). A good example of this is the relationship between Hewlett Packard and Richgold Industries, the PCBA subcontractor who build the Desk-jet printer on Hewlett Packard’s behalf. Richgold was consigned all the materials that were necessary to manufacture the product. A more developmental OEM relationship exists between Venture and its customers, including full materials procurement on its behalf.

Another factor delineating OEM suppliers is the level of design input performed by the supplier. Under own design and manufacture (ODM) arrangements, the contractor carries out some, or all, of the product design and process tasks needed to produce the final product. This contrasts with the less autonomous situation depicted above where strict manufacturing guidelines are part of the contract between the two firms. Even between the two most capable suppliers, PCI and Venture, differences in competency arose in this area. For example, the design level of PCI outstrips that of Venture; PCI employs 70 design engineers whereas Venture employs a mere five. PCI has developed this capability in order to avoid price-driven competition in the more general PCBA market in Singapore. Together with PCI’s level of vertical integration, this means that it is probably the most developed ODM examined in Singapore. It has, however, been noted that ODMs are still disadvantaged owing to their subordinate position in relation to the buyer in terms of technological levels and loss of post-manufacturing value-added such as sales and distribution (Hobday, 1995).

The hard disk drive sector

The internal dynamics of this supply sector cannot be surmised from the two HDD firms analysed. This sector is arguably more complex than those mentioned above and deserves fuller examination. However, Conner Peripherals and Integral Peripherals do provide a good illustration of some of the sector’s unique features, as well as its contribution to the supply base as a whole. The current growth in this sector is being driven by the needs for storage-intensive PC software and the need for storage in a host of other applications. As elsewhere in Singapore, the industry is moving towards the manufacture of higher-end HDD with storage capacities in excess of 1,000 megabytes (EDB, 1994). Primarily, this sector differs from the previous two in that it is almost entirely foreign-owned.

The contrast between Conner and Integral is substantial. Conner’s plant is a large (3,000 employees) globally-oriented high-volume facility, manufacturing the industry standard 3.5 inch HDD. Integral, on the other hand, is a small firm manufacturing the niche 1.8 inch HDD in very low volumes. Although it is planning to grow rapidly in the coming years, at present the plant employs 110 people. Both Conner (ten per cent) and Integral (less than one per cent) are weakly linked to the electronics industry in Singapore in terms of forward linkages. Conner’s local linkages mostly result from its relationship with Apple and Compaq. However, the plant in Singapore also supplies these firms on a global basis from its Singapore plant which may indicate that its location in Singapore is not the main factor driving its local linkages. Integral, meanwhile, is a highly innovative
technology-led company making a niche disk-drive product which is yet to become widely used within the industry. The fact that the main users of its product are independent distributors explains its lack of local forward linkages.

Both firms have little in the way of higher-order functions. All the R&D for Peripheral is done at its home base in Colorado. The majority of Conner’s R&D is also done outside Singapore although there is some evidence to suggest that local design work is increasing (Hobday, 1994). The lack of sales and marketing operations at both plants hinders the process of establishing intra-Singapore supply relationships. Although some day-to-day inventory scheduling occurs locally, top-level supplier negotiations between Conner and Compaq are done in the USA where both have their headquarters. The absence of these functions may reduce the opportunities for local linkage formation in Singapore. The reason why local linkages have developed to some extent may owe more to chance than any real backward linkage development, at least in the conventional sense.

Earlier, it was noted how HDDs account for a substantial proportion of the local materials procured by PC manufacturers. Their inclusion within Singapore’s supply base, together with their high development potential (growth, technology and backward linkage generation), make both Conner and Peripheral significant for localised linkage formation in Singapore.

### Explaining linkage development in Singapore

Although the examples above demonstrate some of the firm-level issues which shape linkages, they do not illustrate the wider issues involved in linkage development which must also be taken into consideration. Obviously, different factors constrain different parts of the supply base but some common themes emerged from the research. A number of complex issues, such as supplier strategy, labour market circumstances, the quality and type of FDI and government policy towards MNEs and suppliers, all influence linkages in Singapore.

#### Supplier strategy

Suppliers varied markedly in the strategic position they adopt in order to remain competitive. It appears that different suppliers are pursuing different long-term restructuring strategies in Singapore which have discernible implications for linkage patterns in Singapore. The low-cost restructuring route is available to firms owing to the areas adjacent to Singapore which offer low-cost production possibilities. On the whole, however, the suppliers examined are not using lower-cost areas to supply the Singapore market. The majority of the suppliers interviewed remained within Singapore and upgraded their operations often with financial support from the government to aid this automation process. Likewise, the overseas plants owned by these suppliers were often geared towards the host MNE market.

