ECONSTOR
Make Your Publications Visible.

A Service of

ZBW Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Hiratsuka, Daisuke

Working Paper

Production networks in Asia: A case study from the hard disk drive industry

ADBI Working Paper, No. 301

Provided in Cooperation with:
Asian Development Bank Institute (ADBI), Tokyo

Suggested Citation: Hiratsuka, Daisuke (2011) : Production networks in Asia: A case study from the hard disk drive industry, ADBI Working Paper, No. 301, Asian Development Bank Institute (ADBI), Tokyo

This Version is available at:
https://hdl.handle.net/10419/53557

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

WWW.ECONSTOR.EU

Mitglied der Leibniz-Gemeinschaft

ADBI Working Paper Series

Production Networks in Asia: A Case Study from the Hard Disk Drive Industry

Daisuke Hiratsuka

No. 301
July 2011

Asian Development Bank Institute

Daisuke Hiratsuka is director-general of the Institute of Developing Economies, Japan External Trade Organization.

This paper is the revised version of the paper presented at the ADBI-WIIW Conference, "Comparative Analysis of Production Networks in Asia and Europe", held in Vienna on 15–16 July 2010. The author would like to thank Dr. Nippon Poapongsakorn, president of the Thailand Development Research Institute, for his helpful comments on the previous version.

The views expressed in this paper are the views of the authors and do not necessarily reflect the views or policies of ADBI, the Asian Development Bank (ADB), its Board of Directors, or the governments they represent. ADBI does not guarantee the accuracy of the data included in this paper and accepts no responsibility for any consequences of their use. Terminology used may not necessarily be consistent with ADB official terms.

The Working Paper series is a continuation of the formerly named Discussion Paper series; the numbering of the papers continued without interruption or change. ADBI's working papers reflect initial ideas on a topic and are posted online for discussion. ADBI encourages readers to post their comments on the main page for each working paper (given in the citation below). Some working papers may develop into other forms of publication.

Suggested citation:

Hiratsuka, D. 2011. Production Networks in Asia: A Case Study from the Hard Disk Drive Industry. ADBI Working Paper 301. Tokyo: Asian Development Bank Institute. Available: http://www.adbi.org/working-paper/2011/07/28/4669.production.networks.asia.hard.disk.case/

Please contact the author for information about this paper.

Email: daisuke_hiratsuka@ide.go.jp

Asian Development Bank Institute
Kasumigaseki Building 8F
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500
Fax: +81-3-3593-5571
URL: www.adbi.org
E-mail: info@adbi.org

© 2011 Asian Development Bank Institute

Abstract

Production networks have been extensively developed in East Asia. Previous studies on production networks used international trade data or input–output tables, but such aggregate data cannot explain how the networks actually operate. With the aim of understanding the features and characteristics of East Asian production networks, this paper examines the procurement system of a HDD assembler operating in Thailand. This micro-level case study found that this particular production network consists mostly of arm's-length suppliers, who are independent and on an equal footing with the assembler. These arm's-length suppliers are mostly located in the assembling country, but some are located in neighboring countries. This proximity is necessary to establish good relationships between customer and suppliers and allows problems to be solved as soon as they occur. The arm's-length suppliers engaged in each country's leading industries, such as the electronics industry in Malaysia and Singapore and the automobile industry in Thailand, have extended their business to supply the HDD industry. These suppliers have formed an industrial cluster in each country within a two- or three-hour drive area. Each cluster that spans different countries is linked by a well-developed logistic network that employs the just-in-time production method that prevails in East Asia. On a regional level, these separate clusters tend to form international production networks that connect to each other across neighboring countries within a distance that provides a quick response time for problem solving. This study also found that American HDD assemblers outsourced indigenous suppliers in Malaysia and Singapore because American suppliers did not follow the assemblers' move to the region. However, since Japanese suppliers did follow the Japanese HDD assemblers to the Philippines and Thailand, indigenous suppliers were not outsourced.

JEL Classification: F14, F15, F23

Contents

1. Introduction 3

2. Literature on Production Networks 3

3. Evolution of the HDD Industry in East Asia 6

3.1 Production fragmentation in the HDD industry 6
3.2 Extension to a new frontier of Thailand 6
3.3 Clusters in other Southeast Asian countries 7
3.4 Emergence of the PRC 8

4. Production Networks in the HDD Industry 8

4.1 Procurement from overseas suppliers 9
4.2 Procurement from domestic suppliers 10

5. Features of Production Networks 10

5.1 Determination of international production networks 10
5.2 Logistics to facilitate production networks 11

6. Participation of Indigenous Suppliers in Production Networks 12

6.1 American anchor firms and indigenous suppliers in Singapore 12
6.2 American anchor firms and indigenous suppliers in Malaysia 13
6.3 Japanese dominant suppliers in Thailand 14
6.4 Dominant Japanese suppliers in the Philippines 14

7. Summary 15

References 17

Appendix 19

1. INTRODUCTION

In the last two decades, intermediate input trade has grown at a much faster rate than the other types of goods in the world trade and is considered an important factor for explaining the recent high growth rate of world trade. In East Asia in particular, intermediate input trade has grown at a rate faster than the world average. According to Feenstra (1998), the increasing integration of the world's markets has brought with it a disintegration of the production process, meaning assemblers are finding it profitable to outsource increasing amounts of the production process, either domestically or internationally. Intermediate trade has increased so remarkably that international production networks have developed that span a number of different countries.

Studies on international production networks are usually conducted using international trade data, but these analyses are unable to see the substance of international production networks. With the rapid increase in intermediate trade, elucidation of what is actually happening in East Asia is an important research topic for further economic development in the region. There are many specific issues that need to be addressed, such as what are the features of international production networks in East Asia? Who are the players in the international production networks? Where are the players located? How can suppliers participate in international production networks? What are appropriate policy measures to expand production networks? Will international production networks expand or contract?

To answer these questions, this study examines the hard disk drive (HDD) industry by looking at procurement by major HDD assemblers. HDDs and their constituent components are compact and lightweight, meaning the associated transportation cost per unit is very low. Due to the low cost of transportation, the HDD industry has developed a system of production fragmentation, where the production process is divided into several discrete stages and the separate production blocks are located in different countries. In this system intermediate goods are traded for final products. The HDD industry provides an insight into how international production networks work in the integrated market when transportation costs are extremely low.

Section 2 of this paper briefly reviews the past theoretical and empirical studies of production networks. Section 3 presents the evolution of the HDD industry, which is clustered across East Asia, and section 4 examines the procurement sources of an actual HDD assembler operating in Thailand. Section 5 discusses the ratio of procurement from overseas suppliers by comparing the HDD industry with the automobile industry. Section 6 discusses the role of indigenous firms in international production networks and industrial clusters. The final section summarizes this study.

2. LITERATURE ON PRODUCTION NETWORKS

To understand the formation of international production networks, new economic geography and fragmentation theory are extremely useful concepts. The first concept, new economic geography, attempts to explain the agglomeration and dispersion of economic activities in geographical space. The spatial structure of economic activities is considered to be the outcome of a process involving the opposing forces of agglomeration and dispersion. New economic theory analyzes the balance of these two opposing forces that results in a variety of "locational" patterns of economic activities.

Krugman (1991) explains how agglomeration forces emerge using a core/periphery model where, when transportation costs are low, a country becomes differentiated into an industrialized core and an agricultural periphery, with labor freely moving between the regions.

