Hard Disk Drive Industry in Thailand:
International Production Networks versus Industrial Clusters

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ABSTRACT: The paper probes the nature of international production networking (IPNs) of hard disk drive using Thailand as a case study. The research methodology is based on interview evidence of samples purposively selected in order to reveal how firms make use of IPNs. The key finding is that Thailand is well integrated into the global production network of the multinational enterprises (MNEs). Starting with assembling task for further process, the affiliates in Thailand gradually acquired more technological capability over periods and reach process engineering stage in which the affiliates are capable in developing basic and detailed designs for production process. At this developmental stage, industrial clustering starts as there is need for intensive cooperation between HDD makers and suppliers to create effective coordination and achieve ‘virtual integration of the entire system’. Our finding suggests that industrial clustering does not necessarily rule out possibility for firms to source their input internationally. In fact, they coexist, i.e.industrial clustering occurs in the first layer of production network where HDD makers and Tier-1 suppliers work together to avoid any coordination failure. When parts are less customized as found in the second layer Tier-1 suppliers internationally source their intermediates and benefit the existing dispersion of resource endowment around the globe. The key policy inference is that industrial clustering is not a synonym of complete localization. Local content would increase as a consequence of industrial clustering but how much local content would achieve depends entirely on supply-side capability.

Key words: International Production Networking, Hard Disk Drive, Industrial Cluster, Thai Manufacturing, Multinational Enterprises

JEL Classification: D21, F23, L63, O14 and N65
1. Issues
International Production Networks (IPNs), the cross-border dispersion of component production/assembly within vertically integrated product processes, is an important feature of the deepening structural interdependence of the world economy. An array of alternative terms has been used to describe IPNs including international production fragmentation, vertical specialization, slicing the value chain and outsourcing. IPNs open up opportunities for countries to specialize in different slices (different tasks) of the production process depending on their relative cost advantage and other relevant economic fundamentals. Consequently, parts and components are now exchanged across borders at a faster rate than final goods. In this context, the decisions of how much to produce and for which market have to be combined with decisions of where to produce and with what degree of intra-product specialization (Athukorala, 2006; Kimura, 1998, 2000). Based on trade flows analysis at the highly disaggregated level (5-digit SITC), a consensus has been reached about the relative importance of IPNs on export dynamism in East Asia as opposed to North America and Europe.\(^1\)

On the other hand, while deregulation, globalization process and advance in information technology continue, why do MNEs agglomerate in certain places rather than disperse around the globe? This is important as industrial clusters are often the drivers of regional and national economic growth. The industrial cluster is also popular among policymakers as an indicator of success in industrial development. Clustering in an industry not only implies that most of the activities in the value chain are located in the same country but also indicates a level of industrial deepening. More interestingly, IPNs and industrial clusters seem to be mutually exclusive. The former term refers to the break-up of the production processes into geographically separated stages – a decentralised phenomenon – whereas the latter’s outcome is a localised and concentrated constellation of the elements of a global production network. Despite their immense policy relevance, there has not been any systematic analysis that brings the two phenomena together.

Against this backdrop, this paper examines how enterprises in hard disk drive (HDD) industry make use of IPNs industrial clustering. HDD industry is by far the most complex component in a personal computer in terms of moving parts, and its value chain is extremely differentiated. In Thailand, HDD industry has long established since the early 1980s where Seagate set up its first factory for assembling head-stack assembly (HSA). Over the past two decades, the industry grew rapidly and becomes a major production hub of leading HDD MNEs. In 2008, Thailand is the second largest HDD exporters in the world, accounting about 17.4 per cent of world export. Four out of six major HDD producers have affiliates in Thailand, including Seagate (1983), Hitatchi GST (1991), Western Digital (2002) and Toshiba (2008). Thus sufficient time has passed to assess the development of HDD industry in Thailand. Nevertheless, the relative importance between IPNs and industrial cluster remains puzzle in Thailand’s HDD industry. On the one hand, Hiratsuka (2006, 2008), Berger (2005), and McKendrick et al. (2000) point a clear evidence of break-up of HDD production process and found that HDD makers source their input internationally. This seems to be in contrast to the cluster development of HDD industry in Thailand observed in the past decade. There have been a number of foreign parts suppliers setting up their affiliates in Bangkok in order to supply inputs for HDD makers.

The paper’s organization is as follows; Section 2 discusses research methodology employed in this paper. The following section (Section 3) provides analytical framework. In Section 4, policy environment is discussed with emphasis on trade and investment policy. Section 5 provides fragmentation in HDD production, global integration and industrial clustering, and economic performance of Thai HDD industry over the past two decades. Section 6 probe how MNEs in HDD industry make use of IPNs and industrial cluster to enhance their international competitiveness, followed by conclusion and policy inferences in the final section.

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2 Fujitsu sold out its production facilities in Thailand in the early 2008 to Toshiba as the former ceases HDD production worldwide.