In many cases expansion abroad was intended to seek new markets. This was the case with Amtek’s expansion into Malaysia and China. It also seemed to explain Venture’s expansion plans abroad. Simultaneously, these firms maintained and upgraded their operations in Singapore while developing new market opportunities abroad. For example, although Venture Manufacturing now has three overseas manufacturing facilities, its plant in Ang Mo Kio remains the group’s flagship operation for technical leadership in SMT. The fact that Venture’s plant has 18 SMT lines would suggest that it remains committed to the automation and upgrading of its Singapore operation.

Similar factors do not explain the lack of local market interaction on behalf of the HDD industry. Although the level of its output remaining in Singapore seems low, this is probably attributable to the global nature of the PC industry. Plants in Singapore supply the huge PC manufacturing market worldwide. The initial development of disk-drive manufacturing in Singapore was driven by the needs of US firms seeking low-cost production operations from which to re-import the majority of output back to the domestic market. Even today, Singapore is by far the largest source of HDDs in the US PC market, both in terms of customs value (56.8 per cent) and units shipped (50.3 per cent) (Angel and Engstrom, 1995, p. 89). In terms of future linkage development in this area, further integration within the local electronics industry may also be impeded by the truncated nature of HDD operations in Singapore.

Worryingly, for economic planners in Singapore, some of the most progressive local
firms in terms of overall size, growth potential and technical capability are becoming increasingly focused towards non-local supply relations. For example, both PCI (5 per cent) and Venture (10 per cent) did little business within Singapore. This was also true for the higher technology foreign-owned suppliers in the HDD industry. Undoubtedly this was due to the increasing emphasis placed on export markets as a source of domestic expansion, but it also reflects another feature of the supply base in Singapore. Domestic expansion was increasingly being accompanied by the growth of investment in overseas productive capacity. Amtek, San Teh, Nex, PCI and Venture had all established a sizeable manufacturing capacity outside Singapore.

Labour market issues
Increasing labour costs, caused by Singapore's extremely tight labour market, were cited as the main reason underlying the decision by a number of suppliers to move capacity outside Singapore. This motivation reflected the decision by San Teh, the precision rubber manufacturer, to move production of its labour-intensive processes to a lower cost production location. Prima facie, such relocations would signify trouble for the supply base (and hence linkage levels) in Singapore. However, the positive side of Singapore's very tight local labour market is the pressure this places on suppliers to upgrade their operations vis-à-vis automation. This may actually hasten the process of capital investment and hence supplier development. In fact, Showa Plastics claimed that it invested in sophisticated robotics in order to reduce the labour content of its manufacturing process.

MNE design issues
Another important issue concerned supplier "lock-in". Just as suppliers differed, there was also a good deal of diversity within the MNE population. On the whole, higher local sourcing is undertaken by higher quality plants, especially those with design capabilities (Brown, 1996). Without the necessary interaction on design and development issues, the ability of the local suppliers to work with MNEs on new product development is undermined. Therefore design control for products is important if more higher value components are to be sourced locally within Singapore.

Indeed, some suppliers claimed that the lack of design-intensive MNEs inhibited this type of buyer-supplier interaction. PCI claimed that its lack of local linkages was due to the poor quality of buyers in Singapore. PCI focused on design-intensive supply interaction with firms in the telecommunications and industrial electronics sectors, all of which are poorly represented in Singapore. This was less of an issue for suppliers to the consumer electronics sector because even when full design autonomy was not granted to a MNE, design for basic (metal parts and plastics etc.) commodities was frequently devolved. For example, plastic component maker, Showa Plastics, was able to collaborate closely with its customers on design issues. Although design does not guarantee localised linkages, it does allow suppliers a good opportunity for breaking into the MNEs sourcing framework at an early stage of new product development.

Policy issues
Policy measures undertaken in Singapore also play a vital role in linkage formation. According to Yuan and Low, the Economic Development Board (EDB) firmly maintains that: for the multinationals to compete and flourish in Singapore, support from local companies is necessary and vital (1993, p.117).

Singapore's policy environment develops local linkages through a range of financial assistance designed to develop suppliers, upgrade MNEs and improve the quality of human capital. The most important strand of Singapore's policy initiatives towards the supply base is the Local Industry Upgrading Programme (LIUP). LIUP was established in 1986 and targets locally-owned suppliers in the electronics industry. Essentially LIUP is a tripartite partnership between MNEs and larger local companies, under which the MNEs and the local companies provide focused assistance to their local suppliers so that they can improve their operations and become more competitive (Toh and Low, 1993). The supply firms targeted by LIUP are drawn from a number of sectors, most notably the plastic and metal-fabricated parts sectors. It basically involves some MNEs "adopting" their local suppliers and helping them to improve operational efficiency, enabling the introduction of new processes to participating SMEs. This is done by a manager from the MNE working full-time in conjunction with the supplier to
implement improvements at the supplier’s operation. It has been implemented in three main stages since its inception, involving an increasing level of collaboration:

1. The first phase is aimed at improving the overall efficiency of local manufacturers in areas such as production planning and inventory control, plant layout and financial and management control techniques.
2. The second phase involves new products and processes being transferred to local enterprises.
3. The final phase involves joint product and process research and development with MNE partners.