In other words, manufacturing firms tend to locate in regions of high demand when transportation costs are low. In the context of production networks, this means that interconnected firms and their supporting industries become geographically clustered in a single region. An important factor that affects the core/periphery structure is the constant elasticity of substitution. If the constant elasticity of substitution is low, that is, if a good is highly differentiated, the core and periphery emerge easily. On the contrary, if the constant elasticity of substitution is high, or a good is less differentiated, the core and periphery do not emerge. For instance, bakeries are usually geographically dispersed due to a low degree of differentiation, while manufacturing tends to concentrate in one area because of a high degree of differentiation. Agglomeration forces are, therefore, largely dependent on both transportation costs and the degree of differentiation of goods.

Agglomeration forces also generate dispersion forces due to congestion in the labor and property markets. Krugman and Venables (1995) extended Krugman's original model (1991) in which labor can't move between regions and concluded that manufacturing production moves from the industrialized and innovating country (the core) to the non-industrialized and non-innovating country (the periphery). Initial decreases in transportation costs cause the economy to organize itself into an industrialized core and a de-industrialized periphery. However, if transportation costs fall enough for the advantage of low wages in the periphery to offset the disadvantage of it being remote from its markets and suppliers, manufacturing in the core will move to the periphery. Dispersion forces depend on the relative labor costs of the core and peripheral countries as well as the degree of differentiation of goods. For goods that are not well-differentiated, dispersion forces emerge early.

A key property of agglomeration forces resides in the circular causality of economic activities. For example, if an automobile assembler attracts a number of upstream suppliers to the same region, the resulting productivity enhancement and market expansion might in turn also attract other automobile assemblers. Such circular causality generates not only agglomeration forces, but also dispersion forces. The concentration of economic activities increases land prices and wage rates, resulting in severe price competition between firms. Traffic congestion, difficulties in telecommunication, and air pollution also increase. These congestion effects intensify dispersion forces, enabling the periphery to take advantage by attracting economic activities. One important factor that subtly affects the balance between agglomeration and dispersion is the cost of transport, which includes freight costs, tariffs, non-tariff barriers, and the risk of exchange-rate variations.

The second useful concept for understanding the formation of international production networks is fragmentation theory. Fragmentation theory focuses on the location of production processes, and it suggests that production processes should be fragmented into several stages with separate production blocks being located at different sites, either domestic or international. By dividing the production process into separate blocks and situating each block in the most appropriate location, the total cost of production can be reduced. Production fragmentation has been discussed by many authors (Jones and Kierzkowski 1990; Deardorff 2001; Yi 2003). Deardroff (2001) claims that the incentives for fragmentation are larger when fragmentation is applied across different countries due to differences in factor prices and the availability of technology, and that the service costs of international fragmentation are larger if regulations and restrictions impede the international provision of services. Deardorff (2001) contains important policy implications in the context of economic development. If service link costs and network set-up costs are reduced, production can be fragmented, and as a result, large disparities in factor prices can be transformed into a dynamic economy. Yi (2003) verifies that high tariffs prevent vertical specialization, while low tariffs enable vertical specialization. This means that reductions in service link costs are essential for further production fragmentation. The border

effect is very large in vertical specialization because the tariffs impose two taxes on the first stage of production for only one fragmentation—once when the first stage good enters the foreign country and again when the second-stage good is imported back to the home country.

One possible interpretation of the combination of new economic geography and fragmentation theory is that when transportation costs are low, production can fragment, and that while fragmented production blocks tend to concentrate in one region within a country, they eventually disperse throughout the neighboring countries. However, few studies have examined location with respect to geography. Hillberry and Hummels (2005) tracked manufacturers' shipments within the United States (US) and concluded that the number of shipments rapidly declines with distance, dropping off almost an entire order of magnitude between one- and two-hundred miles, and being nearly flat thereafter. They also found that the price of shipments sharply rises over distance, while average shipment weight falls. The study suggests that most goods are shipped only to geographically proximate customers, with only high unit-value goods being shipped to geographically distant customers. Hillberry and Hummels (2005) also verified that industry tends to cluster within a limited area of 200 miles.

Kuchiki (2005) examined how industrial clusters develop. He explained the process of clustering in the periphery by incorporating the concept of an *anchor firm* and by addressing the role of anchor firms in industrial agglomeration. When an anchor firm moves to the periphery, suppliers from the core country follow the anchor firm and move to the same area. This movement improves the locational advantage of the periphery on the supply side and catalyzes the movement of other anchor firms and suppliers to the same area. Eventually, after the movement of several groups of anchor firms and suppliers, industry has clustered and the periphery has been industrialized.

Kuchiki's concept of anchor firms and suppliers moving from the core to the periphery is true for Japanese manufacturers but not always true for American ones. American affiliates outsourced to indigenous suppliers in Malaysia and Singapore because American small suppliers did not follow the would-be anchor firms (Hiratsuka, 2006).

Why are there such differences between Japanese and American affiliates? Helpman (2002) explained that the extent of international outsourcing depends on the depth of the domestic and foreign markets for input suppliers, the cost of researching suppliers, and the cost of customizing inputs. Applying Helpman (2002), the difference in behavior between Japanese and American affiliates can be interpreted that the cost of researching suppliers by American affiliates are lower than the one of Japanese. American affiliates that have employed local managers can source indigenous suppliers through local networks and reduce the cost of researching suppliers, while Japanese affiliates, whose mangers are often Japanese, are unable to reduce costs in the same way.

Several empirical studies have been conducted on fragmenting production across different countries. Hummels, Ishii, and Yi (2001) assessed the degree of vertical specialization in the Organisation for Economic Co-operation and Development countries by using input–output tables. They used the imported contents of exports as an index of vertical specialization. Hanson, Mataloni, and Slaughter (2003) examined vertical specialization in US multinational firms and their host countries, and showed that low transportation costs, low wage levels for unskilled labor, and a low corporate tax rate all had a positive influence on vertical specialization between the home country and the host countries.

Several empirical studies have examined production networks in East Asia. Ando and Kimura (2003) addressed the fact that production networks in the machinery industry have developed more in East Asia than in other regions. Ando and Kimura (2008) suggest that the spatial microstructure of vertical production chains effectively combines intra-firm and arm's-length

transactions where the parties in a transaction are independent and on an equal footing. The development of arm's-length transactions and the formation of agglomeration form a mutually enhancing causal link. Kimura (2010) stratified the procurement of parts and components and the sales of products into four layers in terms of gate-to-gate lead-time and delivery frequency: local, sub-regional, regional, and world. Ozeki (2009) found that the share of international input from Japan of total inputs tends to decrease for the automobile industry, while the share of international input is stable for the electronics industry.

Hayakawa and Matsuura (2009) categorized foreign direct investment (FDI) into three basic types: 1) horizontal FDI (the setting up of plants within the target market/country rather than exporting from the home country), 2) vertical FDI (affiliates engaging in a labor-intensive process by inputting capital-intensive parts and components supplied by the home headquarters), and 3) export-platform FDI (affiliates serving third markets by exporting final goods). These three types of FDI were further categorized into a total of seven types of FDI according to their sales and procurement destinations. In terms of affiliate numbers, in opposition to the theoretical literature in which horizontal FDI prevails, export-platform FDI holds the largest share for Japanese multi-national affiliates; in particular, in the textiles and precision machinery industries. Furthermore, complex vertical-FDI, in which a parent country invests in a particular host country with the intention of serving third markets with exports of final goods from an affiliate in the host country, and of procuring from the third country, accounts for a large share in the electronics, information and technology, and precision machinery industries. These observations are consistent with the study by Ando and Kimura (2003) that Japanese firms have played an important role in developing vertical production networks in the region.