3 For example, see HDD cluster in Thailand in NECTEC (2007).
2. Research Methodology

To gain insight of development of Thai HDD industry, purposive rather than probability sampling techniques are employed. As defined by Patton (1990), the latter refers to the method that obtains samples by random selection amongst all units of the population and permits confident generalization for a larger population, while in the former method, samples are purposively chosen from information-rich cases for in-depth analysis related to the central issues under study. In this paper, the main objective is to probe development of HDD industry in Thailand. This cannot be achieved by probability sampling that uses a variety of sample characteristics to draw quantitative inference. To gain insight, interaction with interviewees is needed.

A flexible interview guide was used which allowed the respondents to relate their experience in their own words and based on their own sequence of the topics asked. The main advantage of this approach is that it minimizes the likelihood of missing important aspects of the story. The main disadvantage is that some respondents whose experience may be limited to a particular interest cannot always be asked all of the questions in the interview guide (Morawetz 1981). Second-round interviews with different interviewees could mitigate this disadvantage in several cases.

The interview guide begins by establishing the general company profile, i.e., size, past performance, ownership, production process, product destination, product covers, etc. This is followed by a series of opening probes sourcing behavior of enterprises and how centripetal forces work against centrifugal ones. This starts with their general perception of industry development, followed by their opinions about the overall industry development, input procurement and recent changes. Finally, general questions concerning current problems, the role of government, and future prospects for the industry are addressed. The top-level managerial staff in these Thai enterprises was interviewed. As the results, five firms and 4 government officers are interviewed during November 2008- April 2009. Characters of interviewed samples are reported in Appendix 1. All interviews were conducted by the author.
3. Analytical Framework

IPNs are referred to the globally organized nexus of interconnected functions and operations by firms and non-firm institutions through which goods and services are produced, distributed and consumed (Coe et al. 2004). Such networks not only integrate firms (and parts of firms) into structures but also integrate national economies in ways which have enormous implications for their economic development. As a result of the increasing importance of IPNs, national and regional boundaries are cut through in highly differentiated ways and blur traditional organization boundaries-through the development of diverse forms of equity and non-equity relationships. Multinational enterprises (MNEs) have played a pivotal role in linking the countries in the region to regional and global production networks.

IPNs are now a global phenomenon having considerable impact on international trade and cross-border investment (Athukorala, 2008). Empirical studies (e.g. Athukorala, 2008; Athukorala & Kohpaiboon, 2009) highlight the relative importance of IPNs in the East Asian economies. IPNs as opposed to North America and Europe. IPNs now become important for economic growth and structural transformation in the East Asian economies than elsewhere. The increasing importance of IPNs implies that opportunities for countries to specialise in different slices (different tasks) of the production process are opened up. Where each country is integrated into value chain depends on their relative cost advantage and other relevant economic fundamentals (Feenstra 1998, Jones 2000, Jones & Kierzkowski 2001). As a consequence, cross-border dispersion of component production/assembly within vertically integrated manufacturing industries is internationally traded across countries.

The increasing importance of IPNs seems to challenge the concept of industrial clusters and its contribution to industrial upgrading and competitiveness enhancement. While consensus has not reached the precise definition (Cortright, 2006), industrial cluster is usually referred to geographic concentration of

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interconnected companies and institutions in a particular field.\footnote{Such a definition of cluster is to a certain extent in line with the concept proposed by Porter (1990: 78). The reason the Porter’s definition used here is simply because it is the most influential one in the policy circle (Hendry, 2008). In fact it is not widely accepted among academics. For example, Martin & Sunley (2003) argue that such a definition is vague and ambiguity and its policy implication is very risky as it is one-size-fit-all approach to understanding clustering.} Industrial clustering was very influential especially among policymakers throughout the late 1980s and 1990s as it would be a crucial step of industrial upgrading and deepening. There are a number of studies pointing out potential contribution of industrial clustering to enhance competitiveness. Gains can be in several forms such as spatial externality, saving in transport and logistics costs, and knowledge externality. In addition, tacit knowledge which is crucial in many industries in East Asia cannot be easily transferred because it has not been stated in an explicit form. Effectively tacit knowledge can be transferred through face to face communication among brain workers, and knowledge externalities are expected to occur as a result of such interactions. Therefore, the impacts of declining transport and communication costs on the knowledge intensive activities are not dispersion of such activities but local accumulation of brains resources and knowledge externalities in a small number of selected cities or region.