At present there are over 200 local firms engaged on the LIUP. According to the EDB, the government remains firmly committed to the programme. The establishment of the LIUP Centre in January 1993, to co-ordinate the interface between suppliers, MNEs and policy bodies, is evidence of the continued commitment to the scheme. The centre provides a platform for LIUP managers to interact with one another and work on joint projects. In fact, the perceived success of the policy has seen LIUP extended to other sectors of the economy (e.g. petrochemicals, services sectors and even government departments).

The first stage has been undertaken by most LIUP partners and most relationships are now moving to the second and third stages, especially joint product and process development. Indicators concerning the policy suggest that it is working fairly effectively. Between 1986 and 1989 LIUP companies improved their sales by an average of 42 per cent against 26 per cent for the supply sector as a whole (Toh and Low, 1993). Their share of total sales to the whole supporting industry has grown from 7.4 per cent to 10.5 per cent for the same period. Value added per worker went up by an average of 13.7 per cent a year during the same period.

On a case study basis LIUP appears effective. For example, suppliers such as San Teh has developed with their LIUP partner AT&T to become a global supplier in this area. San Teh, which makes rubber conductive key pads, commands 14 per cent of the global market for its product. A number of other firms examined also had experience of the programme (Next Technology, Richgold Industries and San Teh). According to N ex Technology, the close involvement of its LIUP partner allowed it to satisfy the United States Food and Drug Administration’s good manufacturing criteria. A number of firms said LIUP was most important for smaller, less capable suppliers.

Public policy in Singapore also aids linkages by upgrading the quality of local MNEs. One of the main fiscal incentives offered by the state was Pioneer Status. Pioneer Status entitles firms exemption from corporation tax for five to ten years on profits arising from Pioneer activity (Singapore International Chamber of Commerce, 1994). The precise nature of activities and exemption period remains contingent on the nature of the investment involved. Plant upgrading also qualifies for Pioneer Status funding. Post-Pioneer Status is also available to firms when their Pioneer Status period ends. This allows corporation tax to be paid at a reduced rate of 15 per cent for a further ten years. The opportunity to avoid corporation tax will obviously enhance the locational attractiveness of Singapore as a whole while at the same time allowing firms greater financial leeway to reinvest and upgrade their operations.

Specific policies have been implemented in order to facilitate the process of MNE upgrading, especially in relation to design work within MNE facilities. First, the Research and Development Assistance Scheme (RDAS) is open to projects that involve new R&D (product and process) that is carried out in Singapore. RDAS generally assists with up to 50 per cent of total investment costs. Interestingly, for projects that result in a new patented product, there is a token royalty payment ranging from 0.5 to 0.6 per cent of revenue derived from the sales of the product developed (Singapore International Chamber of Commerce, 1994). However, the degree of funding is contingent on the project’s overall contribution to Singapore’s technological capability. RDAS is an innovative way of encouraging plant upgrading.

The second key programme to enhance MNE design-intensity is the Research Incentive Scheme for Companies (RISC). RISC aims primarily to support activities that develop R&D capabilities in areas of strategic technology, with the longer-term objective of increasing corporate competitiveness (Singapore International Chamber of Commerce, 1994). RISC generally funds part of the
incremental total research spending, up to a maximum of 50 per cent over a five-year period. The degree of support given to any one company remains dependent on the nature of the research. RISC-funded R&D programmes must train a significant number of research scientists and engineers. Although RISC is smaller than RDAS, owing to the wider technological objectives of RDAS, it seems that the electronics MNEs (Apple, Philips) interviewed had benefited from the RISC programme.

The EDB also encourages firms to upgrade their operations to become operational headquarters (OHQ). This programme is also part of Singapore's wider strategy of becoming a total business service centre for MNEs operating in Asia (Perry, 1992). Income derived from the provision of approved services will then be taxed at the lower corporation rate of 10 per cent (Singapore International Chamber of Commerce, 1994). This scheme encourages manufacturing plants to upgrade from basic assembly work towards ancillary activities such as production engineering, R&D, regional marketing, technical service support, fund management, management information systems and procurement (Tan, 1993). Although the EDB views the OHQ scheme as a success, independent assessments of the policy's effectiveness claim that only token regional offices have arisen (Perry, 1992).