3. EVOLUTION OF THE HDD INDUSTRY IN EAST ASIA

3.1 Production fragmentation in the HDD industry

Seagate chose Singapore for several reasons. First, the Government of Singapore provided a tax incentive in the form of a full tax exemption, which was usually for five years (Wong 1999). Second, local suppliers had been nurtured by a similar movement to Singapore by the American semiconductor firms National Semiconductor, who moved in 1968, Texas Instruments (1968), Tandon (1971), and Hewlett Packard (1972). This shift in production helped the development of supporting industries and nurtured indigenous firms in precision engineering. This all meant that for Seagate, the cost of finding quality outsourcers was reduced. Singapore was home to many engineers who spoke English and there was a large market. HDD users, such as Digital Equipment Corporation and Apple, who both moved in 1981, began to concentrate in Singapore. The location advantages of tax incentives, knowledgeable suppliers, plentiful human resources, and market availability all made Singapore a hugely desirable location.

3.2 Extension to a new frontier of Thailand

The development of the HDD industry in Singapore brought about a relocation of the HDD industry across East Asia stemming from the agglomeration and dispersion forces taking place between the core and periphery and between the anchor firms and suppliers. American HDD makers gradually shifted their lower-end factories out of Singapore to the cheaper manufacturing countries of Malaysia, Thailand, and more recently, the People's Republic of China (PRC) (Hiratsuka, 2006).

In the mid-1980s, many production processes were moved from Singapore to Thailand. Due to the concentration of manufacturing, Singapore began to become congested. Agglomeration

forces eventually resulted in dispersion forces in the HDD industry. At that time, the Singapore dollar was appreciating against the US dollar like the currencies of the other newly industrialized countries, the Republic of Korea and Taipei,China, and a shortage in the supply of labor resulted in high wage rates. In 1983, Thailand allowed foreign capital participation for export purposes, and, in 1985, announced a list of areas promoted for investment. In 1987, regulations on foreign capital participation were further relaxed so that 100% of foreign capital participation was allowed when business exports reached more than 80% of products, or if firms located in remote areas. The promoted firms received a full tax exemption for between three and eight years, according to the industry and whether the firm was located in a rural area. For these reasons, a large number of multinational corporations moved to Thailand, particularly those located in Singapore who were involved in the metal fabrication process of cutting, shaping and assembling parts and components made from raw materials.

The development process of the HDD industry in Thailand started when Seagate shifted head-stack assemblies (HSA) from Singapore to Samutphrakarn, a suburb of Bangkok, in 1983. The assembled head-stacks were shipped from Thailand to Singapore. This event began the transformation of Thailand into a global HDD production base due to the anchor firm and supplier relationship and the agglomeration and dispersion forces working intensively in the core and periphery structure of Singapore and Thailand.

In 1987, Seagate started final assembly in Chok Chai, Nakhon Ratchasima province, in the northeast of Thailand (McKendrick, Doner, and Haggard 2000). Chok Chai was one of the provinces that the Board of Investment of Thailand defined as being Zone 3, the most remote from Bangkok. The Government of Thailand, therefore, provided the most attractive investment incentives. Indeed, Seagate got a long tax holiday by locating there. However, Seagate stopped final assembly in 1999 when the full tax holiday expired. Seagate then restarted final assembly in Chok Chai in 2004 because the Government of Thailand provided another full tax holiday for eight years in order to promote the HDD industry.

Fujitsu, a Japanese manufacturer that participated in the HDD business in the US in 1986, started final assembly of desktop PCs in Bangkok in 1994. In 2001, Fujitsu switched from using 3.5 inch HDDs for desktop PCs to 2.5 inch HDDs for notebooks.

IBM began HDD assembly in 1991, at Union Technology Thailand in Sriracha, Chon Buri province, through a contract manufacturing agreement with Saha Union, an industrial conglomerate. IBM started its own facility in 1997 in Prachinburi province, and began expansion to a phase 2 plant in 1999. In 2003 IBM's HDD operations were renamed to Hitachi Global Storage Technologies (HGST) after being acquired by Hitachi.

In 2002, Western Digital Technologies began operating a manufacturing facility that had previously been owned by Fujitsu in Navanakorn in the Bangkok area (Western Digital, 2002 and 2003). Fujitsu sold some of the land and facilities from the 3.5 inch HDD plant to Western Digital, and switched to 2.5 inch HDD production.

Since the 1980s, four assemblers (Seagate, Fujitsu, IBM/Hitachi, and Western Digital) have begun final assembly in Thailand, which has created the largest industry cluster of the HDD downstream processes in the world.

3.3 Clusters in other Southeast Asian countries

The HDD industry has also clustered in other Southeast Asian countries. Japanese HDD assemblers clustered in Manila, Philippines, for example. Hitachi started operations there in 1995.

There are two reasons why Hitachi moved to the Philippines. The first is the availability of English-speaking engineers. Japanese final assemblers had to start large-scale operations very quickly due to market competition with American firms. The Philippines had many thousands of English-speaking engineers available. The second reason was the tax incentives available. The Government of the Philippines provided a full tax exemption for five years to projects that employed new technology. Japanese assemblers could indefinitely avoid paying income tax under the tax exemption program by continuously employing new technology. In 1996, Fujitsu and Toshiba followed Hitachi.

The third largest American HDD assembler, Western Digital, has taken a different locational strategy. Western Digital closed two of its manufacturing facilities in Singapore in 1999 and 2000, and relocated its HDD production lines to low-cost Kuala Lumpur, Malaysia, in 2000 (Western Digital, 2002). The new location is close to both Penang, Malaysia, and Singapore where there are many suppliers and markets. In Penang, Dell computers started operations in 1995, and the world's top-five largest electric manufacturing services all began operations there in the 1990s. A large HDD industry has clustered in Penang around the American core and indigenous suppliers.

3.4 Emergence of the PRC

Locations with good market access tend to be relatively attractive for firms (Venables 2004). The development of the HDD industry in the PRC is typical of this. Apple, Dell, Hewlett-Packard, and Toshiba have all assembled PCs in the PRC. Due to the market access effect, the HDD industry has agglomerated in the PRC. The emergence of the PRC is quite different from the development of Southeast Asia, which was driven by the supplier access effect.

The industry leader, Seagate, was again a pioneer when it moved its manufacture of low-end drives to Shenzhen in 1995. This became Seagate's third largest final assembly site. In 1998, IBM/Hitachi also started a HDD assembly plant in Shenzhen, through a contract manufacturing agreement with ExcelStor, a subsidiary of Great Wall. In 2005, Hitachi started its own factory in Shenzhen to produce 3.5 inch HDDs. Maxtor set up a new factory in Suzhou, PRC, in mid-2005, which took over the manufacturing of entry-level disk drives from the first and second plant in Singapore, leaving just the high-end production (Hiratsuka, 2006). IBM/Hitachi, Maxtor, and Seagate have transformed the PRC into the largest HDD final assembly center in the world due to the market access effect; however, large amounts of parts are still procured from Southeast Asia.

Looking at East Asia, the HDD industry clustered first in Singapore, and then dispersed to Thailand, Malaysia, and then the Philippines due to the supply access effect, and eventually the PRC due to the market access effect. Kohpaiboon and Poapongsakorn (2009) and Kohpaiboon (2010) noted that Thailand had become the second largest exporter of HDDs behind the PRC. Thailand's trade share of HDDs accounted for 17% in 2007, compared with the PRC's 35%.

4. PRODUCTION NETWORKS IN THE HDD INDUSTRY

As mentioned in the previous section, HDD assembling factories are concentrated in East Asia, but are dispersed across the different countries in the region. This section examines the features and characteristics of production networks in the HDD industry by looking at the location and profiles of suppliers who provide components and parts for HDD assembling factories.