It seems that IPNs and industrial clusters are mutually exclusive. IPNs are referred to the breakup of the production processes into geographically separated stages, a decentralized phenomenon whereas the outcome of industrial cluster is a localized/concentrated constellation of different configurations of global production network. How these two literatures can be reconciled remains a challenge among academic. One sensible explanation echoed in the literature of new economic geography is that the spatial structure of an economy would be the result of tug-of-war between external economies and diseconomies, between linkages and information spillovers that foster concentration and between congestion and other diseconomies that discourage it (Fujita et al. 1999). The \textit{centripetal} forces are external economies such as linkages, thick markets and knowledge spillovers (research and development) while the \textit{centrifugal} forces opposing agglomeration include immobile factors, land rent/commuting and congestion and other pure diseconomies as well as efficiency gains generated by division of labour across countries in IPNs.
4. Policy Environment
Over the past four decades, trade and investment promotion policies have been used as a main instrument to influence resource allocation in the HDD industry. Where trade policy is concerned, tariff is the main trade policy instrument to influence the country’s resource allocation. Table 1 reports a tariff structure in HDD industry during the period 1995-2006. The 1995 structure reflected the overall structure in the 1980s whereas the 2002 structure is a consequence of the major tariff restructuring implemented in 1997. The 2003 and 2006 ones illustrate the current status of tariff structure. Two key inferences are drawn from Table 1. Firstly, HDD industry is relatively less restrictive as opposed to other industries. Tariffs related to HDD industry (both intermediates and final goods) are usually lower than the average rates during the period 1995-2006. Secondly, there is distortion in a tariff structure in HDD industry, in which intermediates’ tariffs are always higher than those on final goods (HDD). For example, hard disk drive was tariff-free during the period 2002-06 whereas tariffs on inputs like motor, bearing, aluminum plate were not zero.

Nonetheless, the distorted effect from such a tariff structure is offset by investment promotion measures. Since most of HDD makers and their parts suppliers are foreign-owned and export-oriented (McKendrick et al. 2000), they are eligible for investment privileges offered by Thailand’s Board of Investment (BOI). One investment privilege was tariff exemptions which started offering in 1983. This was very important during the mid-1980s for export-oriented foreign investors as tariff in Thailand remained high (Tables 1 and 3). Besides, the timing of offering such privileges was more or less in line with changes in the global environment when many East Asian manufacturers started losing their international competitiveness in labor-intensive products. This was instrumental in making Thailand an attractive location for export-oriented labor-intensive FDI for East Asian investors (Kohpaiboon, 2006).

It is worth clarifying the difference between tariff exemptions granted by the BOI and the alternative schemes. While tariff exemptions and tax rebate schemes are administered by the Department of Customs, the BOI scheme offers a prior exemption scheme that is less cumbersome than the two existing schemes. After receiving approval from the BOI, export-oriented promoted firms are automatically allowed to
access their imports without a delay to calculate and pay levies. This reduces custom procedures that before 1997 were considered unusually cumbersome and imposed costs on importers (European Commission, 1999; and United States Trade Representative, 1999, cited in Warr, 2000: p.1233).

In the new millennium, there is a policy shift toward strengthening supply-side capability of firms, e.g. promote human capital development, financially support research and development (R&Ds) projects, and strengthen linkages from MNEs to indigenous enterprises. There are several government agencies involved such as National Electronics and Computer Technology Center, Ministry of Science, Offices of Industrial Economics, Ministry of Industry and BOI. Most of policy measures are a result of close consultation with the private sector. For example, many R&D projects initiated by the private sector are co-financed by the government. A portion the government financially contributes depends on a nature of the project’s outcomes, i.e. whether they are proprietary or common knowledge. The more common the knowledge created by the projects, the larger the government contribution. In addition, BOI extended investment privileges if foreign firms upgrade their existing production. For example, to beeligible for one additional year of the tax holiday, three criteria are used. Firstly, eligible firms for additional year of the tax holiday must have average R&D or design expenditures for the first 3 years either not be less than 1-2% of annual total sales; not less than 50 million baht for HDD manufacturing, or not less than 15 million baht for HDD parts manufacturing. Secondly, at least 5% of the total workforce in the first 3 years should consist of science and technology personnel with a minimum of a Bachelor’s Degree in science, engineering or other fields related to technology, R&D or design. Finally, average costs to train Thai staff for the first 3 years are at least 1% of total payroll costs.

5. HDD Industry in Thailand

5.1 Fragmentation in HDD Production

The HDD is by far the most complex component in a personal computer in terms of moving parts, and its value chain is extremely differentiated. Figure 1 illustrates the HDD decomposition. Broadly there are five main parts; head
subassemblies, media, motors, electronics and other accessories. Each of them has its own production process and has different production process from each other. For example, read/write heads, the single most costly component impacting on drive performance, are manufactured in stages. It begins with highly automated and technically complex wafer fabrication. Wafers are then machined into sliders, which are the tiny read/write elements. Each slider is then attached to a suspension, a small arm that holds the head in position above or beneath the disk. This process is called head-gimbal assembly (HGA). Sets of HGAs stacked together for installation in a disk drive are called a head-stack assembly or HSA, modular units that include the required circuitry and actuators; this process has also been highly labor intensive.

Another example, electronic parts in HDD include semiconductors and discrete components (including those designed specifically for disk drives), printed circuit boards (PCBs), and the flexible circuits or flexcircuits that connect the PCB to the rest of the HDD. The semi-conductors include a read channel to store and retrieve data bits and a read/write preamplifier (preamp) that amplifies the strength of the signals so that chips on the PCB can convert electrical impulses to a digital signal. Spindle and actuator motor controller electronics ensure that the platters spin at the correct speed and the actuator arms place the read/write heads over the precise spot on the platter. Interface electronics communicate with the system’s CPU in the proper format. A microprocessor and associated memory chips oversee drive operations. For high-performance drivers, an additional digital signal processor is required. All of these electronic components are typically mounted (‘stuffed’) onto PCBs in highly automated procedures.