Overall, these policy initiatives have had some success. For example, Philips accorded its Singapore plant the worldwide audio headquarters. The audio centre has responsibility for product development, product management and industrial design. This augments the regional design centre Philips had already established for CTVs in Singapore. It seems that other MNEs also have considerable design capacities within Singapore (see Botham, 1997; Tilley et al., 1997). The close collaborative relationships developed between the EDB and investors in Singapore seem to play a fundamental role in this upgrading process (Schein, 1996). Although the accretion of product development work will not ensure a transfer of basic research to Singapore plants, it may enhance the opportunities for local suppliers to break into the new product development process by becoming involved in important prototype work.

Although these fiscal incentives have undoubtedly played some kind of role in upgrading the functional nature of MNEs and suppliers in Singapore, it is important to recognise the development of local human resources, especially regarding education and training. Together, the universities, polytechnics and training institutes supplied around 22,000 engineers and craftspersons per year in 1991, representing 38 per 100,000 population, one of the highest levels on a worldwide per capita basis (see Hobday, 1994). Ostensibly, then, Singapore's policy has been highly focused on training people for more skilled and demanding employment functions within MNEs. Owing to the existence of a pool of relatively inexpensive design engineers, the cost of establishing this type of design facility is partly underwritten by the state:

'It will therefore be cheaper for multinational enterprises to grow design teams within Singapore than within the parent country (Williams and Conway, 1992, p. 163).

Public policy is also aimed at upskilling local supply sectors. A number of joint government-industry training bodies were established during the 1960s and 1970s to fulfil the skill needs of foreign investors (Soon, 1993). Singapore established a number of joint training centres between the EDB and individual firms (e.g. Philips-Government Training Centre), as well as general training bodies such as the Precision Engineering Institute. Their main focus is engineering, technology, and craft education for manufacturing industry. Nowadays the institutes provide two- and three-year training courses in tool and die, precision engineering, plastic technology, mechatronics, industrial electronics and automation (see Hobday, 1994).

Some observers claim that Singapore's targeted industrial policies (especially tax holidays and R&D grants) are significantly promoting R&D activity within MNEs (Tilley et al., 1996). Owing to the association between design and linkage formation outlined earlier, policies geared towards subsidiary upgrading could potentially play a significant role in influencing linkage levels in Singapore.

Conclusions

Backward material linkages within Singapore's electronics industry have developed as a result of two processes: indigenous growth, especially in the fabricated parts sector, and further rounds of FDI, especially in higher
value supply areas such as HDDs. Not only have these local supply linkages boosted output and value-added within the electronics industry as a whole, they have also worked to the advantage of the local economy through the exposure of local firms to world-class manufacturing techniques.

Singapore’s suppliers portray a disparate level of all-round strategic competence and technological capability. Although basic inputs are the mainstay of Singapore’s supply base, these should not be underestimated. Only by developing capabilities in fields such as plastics, mouldings, machinery, assembly and electro-mechanical interfacing, did East Asia emerge as the leading export region for electronics (see H obday, 1995). Few local firms, however, have managed to upgrade and develop into fully rounded suppliers with their own design and development functions. In fact, the most well-equipped firms were those manufacturing HDDs, all of which were foreign owned. Owing to the truncated nature of decision-making functions within these suppliers (i.e. no sales, marketing or R&D functions), opportunities for local linkages and technology-transfer may be reduced.

Local suppliers within the contract manufacturing sector (PCI and Venture Group) possibly offer the most hope for future indigenous growth within the supply base. This owes to their adoption of sophisticated process manufacturing technology which is being further developed through ODM arrangements with MNEs. Furthermore, they often include higher value head office functions within Singapore (e.g. design, purchasing, marketing and personnel) which further contributes to the development of the country’s economy.

Although a variety of factors influence linkage levels in Singapore, such as supplier strategy, labour market issues and design levels within MNEs, the research suggests that proactive government policies play a leading role in shaping this process. This confirms earlier empirical research which suggests that a main determinant of linkage creation is host government policy (Lall, 1981; Raj, 1975). The success of Singapore’s industrial policies in upgrading MNEs and suppliers provides valuable lessons for other sectoral clusters dominated by inward investment.

Notes
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2 In March 1998, £1 = $2.65.
3 Pitch is the distance between the centre-lines of two adjacent legs of a packaged component.
4 The component manufacturers interviewed were: Alta Technology, Amtek Engineering, Meiki Plastics, San Teh and Stamping Industries. Contract manufacturers interviewed included: Next Technology, PCI, Richgold Industries and Venture Manufacturing. Conner Peripherals and Integral Peripherals were the two HDD firms examined.

References

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