4.1 Procurement from overseas suppliers

Diagram 2 shows the procurement sources of HGST Thailand for 2005. There are several notable features. First, HGST Thailand procured components and parts from a number of countries (Indonesia; Hong Kong, China; Japan; Malaysia; Mexico; Philippines; the PRC; Singapore; Taipei,China; and the US), and in terms of the number of suppliers, procurement from overseas suppliers surpassed procurement from domestic suppliers.

Second, most suppliers are arm's-length suppliers located in neighboring Indonesia, Malaysia, Philippines, and Singapore. This close proximity makes it possible not only to provide overnight delivery services to customers, but also minimizes losses incurred from defective units. In other words, a location that is close to customers is part of the service for customers. For example, Soode Nagano, which is a Japanese supplier operating in Johor, Malaysia, frequently sends its engineers to HGST Thailand to improve inter-company communication, and the companies location means that they are able to immediately dispatch engineers to solve problems if defective units are found. Considering the logistical issues of responding to problems, most overseas suppliers tend to locate in their customers' neighboring countries, and, therefore, international production networks tend to be concentrated within a limited economic space. Locating in neighboring countries also helps customers reduce their transportation costs.

Third, HGST Thailand sourced the same components and parts from multiple suppliers located in different countries. Media was procured from Japan (Hoya), Malaysia (Komag), PRC (HGST), Singapore (Hoya), and US (HGST). Printed circuit boards were procured from Indonesia (Solectron), Japan (Bridgestone), the Philippines (Ionix), PRC (Global Brands Manufacture and Sanmina-SCI), and Thailand (Sanmina-SCI). Pivots were procured from Malaysia and Singapore (NSK) and Thailand (MNB). Voice coils were procured from Indonesia and Malaysia (Shinetsu) and Thailand (SMT and TDK). Bases were procured from Malaysia (Kenseisha), PRC (Brother Precision), and Thailand (Wearns). It should be noted that HGST Thailand procured the same components and parts not only from domestic suppliers but also from overseas suppliers, and procured from inter-firms rather than intra-firms. There are several reasons for the procurement of the same components and parts from multiple suppliers. Outsourcing to multiple suppliers encourages competition between suppliers, and more importantly, it reduces the risk of issues arising from components being unavailable due to accidents or political incidents. However, multiple suppliers that outsource the same components and parts to several arm's-length suppliers located in different countries are opposed to the "fragmentation theory" which suggests that each locational advantage is assumed to differ according to country. This shows that corporate strategies differ by firm. Some firms locate production bases according to locational advantage. For example, TDK's media production facility is located in Singapore where high-level engineers are available, while carriage production and voice coil production is located in the PRC and Thailand, respectively, where there are plenty of sufficiently skilled mechanics. On the other hand, some firms choose to locate the same production facility in multiple countries. Shinetsu, for example, has voice coil production facilities in both Indonesia and Malaysia.

Lastly, core components were procured through intra-firm trade. HGST's head office is located in San Jose, US. The head office produces silicon wafers for HDD heads and suspension. HGST Mexico fabricates thin chip sliders from the wafers. Heads and suspension made in the US and thin chip sliders fabricated in Mexico are sent to HGST PRC and HGST Thailand for assembly into Head Gimbal Assemblies (HGA) and Head Stacked Assemblies (HSA). HGAs are composed of a head and suspension, and HSAs are attached to an actuator with HGAs. HGST Thailand procured HGAs and HSAs from the PRC and the US on an intra-firm basis. In other words, the HGST group is engaged in producing the core components of the head-related

core components. The HGST headquarters also produces media. Media is another HDD core component. HGST Thailand procures media both in-house and from both the American arms'-length supplier, Komag, operating out of Penang, Malaysia, and the Japanese supplier, Hoya, operating out of Japan and Singapore. HGST Thailand partly outsourced media production as a response to increasing demand and to encourage competitive research and development between in-house suppliers and arm's-length suppliers, and between different arms'-length suppliers.

4.2 Procurement from domestic suppliers

HGST Thailand procured 11 components and parts from 12 domestic suppliers. HGAs and HSAs were procured from Union Technology Thailand, which was HGST's first HDD related factory in Thailand that was operated based on a contract manufacturing agreement with the Saha Union group.

Other components and parts were procured on an inter-firm (arms'-length) basis. It is noteworthy that spindle motors were only procured domestically from NIDEC and NMB, which are both located in Ayutthaya. In fact, NIDEC has a corporate strategy to source nearby customers. Pivots were also procured from NMB. Bases were provided by WEARNS, which is located in Si Racha, Chon Buri province. Carriages were procured from Fujikura and Sanei. Fujikura has three factories in Thailand and they supply various electronics goods including PC code and flexible printed circuits. Fujikura provides carriages from a factory located in Lamphun. Sanei supplies automobile parts and precision parts for electrical appliances, and is located in Samutphrakarn where Toyota has a pickup truck assembly factory. Flexible cables were supplied by NOK, which is an automobile supplier located in Samutphrakarn. Seals were provided by Kokoku, which is an automobile supplier located in Ayutthaya. Voice coils were procured from SMT (JUKI) and TDK. SMT (JUKI) is an automobile supplier located in Chon Buri, and TDK is an electronics supplier located in Ayuttaya. Top covers were procured from NOK and NHK. NHK is an automobile spring supplier located in Chachoengsao. Printed circuit boards were provided by SANMINA SCI, which is an American electronic manufacturing service located in Pathum Thani, one of Bangkok's neighboring provinces.

The HDD suppliers that are located in Thailand all have the following points in common. First, they all are located within two- or three-hour's drive of HGST Thailand, except for Fujikura, which is located in the Lamphun industrial estate in northern Thailand. Second, the HDD components and parts suppliers are engaged in other industries such as the automobile, electrical appliance, and precision part industries. There are no suppliers who specialize in the HDD industry. Third, the HDD suppliers provide components and parts not only for HGST Thailand, but also for other HDD assemblers in Thailand such as Fujitsu, Seagate, and Western Digital. The suppliers can survive by providing parts across firms and industries. Last, most parts are supplied on an inter-firm network basis under the arms'-length principle where both parties in a transaction are independent and on an equal footing.

5. FEATURES OF PRODUCTION NETWORKS

5.1 Determination of international production networks

Diagram 3 shows HGST Singapore's procurement for the assembly of HDD servers in 2005. Compared to HGST Thailand, HGST Singapore procured parts and components from more overseas suppliers. It is noteworthy that both HGST Singapore and HGST Thailand both procured spindle motors, which is a core component, from Thailand, indicating that the

production of spindle motors for HDDs has clustered in Thailand not Singapore. This suggests that to what extent international production networks develop depends on where industrial clusters develop. Transportation costs are another factor. Since Singapore is an international logistics hub, it has the advantage of easily procuring goods from overseas. This means that the low transportation costs between Singapore and its neighboring countries encouraged the procurement of spindle motors from Thailand.

Procurement by the automobile industry differs to that of the HDD industry. First, there is large difference in the ratio of local to overseas procurement between the two industries. In Thailand, the local content of a locally manufactured vehicle is approaching 100%; however, the imported content of HDDs, which was 90% in the early 1990s, was only approximately 50% in 2006 (Kohpaiboon and Poapongsakorn 2009). These figures are consistent with the local sales share of Japanese affiliates operating in Asia reported in the *Basic Survey on Overseas Business Activities*, which is an annual survey conducted by the Ministry of Economy, Trade and Industry, Japan, that addresses the activities of Japanese overseas affiliates. Ozeki (2008) pointed out two interesting observations from the survey. The first is that the ratio of procurement from local suppliers to total procurement differed across industries. In the electronics industry approximately 30% of total procurement was from local suppliers, whereas in the automobile industry almost 70% of total procurement was from local suppliers. Ozeki's second observation is that the local procurement ratio is currently rising for the automobile industry, but is flat over time for the electronics industry.