Each part is brought together for final assembly in cleanrooms. They are brought in a base casting or base plate, a single piece of aluminum that also provides a mounting for a PCB, which houses the electronics. A gasket between the base casting and the top cover acts as a seal to provide a contamination-free operating environment for the read/write heads. Once the HAD is assembled, it moves to a station for servo writing, an electromechanical technique to control the positioning of the head. The

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6 Production process is drawn heavily McKendrick et al. (2000).
finished HDD undergoes functional testing, which is automated, and manual rework if necessary.

5.2 Global Integration and Industrial Clustering

HDD production in Thailand began in around 1983 after Seagate Technology shifted Head-stack assembly (HSA), the most labour intensive segment in HDD production process out of Singapore. It was relatively low-wage labours as well as conducive investment climate in Thailand that enticed HDD makers. Import content of HSA export was about 80 per cent. Despite presence of high tariff, HDD makers were eligible for input tariff exemption schemes as their products were for export.

From then on, incumbent expanded its production capacity and add new activities whereas there have been numerous newcomers including part suppliers and other HDD makers. In 1987 Seagate expanded their existing capacity as well as started high-volume production of Head-Drive Assembly (HDA) in Thailand. This demonstrated net gains of carrying HDD production in Thailand to other HDD firms. In addition, Seagate Technology involved training of numerous technical workers and enhanced availability of skilled labour (McKendrick et al., 2000). This in turns created a positive impact in enticing other key players in the HDD industry. This is in line with what the MNE literature postulates that there is a general tendency for MNE affiliates to become increasingly embedded in host countries the longer they are present there and the more conducive the overall investment climate of the host country becomes over time (Rangan & Lawrence 1999).

Fujitsu as a result of the joint investment in manufacturing HDD from both companies (Interview; Bloomberg, January 14, 2009).  

A number of parts suppliers also entered Thailand. In 1988, NMB, a large Japanese producer of bearings and other metal products, which had been in Thailand for several years, began motor production for HDD. Nidec, a major Japanese motor producer, set up its first Thai plant in 1989 and its second in 1991. K.R. Precision and Magnetric began their operations in 1988 and 1992, respectively, to service Seagate Technology for suspension parts. T.P.W., a precision machining firm based in Singapore, shifted its operations to Thailand in 1989 to manufacture actuators and base plates for motor.

Expansion of HDD industry continued in the 1990s so that industrial clustering was observed in the 1990s. While HDD makers introduced several new production activities, there were many new parts that started manufacturing in Thailand. Seagate Technology expanded its spindle motor capacity in 1994. Such an expansion induced parts suppliers such as Eiwa, Habiro, Nippon Super, Thai Okoku Rubber, Shin-Ei Daido etc, whose main products are motor hubs and related parts for spindle motor, to set up their affiliates nearby. Each of the three largest HDD assemblers manufactured HDD heads subassemblies for internal use during this period. Magtric and Read-Rite, two independent HGA and HSA firms, also set up Thai operations in 1990 and 1991, respectively. A few producers of PCB and PCBA and flew circuits established operations in the mid-1990s. This trend continues as a number of firms in HDD industries increased from 5 during the period 1981-85 to 74 between 2001-2006 (Table 2).

5.3 Economic Performance

HDD industry is the most important industry in electronic sector in Thailand, accounting for more than 70 per cent between 1988 and 2006. Over the past two decades HDD industry experienced rapid growth. Its annual (real) growth rate averaged out at about 16 per cent during the period 1988-2006. This outperformed

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other industries so that its share in manufacturing value added increased from about 1 per cent in 1988 to more than 10 per cent by 2006 (Figure 2).

HDD is one of the most important electronic exports of Thailand. Figure 3 illustrates export value and its relative importance in information technology (IT) exports during the period 1988-2008. Its export value increased from $37 mil in 1998 to $4,500 mil in 1996-97. Between 1999 and 2003, there was slightly downward trend in export value as a consequence of the crisis in global IT industries. Its export value dropped to $3,400 mil, the average figure during the period 1999-2003. From then on, HDD export grew at the phenomenon rate, reaching $8214 mil in 2005 and $15,493 mil in 2008. As a result, HDD exports accounted 45 per cent of total IT exports in 2008. Its share of Thailand’s total export was 15 per cent in 2008 (Figure 2).

Note that the export value reported in this paper is far lower than that reported in official documents such as Annual Report of Hard Disk Drive Institute. Specifically, in 2003-05, the paper’s export value is on average about 55 per cent of what reported in the official document. This is due to the different data source. Here, export of HDD is based on actual trade data (SITC 75270 equivalent to HS847170) whereas the figure in the official document is extrapolated from annual reports of BOI–promoted firms. The latter approach seems to be problematic as it is likely to be subject to double counting problem. Export value consists of two parts, HDD and parts, which are export value reported by HDD makers and related parts suppliers, respectively. The first component is regarded as finished HDD whereas the second component is parts. In fact the second component is indirect export as these parts are assembled to be finished HDDs and then export. Hence, adding them together simply double counting.