Ozeki's observations can be interpreted as follows. First, the difference in the local procurement ratio between the automobile/electronics industries and the HDD industry means that because of high transportation costs, geographical proximity is more significant for the automobile industry for procuring input goods than it is for the electronics industry. Second, the rise in the local procurement ratio for the automobile industry suggests that the automobile industry's supporting industry in Thailand is rapidly developing, presumably because the automobile assemblers are keen to reduce transportation costs. Third, the local content of HDDs increased from 10% in the early 1990s to 50% in 2006 meaning that the HDD industry's supporting industry has developed in Thailand, with the HDD suppliers clustering within a distance of two- or three-hour's drive of Bangkok. The relationship between the HDD industry and the other machinery industries is noteworthy considering the development of the industrial cluster. In Thailand, the large demand for motorcycles has developed the motorcycle industrial cluster, which has in turn supported the country's automobile industry. The development of the Thai motorcycle and automobile industries has produced a huge supporting industry, which has enabled the provision of components and parts to other industries, such as the HDD industry. The printed circuit board industry, however, has not developed in Thailand, and, therefore, printed circuit boards must be procured from Penang, Malaysia, where the electronics industry has developed. As Hillberry and Hummels (2005) noted, firms in the US tend to procure within a distance of 200 miles and only procure high price goods from further away. This suggests that low transportation costs encourage international production networks. Kohpaiboon and Poapongsakorn (2009) and Kohpaiboon (2010) argue that HDD outsourcing depends on both the global production network and the industrial clustering within a country. International production networks depend on industrial clusters and are affected by the cost of transport between industrial clusters.

5.2 Logistics to facilitate production networks

HGST Thailand employs the just-in-time (JIT) warehouse system to meet the logistic needs of procuring many components and parts from overseas. The JIT warehouse system is designed to provide services to deliver intermediate goods from overseas suppliers. The arrival time at

the airport varies from good to good because the departure and arrival times are fixed by the air carrier. Therefore, when many intermediate goods are procured from overseas, a warehouse is required to store them for JIT delivery. HGST Thailand has outsourced all of their logistical services so that all components and parts are picked up from suppliers, both domestic and international; temporarily stored at the JIT warehouse, which is located near to HGST Thailand; and delivered by JIT delivery to the assembly plant. All of HGST Thailand's suppliers are required to use the JIT warehouse operating logistic firm. Components and parts are regarded as delivered to HGST Thailand when they leave the JIT warehouse.

Components and parts are usually delivered from the JIT warehouse to HGST Thailand four times a day. Components and parts are shipped once a day for domestic suppliers, and two or three times a week for overseas suppliers. The JIT warehouse, major suppliers, and HGST Thailand are all connected online, and suppliers can see the stock levels of components and parts at the JIT warehouse. Suppliers have to cover the transportation costs between their factories and the JIT warehouse against what is standard practice in logistics, namely that transportation costs are borne by the purchasers.[1] After assembly, the HDDs are first shipped to Singapore before being delivered to customers around the world.

The JIT warehouse system is quite different from the milk-run logistic system that is employed by the automobile industry. The milk-run logistic system is most appropriate when components and parts are procured from domestic suppliers located within two- or three-hour's drive of the shipment destination. The milk-run system also provides JIT services for assemblers. For this, an assembler outsources a logistic firm. The logistic firm arranges trucks to pick up components and parts at each factory and transport them to factories JIT. Both the JIT warehouse system and the milk-run logistic system help to facilitate JIT production and reduce transportation costs.

6. PARTICIPATION OF INDIGENOUS SUPPLIERS IN PRODUCTION NETWORKS

Kuchiki (2005) examined the role of anchor firms in industrial agglomeration. When an anchor firm moves to the periphery, suppliers in the core country follow the anchor firm and also move to the periphery. After several anchor firms and suppliers have clustered in the periphery, the originally non-industrialized periphery becomes industrialized. This anchor firm/supplier industrial cluster movement is true for Japanese anchor firms as Kuchiki (2005) investigated. If components and parts are imported from the home countries, the production costs are not greatly reduced. To reduce production costs, Japanese multi-national corporations outsource to Japanese affiliates in the host countries. The anchor firm/supplier argument raises concerns over whether or not developing countries and their indigenous firms can participate in local industrial clusters and international production networks.

6.1 American anchor firms and indigenous suppliers in Singapore

American anchor firms contributed to the clustering of the HDD industry in a different manner compared with the Japanese ones who invited suppliers from their home countries. American anchor firms outsourced to indigenous firms because American suppliers did not follow the anchor firms to Singapore. Initially, Seagate located head assembly in Singapore, and had to outsource the mechanical parts of the heads and printed circuit boards to the local Singaporean engineering suppliers. However, at first, the technological level of the local suppliers did not

[1] Interview conducted at Soode Nagano, Johor, Malaysia, on 30 August 2005.

satisfy Seagate's requirements because the production of HDDs requires a relatively higher level of technology than other electronics industries. With technical support form Seagate, the local suppliers were finally able to supply precision parts and components to Seagate (Wong 1999, McKendrick, Doner, and Haggard 2000). Other American suppliers also outsourced to local suppliers. Fourteen of them are now listed on Singapore's Stock Exchanges, namely Cheung Who Technology (1972)[2], Amtek Technology (1980), Seksun (1981), and Brilliant Manufacturing (1984) for top covers; Beyonics Technology (1981), Venture Capital (1984), Jurong Technologies (1986), and Elec & Eltek (1993) for printed circuit boards; MMI (1989) and Magnecomp International (1995) for suspension; and First Engineering (1980); Hi-P International (1980) for plastic components; Unisteel Technology (1988) for stamped components; and Norelco (2001) for HDD manufacturing equipment.

6.2 American anchor firms and indigenous suppliers in Malaysia

The American semiconductor firms Motorola (1967)[3], National Semiconductor (1972), Texas Instrument (1972), and Intel (1972) have clustered in Malaysia and have outsourced local engineering services. National Semiconductor in Penang outsourced eight local suppliers of precision engineering in the early 1970s, including Engtek (1974) and LKT Technology (1978), and many local subcontractors were contracted by Intel in the 1980s.

In the late 1980s, Singapore-based American and Japanese firms began to move head assembly operations to Penang. Maxtor (1988), Control Data (1988), Hitachi Metal (1989), Seagate (1989), and Read Rite (1991) all started head assembly operations in Penang. Singaporean firms, such as CAM Technology (1992) for base plates and MMI Industries (1992) for voice-coil motors and base plates, extended their operations by expanding into Penang from Singapore. This led to the producers of HDD mechanical parts clustering in Penang.

Due to the forward linkage effect, printed circuit board industries have also clustered in Penang, with the world's top-five electronic manufacturing services moving there in the 1990s. They are Celestica, Flectronics, Jabil, Sanmina-SCI, and Solectron. Singaporean printed circuit board manufacturers have also extended into Penang. Natsteel Electronics (1992) is one such printed circuit board manufacturer from Singapore. Local printed circuit board manufacturers such as Trans Capital (1992) have also grown. These developments in the printed circuit board industry prompted Komag, America's largest media disk supplier, to build a manufacturing plant in Penang in 1993. The disk plant was the first to produce advanced thin-film disks outside of Japan and the US. Komag expanded the first Penang plant in 1995, and built a second plant in Penang in 1997. Electronic manufacturing services and Komag have transformed Penang into a printed circuit board and disk-media center.

A large number of local subcontractors, who were nurtured by the American semiconductor and printed circuit board industries, participated in the HDD industry. Eng Technology (1988) and LKT Technology (1978) produced actuators. Eng Technology provided HDD parts for Maxtor who started the HDD business in Penang in 1986. Maxtor expanded operations into the PRC in 1996 and into Thailand in 1997, where they supplied Seagate, and into the Philippines in 1997 where they supplied NIDEC and Fujitsu. LKT Technology provided HDD related parts for Seagate in Penang, Malaysia, and Thailand and for NIDEC in Thailand. Several indigenous Malaysian subcontractors expanded overseas to countries such as Thailand, the Philippines and THE PRC and became regional suppliers.

[2] The year the firm was established in the country.

[3] The year the affiliate was established in the country.

The development of the electronics, mechanical part, and HDD industries generated a backward linkage effect that helped develop the industrial machinery industry. Kobay Technology (1984) provided automate industrial machinery for AMD, Intel, and Motorola.[4] Pentamaster (1987) provided automate industrial machine for Dell (1984).[5] Micro Modular System (1997) started with a small factory shop and went on to become listed on NASDAC Malaysia in 2005.[6]

The Penang Skills Development Centre (PSDC), which was established in 1989, was instrumental in the growth of indigenous firms by providing human resources. Many American anchor firms and some Japanese anchor firms are Board Members of the PSDC, and have contributed towards training programs and have sent teachers to PSDC. Thanks to the efforts of the anchor firms and PSDC, high quality and demand/supply matched engineers have been made available in Penang.

6.3 Japanese dominant suppliers in Thailand

The supporting industries of the HDD industry have also clustered in Thailand. In contrast to the indigenous firms in Singapore and Malaysia clustering around American assemblers, in Thailand, mainly Japanese mechanical parts suppliers have clustered. Seagate established a labor-intensive process facility for HSA in Samutphrakarn, a suburb of Bangkok, in 1983. Seagate started head disk assemblies in Chokchai in 1987. The American HDD head assemblers outsourced to suppliers in Thailand. Most of them were not indigenous firms but foreign affiliates, in particular, Japanese ones. The assembly of actuators for heads was operated by Fujikura (1985)[7], Minebea (1985), Thailand-based KR Precision (1988), Singapore-based Magnecomp (1992), and Eng Precision (1999). Voice coil magnet assembly was started by TDK (1992) and Hana (1993). Most of these facilities were located in Ayutthaya. Spindle motor production was operated by Japanese affiliates Minebea (1988) and Nidec (1989). Daido (1994) built facilities for producing magnets used for spindle motors. The HDD component and parts suppliers in Thailand were dominated by Japanese affiliates because Japanese supporting industries had previously clustered around the motorcycle and automobile industries. The suppliers extended into the HDD industry.

6.4 Dominant Japanese suppliers in the Philippines

A small mechanical-part cluster has developed in the Philippines, where three Japanese final assemblers—Fujitsu, Global Data Storage, and Toshiba—have located. Prior to 1995, few HDD-parts suppliers were located in Manila, except San Technology for voice coil motors (VCM) (1988)[8] and Shinetsu Magnetic for VCM (1993). However, when the three Japanese HDD final assemblers moved to Manila, many parts suppliers followed suit and started operations there. These were Japanese first-tier and second-tier suppliers, such as Nidec for spindle motors (1996), TDK for magnetic heads (1997), Nitkoshi for head storage (1999), and

[4] Interview conducted at Kobay Technology, 29 August 2005.

[5] Interview conducted at Pentmaster, 29 August 2005.

[6] Interview conducted at Micro Modular System, 29 August 2005

[7] The year the affiliate was established in the country.

[8] The year the affiliate was established in the country.

Touritsu for plastic filters (2001). Singapore- and Penang, Malasia-based second-tier suppliers followed, including Singapore-based CAM Mechatronic for bases (1996) and Malaysia-based Engtek for spoilers and shrouds (1997). By the end of the 1990s, Manila was the new HDD industry center next to Singapore and Thailand.

7. SUMMARY

The international production networks and industrial clusters of the HDD industry, which has relatively lower transportation costs compared to other manufacturing industries, provides an insight on the integrated East Asian economy. This study examined the procurement of an actual HDD assembler factory.

It has been shown that HDD components and parts are procured from more overseas suppliers than from domestic suppliers. International production networks have developed more in the HDD industry than in the automobile industry because the transportation costs associated with the HDD industry are lower. Indeed, in addition to the differences in size and weight, HDDs are completely exempt from import tax while the import tax for cars and motorcycles is 5%, although this can be eliminated by free trade agreement preferential tariffs. The development of international production networks for HDDs suggests that the reduction of transportation costs encourages international production networks and intermediate trade.

Most overseas suppliers are located in the neighboring countries of the assembler factory. Factories in Thailand mainly procured from neighboring Indonesia, Malaysia, Philippines, and Singapore, where the suppliers' engineers are able to easily travel to solve problems arising from defects. In other words, international production networks are mainly formed among neighboring countries.

Most suppliers, both domestic and overseas, are engaged in other leading industries, such as the automobile industries in Thailand and the electronics industries in Malaysia and Singapore. In other words, they are arm's-length suppliers who are independent and on an equal footing with the assembler. These suppliers have formed an industrial cluster within a distance of two- or three-hour's drive in each production base country. On the country level, factories tend to agglomerate and form clusters within two-or three-hour's drive of each other and each country has a number of distinct industrial clusters (i.e., an industrial cluster in the greater Bangkok area, one in the Northeast of Thailand, and one in the North of Thailand). On the regional level, however, industries tend to form international production networks that connect each industrial cluster across neighboring countries within a distance that allows a quick response for problem solving.

International production networks have been supported by the intelligent logistic system. The JIT warehouse system provides services to temporarily store intermediate goods both from international and domestic suppliers and deliver them JIT to the customer. The JIT warehouse system is suitable when there are many components and parts supplied from overseas and the delivery times differ from good to good. International production networks are maintained by local purchaser staff.

Most suppliers are foreign affiliates in Thailand, while most suppliers are indigenous firms in Malaysia and Singapore. These indigenous firms in Malaysia and Singapore became regional players and then advanced to become overseas players. To compete in the global market, assemblers try to procure lower price intermediate goods from indigenous suppliers and suppliers in neighboring countries.

This paper does not address the consequences of a large home market and low transportation costs. HDD production in the PRC is one such case. The PRC has a large home HDD market due to the backward linkage effect of having the largest PC production in the world. HGST PRC currently procures mechanical parts from Southeast Asia as Kohpaiboon and Poapongsakorn (2009) and Kohpaiboon (2010) pointed out that tier-1 and 2 suppliers can be located in different countries: the tier-2 suppliers in Southeast Asia provide parts to the tier-1 suppliers in the PRC Several suppliers have been asked by HGST PRC to begin operations in the PRC. HGST PRC may gradually increase procurement from domestic suppliers. However, this does not necessarily mean that the local content ratio will further increase while international production networks decline. The reduction of transportation costs will encourage network linkage among the separate production blocks.

REFERENCES

Ando, M., and F. Kimura. 2003. The Formation of International Production and Distribution Networks in East Asia. Working Paper 10167. National Bureau Economic Research (NBER).