Figure 4 presents market share of major HDD exporters. Three inferences can be drawn from this figure. Firstly, these six major countries including Thailand accounted 70 per cent of global trade in 2007, reflecting international division of labours and the relative importance of East Asia in supplying HDD to the rest of the

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8 Note that both are regarded as parts and components in the literature of IPNs as most of HDD are for personal computers (PCs).
world. Secondly, according to the export share, Thailand is the second largest HDD exporters, accounting for 17 per cent in 2008, behind only China (35 per cent). Interestingly, Thailand’s market share increased throughout after the new millennium except 2008. The country’s market share went hand in hand with that of China. In other words, there was no crowding out effect from the increasing importance of China to HDD export from Thailand.

In order to gain better understanding market positioning of these major exporters, export unit value of four East Asia is constructed as in Figure 5. The observed downward trend of export unit value simply reflects price deflation in HDD over periods as a result of technological advance. In addition to the deflation trend, the clear pattern is that HDD export from Singapore always has the highest export unit value whereas China is the lowest between 1996 and 2008 (Figure 4). Export unit value of Thailand and Malaysia is in the middle between Singapore and China. This is consistent to resource endowment dispersion in these four countries. That is, HDD MNEs locate relatively high tech HDD in Singapore which is relatively capital intensive whereas use China as a production base for simple HDD. HDDs manufactured in Thailand and Malaysia are to certain extent in the similar quality range although export unit value of Malaysia is slightly higher than that of Thailand.

Table 3 provides trade flows of HDD and its major parts during the period 2001-07. Export destination and import sources are grouped into three main regions, i.e. East Asia, North America and EU-15 in order to contribute to the fallacy of ‘decoupling thesis’, the notion that the East Asian region has become a self-contained economic entity with potential for maintaining its own growth dynamism independent of the economic outlook for the traditional developed market economies.9 In addition, East Asian region is further disaggregated into ASEAN-10 and China for the debate of regional economic integration, i.e. ASEAN plus 3. It is clearly that international trade involving the HDD industry is intra-regional. For example, East Asia accounted for nearly 61 per cent of total HDD export from Thailand between 2005 and 2007, increasing from 51 per cent during the period 2001-03. North America and EU-15

9 This thesis was a popular theme in the Asian policy circles in the first decade of the new millennium until the onset of the recent financial crisis. See Yoshitomi (2007) and Park and Shin (2009) and the works cited therein.
accounted for only 22.1 and 13.1 per cent, respectively, during the period 2005-07. Interestingly, half of HDD exports (34.4 per cent) was for China during the period 2005-07. This increased sharply from 12.5 per cent between 2001 and 2003. In contrast, ASEAN-10 becomes less important in term of export destination of HDD from Thailand. This reflects the role of China in IPNs in East Asia which heavily relies inputs from other countries in the region for extra-regional export. The degree of regional dependence is even larger when sources of inputs are concerned. More than 70 per cent of PCBs, ICs, Semi-conductors, transistor, resistant, media and wafer were sourced in the region.10

6. IPNs versus Industrial Clustering in Thailand’s HDD

HDD makers (e.g. Seagate Technology, Western Digital, Fujitsu, Hitachi Global Storage Technology) utilize international production networking to enhance their international competitiveness. This reflects the corporate strategy evolved during the past three decades. Right now the fragmentation goes beyond manufacturing process as many companies set up testing facilities aboard and East Asia in particular. There are also few companies which establish R&D centre outside their home countries.11 HDD makers also outsource their peripheral activities (Motor, Printed Circuit Board) to third party whereas concentrating on their core business activities (Media, Slider, Heads) (Western Digital 2008: 14; Seagate Technology, 2008: 10-12). Hence, both intra- and inter-firm transactions are observed.

While HDD makers make use of IPNs to enhance their international competitiveness, this does not constraint them to gain agglomeration economies. In fact, evidence from Thai HDD industries suggests the coexistence of IPNs and industrial clustering. Nevertheless, it started with international outsourcing. When affiliates reach certain level of technological capability, industrial clustering begins as

10 Note that import value of these electronics products is the aggregate one, not exclusive for HDD only. Of course, its value might exceed what actually used in the HDD industry. Unfortunately, disaggregated data are not available. Since our purpose here is to illustrate the broad picture of trade flows in HDD industry, import share based on the aggregate value would not create any severe problem.

11 Most of R&D activities are in the United States (i.e. Colorando, Minnesota, Pennsylvania, and Massachusetts) (Seagate Technology, 2008: 36).
HDD makers and first-tier suppliers are located nearby to harness agglomeration economies.

Thailand was firstly integrated into the global production network of HDD MNEs as a result of the entry of Seagate Technology in 1983. It started with a simple assembly task, assembling HDD head with actuator arms and read/write head for export. Most of parts for assembly came from Singapore and Malaysia. The entry was primarily motivated by cheap labour costs. While there was concern about developmental impact of being the so called screwdriver assembly base of MNEs (i.e. industry footloose) at the early stage of industry development, the evidence in the previous section clearly suggests the opposite. HDD industry in Thailand experiences industrial deepening over the period and Thailand is one of the major exporters.