———. 2008. Production Fragmentation and Trade Patterns in East Asia: Further Evidence. Presented at Ninth Global Development Network Conference, Research Workshop "Emerging Trends and Patterns of Trade and Investment in Asia (Brisbane, Australia; 1–2 February 2008).

Deardorff, A. 2001. Fragmentation in Simple Trade Models. *North American Journal of Economics and Finance* 12: 121–37.

Ernst, D. 1997. From Partial to Systematic Globalization: International Production Networks in the Electronics Industry. Paper prepared for the Sloan Foundation project on the Globalization in the Data Storage Industry, the Data Storage Industry Globalization Project Report 97–02, Graduate School of International Relations and Pacific Studies, University of California at San Diego. http://brie.berkeley.edu/pubs/pubs/wp/wp98.html (accessed 16 February 2005).

Feenstra, R. 1998. Integration of Trade and Disintegration of Production in the Global Economy. *Journal of Economic Perspectives* 12: 31–50.

Hayakawa, K., and T. Matsuura. 2009. Complex FDI in Japanese Multinationals. In Input Trade and Production Networks in East Asia, edited by D. Hiratsuka and Y. Uchida. Cheltenham, UK: Edward Elgar.

Hanson, G., J. Raymond, J. Mataloni, and M. Slaughter. 2003. Vertical Production Networks in Multinational Firms. NBER Working Paper No. 9723.

Helpman, E. 2002. Outsourcing in a Global Economy. NBER Working Paper No. 8728.

Hillberry, R., and D. Hummels. 2005. Trade Responses to Geographic Frictions: A Decomposition Using Micro-data.

Hiratsuka, D. 2006. Vertical Intra-Regional Production Networks in East Asia: A Case Study of the Hard Disk Drive Industry. In *East Asia's De Facto Economic Integration*, edited by D. Hiratsuka. Basingstoke, UK: Palgrave Macmillan.

Hummels, D., J. Ishi, and K. M. Yi. 2001. The Nature and Growth of Vertical Specialization. *Journal of International Economics* 54: 75–96.

Jones, R., and H. Kierzkowski. 1990. The Role of Services in Production and International Trade: A Theoretical Framework. In *The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin*, edited by R. Jones and A. Krueger. Cambridge, MA: Blackwell.

Kimura, F. 2010. The Spatial Structure of Production/Distribution Networks and Its Implication for Technology Transfers and Spillovers. In *Input Trade and Production Networks in East Asia*, edited by D. Hiratsuka and Y. Uchida. Cheltenham, UK: Edward Elgar.

Kohpaiboon, A. 2010. Hard Disk Drive Industry in Thailand: International Production Networks versus Industrial Clusters. Discussion Paper No. 23. Thammasat University Faculty of Economics.

Kohpaiboon, A., and N. Poapongsakorn. 2009. Industrial Upgrading and Global Recession: Evidence of Hard Disk Drive and Automotive Industry in Thailand. Discussion Paper No. 22. Thammasat University Faculty of Economics.

Krugman, P. 1991. Increasing Returns and Economic Geography. *The Journal of Political Economy* 99(3): 483–499

Krugman, P., and A. Venables. 1995. Globalization and the Inequity of Nations. *The Quarterly Journal of Economics* 110(4): 857–880.

Kuchiki, A. 2005. A Flowchart Approach to Asia's Industrial Cluster Policy. In *Industrial Cluster in Asia*, edited by A. Kuchiki and M. Tsuji. Basingstoke, UK: Palgrave Macmillan.

Lobo, S. 2000. Stability through Technology. July 15. http://www.dqindia.com/content/

special/100071501.asp (accessed 16 February 2005).

McKendrick, D., R. Doner, and S. Haggard. 2000. *From Silicon Valley to Singapore: Location and Competitive Advantage in the Hard Disk Drive Industry*. California, CA: Stanford University Press.

Ozeki, H. 2008. Vertical Production Networks in East Asia: An Evidence from Survey of

Japanese Firms. In *Vertical Specialization and Economic Integration in East Asia*. edited by D. Hiratsuka and Y. Uchida. http://www.ide.go.jp/Japanese/Publish/

Report/2007_01_08.html (accessed 16 October 2008).

———. 2009. Production Networks in East Asia: Evidences from Survey of Japanese Firms. In *Input Trade and Production Networks in East Asia*, edited by D. Hiratsuka and Y. Uchida. Cheltenham, UK: Edward Elgar.

Venables, A. 2004. European Integration: a View from Spatial Economics. Paper presented at conference, "Globalization and Regional Integration—From the Viewpoint of Spatial Economics". IDE JETRO, Tokyo, 12 December 2004.

Western Digital. 2002. Annual Report http://www.wdc.com/en/library/company/annual02. pdf (accessed 26 February 2005).

Western Digital. 2003. Annual Report http://www.wdc.com/en/library/company/annual03.

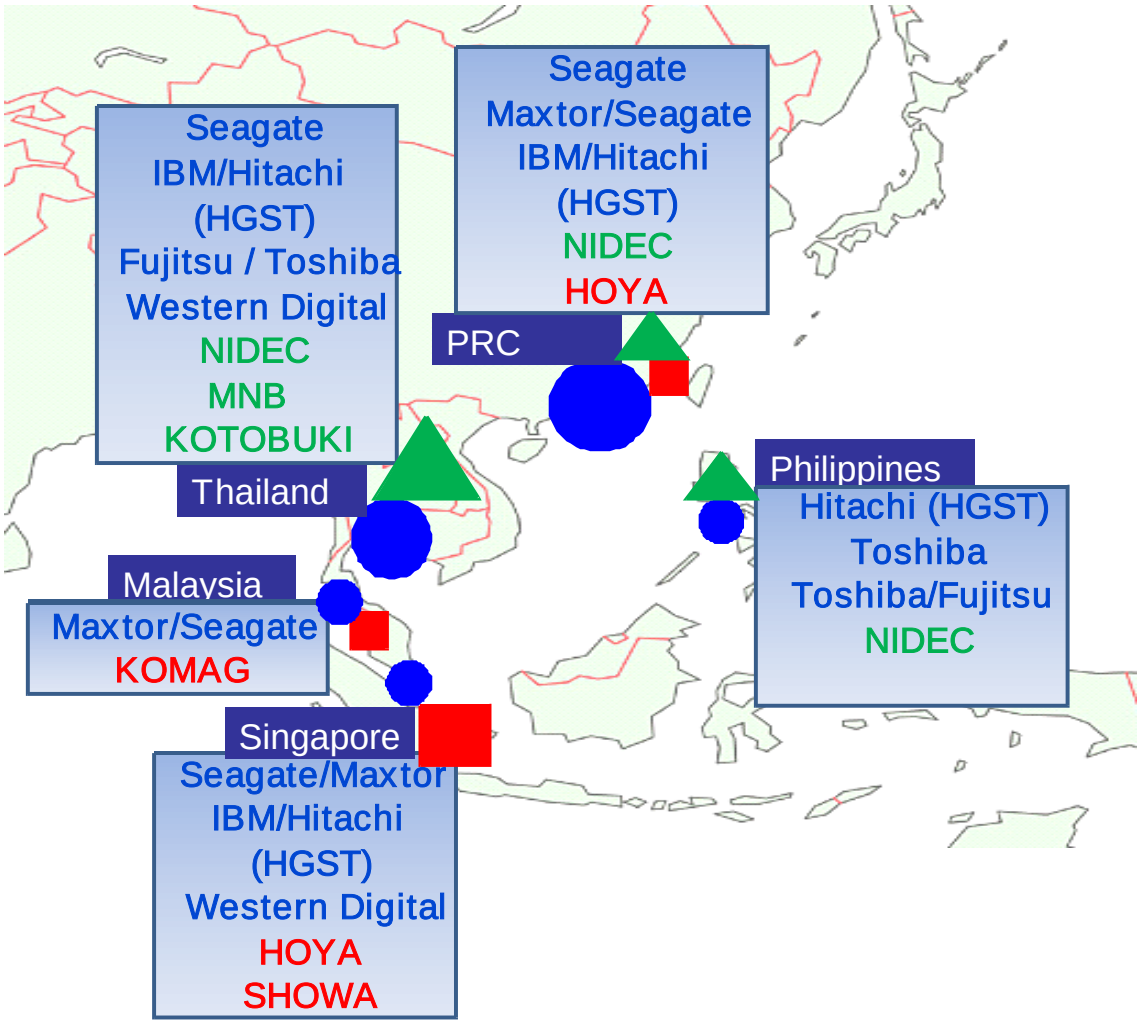
_pdf (accessed 26 February 2005).