Over years the affiliates in Thailand gradually acquired more technological capability as workers gain tacit knowledge from work experience. As revealed in Sample 7, after receiving prototypes/blueprint developed in the parent company, there are several tasks before actual manufacturing process begins. Workers in the affiliates need to develop basic and detailed designs for production processes. Production facilities, tools, molds, and other requirements are then designed and ordered. Task details are prepared for workers in production line. Other tasks include pilot runs, during which production processes are put under final checks in readiness for mass production (Sample 2). This is where tacit knowledge is needed.

In the early stage, Thai workers yet acquired such tacit knowledge so that only mass production was undertaken in Thailand’s affiliates (Samples 1 and 2). This is what is referred to as the labour intensive stage. Over the years, workers gained more experience and accumulated skill so the affiliates started undertaking more complicated tasks. While it is very difficult to reveal any particular examples illustrating moving up quality ladder of these affiliates in the interview, the fact that HDD industry can grow continuously in spite of the increasing wage over the past two decades supports the success in moving up. Right now, the affiliates in Thailand can converse prototypes/blueprint into action plans for manufacturing process. At this stage, the affiliates require more engineers and scientists. This is especially true nowadays where the HDD industry has essentially transitioned from the use of
longitudinal magnetic recording (LMR) head technology for the head writer function to perpendicular magnetic recording (PMR) technology. Sample 1 reveals an increasing number of engineers and scientists in the factory to overcome engineering problems that can emerge in the production process on daily basic. Such a developmental stage is referred to as Engineering Stage in Takayasu and Mori (2004).

After reaching engineering stage, industrial clustering develops as intensive cooperation between HDD makers and suppliers is needed to establish effective coordination and achieve ‘virtual integration of the entire system’. Nonetheless, while the industry is clustering, it does not completely rule out the industry to make use of globalized production. It depends on what layers of process fragmented and parts in consideration.

Consider a HDD production network where HDD makers are at the center. There are at least two layers. In the first layer, HDD makers interact with Tier-1 suppliers. The second layer is where Tier-1 suppliers participate with their suppliers, referred to Tier-2 suppliers. Industrial clustering is observed in the first layer with few exceptions as there are several customized parts and components traded in this layer. Hence, inter-personal participation is required to create effective and efficient coordination (Samples 1 and 2).\textsuperscript{13} Despite the continued improvement of telecommunication technology, it still cannot substitute completely the inter-personal contact in terms of several aspects such as speed to solve problems, effectiveness in trial and error experiments. In other words, distance still matters when it comes to establish effective coordination.

In the first layer, HDD makers usually request their suppliers to assign few staffs to work with the former’s staff as an inter-company team work to exchange information about production efficiency and cost effectiveness and to make changes (Samples 1, 2 and 7). Revealed by Sample 3, a group of staffs (e.g. 1-2 persons) are assigned to work with each customer on daily basic for exchanging production-related information, matching their production and delivery schedules, measuring and informing certain performance measures. Sometimes, HDD makers request suppliers

\textsuperscript{13} The proximity is also found in Kimura (2001:290) who studies Fujitsu’s HDD Production in the Philippines.
to change certain parts like electronic parts from one supplier (i.e. Tier-2 suppliers) to another to improve finished HDDs’ performance. This could happen even in a very short notice and occur like back-and-forth as a part of HDD makers’s experimental process. Sample 4 provides the same impression. Speed to respond to such requests is one of performance indicators HDD makers monitor and rank their Tier-1 suppliers for future order volume.

Under the close coordination, HDD makers also benefit in overseeing their suppliers’ capability and productivity. Since the former is at the network’s center and has better information of all parts assembled in the last stage, they would be in a better position to provide some sensible solution to improve performance of their suppliers. Sometimes, a problem occurs in a particular part but needs cooperation from other parts suppliers to fix it. Even though there are not restrictions for Tier-1 suppliers to serve solely a particular HDD maker, these suppliers have to have individual production line for each individual customer. Even in a relatively generalized part for all HDD makers, it cannot be a single production line for all customers. For example Sample 3 which supplies more than one HDD makers has individual product line to serve each customer. This would be due to the industry nature in which there are extremely short product life cycles and market demand is highly volatile. Leadership position cannot be taken for granted so that HDD makers must be ready for emergence of new and uncharted markets opportunities. Hence, firms in such an industry usually have slightly excess capacity and their suppliers must have capacity ready to respond any immediate changes that might occur. There is any product innovation from R&D labs, the firm who owns such an innovation must have ready production capacity to serve market and harness gains from its innovation. Even though HDD makers outsource peripheral parts to the third party, their relationship is far different from arms’ length transaction in which is characterized by a loose patchwork of stand-alone affiliates, joint ventures, and suppliers. Hence, there is the effort by HDD makers to network its own operations and inter-firm relationships, across both functions and locations (Borrus et al., 2000).

By contrast, it is the second layer where international fragmentation takes place. Intermediates used for Tier-2 suppliers for Tier-1 suppliers are less customized as opposed to the first layer. This is especially true for electronic parts. As revealed
by Sample 4, intermediates traded in the second layer such as printed circuit board (PCB) integrated circuit (IC), resistant, semiconductor are used not only in HDD industries but also other industries. This is reinforced by digitalization phenomenon where electronic elements become an important part in determining performance of manufacturing goods. In addition, there are a number of MNEs such as Celestica, Flextronics, Jabil Circuit, Sanmina and Solectron, whose specialization is to manufacture these parts and components and play an important role in global trade (Lakeman et al. 2001; Yasuf, 2004: 11-12). More importantly, these MNEs have their own production networks around the globe. For example, Flextronics, the largest, had 87 plants in 27 countries and a turnover of $146 billion in 2002 (Yusuf and Evenett, 2002). Celestica have 50 production facilities around the world, most of which in developing countries are in East Asia. The same production network is found in the case of Solectron (Sturgeon and Lester, 2004: Figure 2.1 and Table 2.3). Hence these companies make their own decision where to serve their clients (either setting up another affiliate geographically close to their clients or exporting from their existing production capacity). The longer lead time required in the second layer is another factor explaining possibility that first and second-tier suppliers are not necessarily located nearby. As argued in Kimura (2009) inferring from experience of machinery industries, the first layer’s lead time is usually high-frequency just-in-time system (i.e. 2.5 hours) as opposed to 1-7 days required in the second layers. Besides, most parts and components in HDD production are small and have high values per weight so they can be carried by air transportation (Sample 4; Kimura 2001: 292). Hence, Tier-1 and 2 suppliers can be located in different countries.

Sample 4 reveals its own experience of internationally sourcing parts in the second layer. The company imports bare PCB from Singapore and Taiwan and ICs from Singapore and the United States and then customizes PCB assembly for HDD

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14 Sometimes, they are referred to as contract equipment manufacturers (CEMs) (Lakeman et al. 2001). Emergence of these manufacturers is partly related to changes in high-tech industries’ business environment such as business consolidation strategy and an increasing number of common parts across products (i.e. a certain kind of chips can be used not only in computer but also in other electrical appliances). Under this environment, business opportunities for CEMs are even greater. They can quote the lowest prices because of their high turnover because they are now able to offer a wide range of electronic items and customers. They can switch production from one category of manufacturers to another. They can pool the inventories of several customers and thereby cut total inventories.
makers. Interestingly, parts used for sub-assembly must be sourced from approved vendor lists provided by HDD makers and most of imported parts usually come from East Asian region. Despite possible, it does not necessary that intermediate trade in the second layer must occur internationally. In some cases, it can happen domestically (Sample 3). What we argue here is the option of international sourcing is economically feasible.

The exception part in this layer is wafer, media and other minor and small parts, usually imported from the HDD makers’ affiliates abroad. Their quality tends to be standardized so that geographical proximity is not really needed. Wafer and media play very important role in determining business competency and their production is likely to be in house. This is especially true for the latter so that it is usually in-house production. Both Seagate Technology and Western Digital imported them from affiliates in Johor Malaysia (Samples 1 and 7, Seagate Technology, 2008: Western Digital, 2008). Both parts are very capital intensive and there are huge sunk costs involved in their production. For example, Showa Denko set up its new plant in Singapore in 2006. The factory costs about 60 billion Japanese yen and employed about 600 workers. Hence, once the factory is located in a given location, it takes time to establish a new factory. There are numerous metallic parts for linking several major parts in HDD. They include spring wire, bottom VC, top VCM, TG clamp, Top cover assy, Top cover seal, positional seal, and window clock seal. These parts are physically small and economies of scale matter in their production process. Hence, it is economically worth to supply them for a certain factory.

All in all, evidence of HDD industry in Thailand suggests a possibility of the coexistence between industrial clustering and IPNs. MNEs can complement them to enhance their competitiveness. While industrial cluster is observed in the first layer, MNEs still can manage to harness benefit from dispersion of resource endowment in the second layer (Figure 6).

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15 When HDD makers employ PMR technology, media plays an important factor in determining HDD performance in terms of areal density (Western Digital, 2008: 12).
7. Conclusion and Policy Inferences

This paper examines the nature of international production networking at the industry level, using hard disk drive (HDD) industry in Thailand as a case study. The research methodology is based on interview evidence of samples purposively selected in order to reveal how firms make use of IPNs. The key finding suggests that how MNEs in HDD industry manage their production network, making use of both domestic and international fragmentation. Industrial clustering, domestic fragmentation, is used in the first layer of production network between HDD makers and Tier-1 suppliers to overcome any coordination failure that might occur. At the same time, when parts are less customized as found in the second layer, enterprises in HDD industry internationally source their intermediates to maximize benefit from the existing dispersion of resource endowment around the globe. In other words, based on evidence of Thai HDD industry, industrial clustering and IPN can co-exist.