Wong, P. 1999. The Dynamics of HDD Industry Development in Singapore. Report 99–03. San Diego: University of California, Information Storage Industry Center.

Yi, K. M. 2003. Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy* 111(1): 52–102.

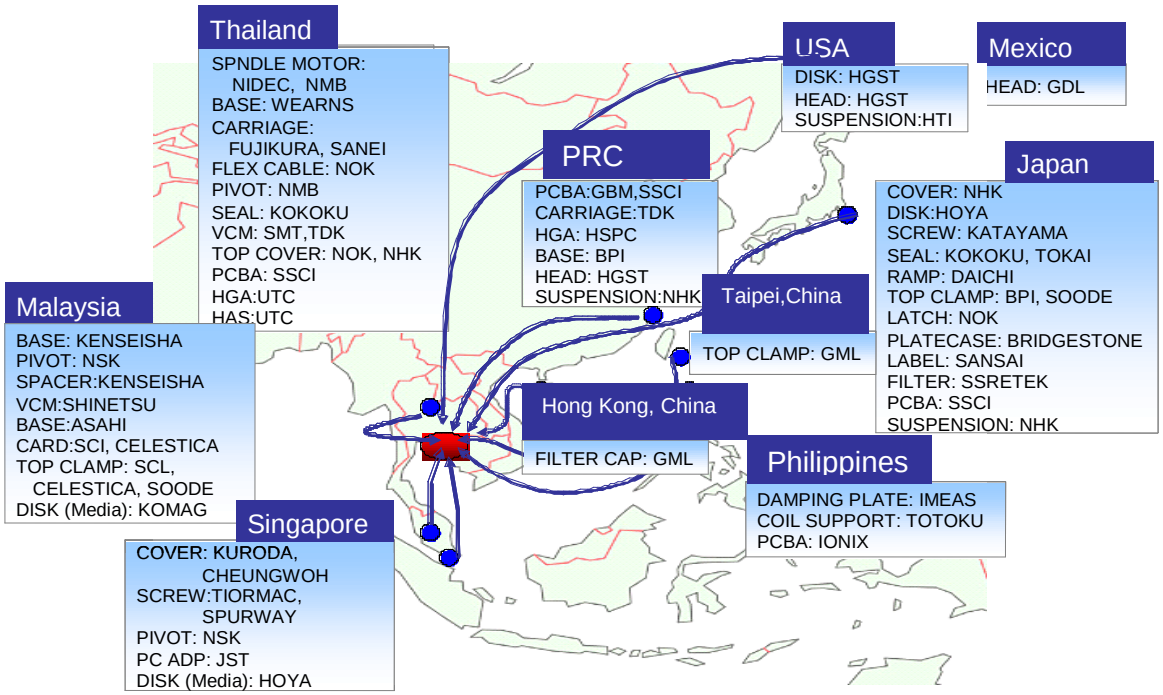
APPENDIX

FIGURE A1: HDD assemblers in East Asia



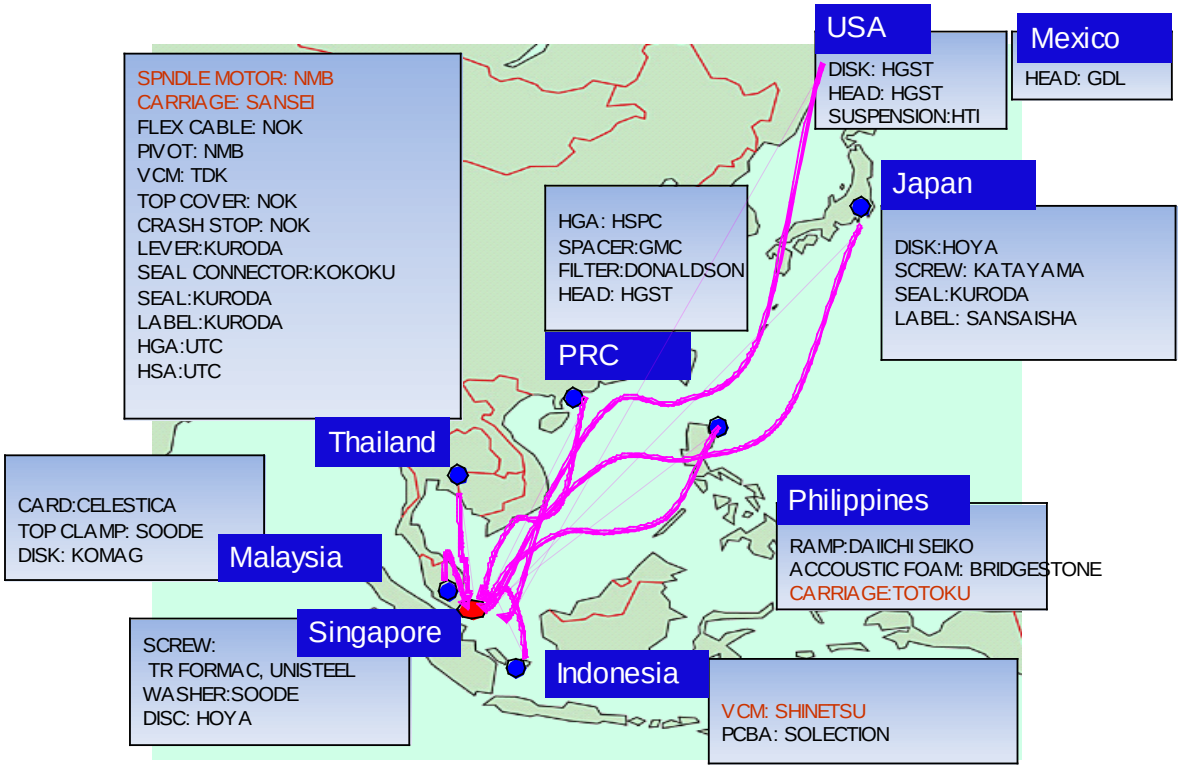
Source: Author

FIGURE A2: International Procurement: A HDD Assembler in Thailand in 2005



Source: Hiratsuka, Daisuke (2006). Vertical Intra-Regional Production Networks in East Asia: Case of the Hard Disk Drive Industry in East Asia. (Chapter 6.) In *East Asia's De Facto Economic Integration,* edited by D. Hiratsuka. London: Palgrave Macmillan.

FIGURE A3: International Procurement: A HDD Server Assembling in Singapore



Source: Compiled by author, based on an interview conducted at Hitachi Global Storage Technology (Thailand), August 2005.