Two policy inferences can be drawn. Firstly the coexistence between industrial clustering and IPN suggests that any observed industrial clustering is not a synonym of complete localization. Local content might increase as a consequence of industrial clustering but how much is purely based on cost-benefit analysis. As long as benefit from geographical proximity exceeds any possible costs of concentration, firms would prefer local sourcing. Secondly, industrial clustering can be regarded as a proxy of development indicator of a given industry. It must occur naturally only after the affiliates reach a certain level of technological capability. It cannot be forced by any policy measures like tax incentives. In fact, it largely depends on supply-side capability. Recent policy initiates like joint program between private and public sectors in education and training would be prudential policy to enlarge qualified engineers and scientists for HDD industries.
REFERENCES


Seagate Technology (2008), Annual Report and Form 10-K.


Western Digital (2008), Annual Report and Form 10-K.


### Table 1

**Tariff Structure in Hard Disk Drive Industry 1995-2006**

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Hard Disk Drive (HS 847170)</td>
<td>9.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Inputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Wafer (HS3818)</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2. Printed Circuit Boards (PCBs) (HS8534)</td>
<td>14</td>
<td>8</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>3. Integrated Circuits (HS8542)</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. Semi-conductors (HS8541)</td>
<td>14</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5. Motors</td>
<td>14</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>5.1 Finished Motors (HS8501)</td>
<td>14</td>
<td>8</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>5.2 Parts for Motor (HS8503)</td>
<td>14</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>6. Ball Bearing (HS848210)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>7. Aluminum Plate (HS 7601)</td>
<td>19</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8. Media (HS 852390)</td>
<td>14</td>
<td>9</td>
<td>7.4</td>
<td>0</td>
</tr>
<tr>
<td><strong>Average Manufacturing Tariffs</strong></td>
<td><strong>21</strong></td>
<td><strong>14.3</strong></td>
<td><strong>13.3</strong></td>
<td><strong>11.1</strong></td>
</tr>
</tbody>
</table>

Notes: * it is proxied by 2 digit HS847170  e.g. tariff of hard disk drive in 1995 is proxied by the average tariff of HS 84

ที่มา: Office of Fiscal Economics, Ministry of Finance
<table>
<thead>
<tr>
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<tr>
<td></td>
<td>5</td>
<td>18 (13)</td>
<td>36 (18)</td>
<td>51 (15)</td>
<td>74 (23)</td>
</tr>
<tr>
<td>13. Magnetc (1990)- HGA</td>
<td></td>
<td></td>
<td></td>
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</table>

Note: * the number in the parenthesis indicates additional establishments.

Sources: Data between 1981 and 2000 are from McKendrick et al. (2000) and those during the period 2001-06 are compiled from BOI database by the author.
Table 3
Trade Flows of Hard Disk Drive Industry in Thailand 2001-07

<table>
<thead>
<tr>
<th></th>
<th>East Asia incl. Taiwan</th>
<th>China</th>
<th>ASEAN-10</th>
<th>NAFTA</th>
<th>EU15</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Export Destination of Hard Disk Drive (%) of total export</td>
<td>50.8</td>
<td>60.7</td>
<td>12.5</td>
<td>34.4</td>
<td>18.0</td>
</tr>
<tr>
<td>II. Import Sources (%) of total imports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Printed circuit boards (PCBs) (HS8534)</td>
<td>79.8</td>
<td>87.0</td>
<td>2.1</td>
<td>5.8</td>
<td>45.1</td>
</tr>
<tr>
<td>2. Integrated circuits (HS8542)</td>
<td>72.9</td>
<td>73.4</td>
<td>0.8</td>
<td>1.7</td>
<td>35.0</td>
</tr>
<tr>
<td>3. Semi-conductors (HS8541)</td>
<td>78.3</td>
<td>76.0</td>
<td>1.5</td>
<td>2.9</td>
<td>32.4</td>
</tr>
<tr>
<td>4. Aluminum plate (HS 7601)</td>
<td>8.1</td>
<td>12.7</td>
<td>1.6</td>
<td>3.1</td>
<td>4.2</td>
</tr>
<tr>
<td>5. Diode Transistor (HS 854110+854121+854129)</td>
<td>71.4</td>
<td>64.3</td>
<td>0.7</td>
<td>1.6</td>
<td>29.1</td>
</tr>
<tr>
<td>6. Transistor and Resistant (HS8532 ฉีร 8533)</td>
<td>94.6</td>
<td>93.7</td>
<td>3.8</td>
<td>5.6</td>
<td>47.2</td>
</tr>
<tr>
<td>7. Wafer (HS 3818)</td>
<td>92.6</td>
<td>95.0</td>
<td>0.1</td>
<td>0.7</td>
<td>48.8</td>
</tr>
<tr>
<td>8. Media (HS 852390)</td>
<td>97.1</td>
<td>97.9</td>
<td>1.1</td>
<td>4.2</td>
<td>79.0</td>
</tr>
</tbody>
</table>

Source: Author’s compilation from UNComtrade and
Figure 1
Product Fragmentation of HDD

Sources: NECTEC (2007)

Figure 2
(Real) Value added of HDD Industry 1988-2007

Sources: National Economics and Social Development Board (NESDB)
Figure 3
HDD Exports 1988-2008

Notes: IT is referred to SITC 75-77, Manufacturing is SITC 5-8 net of 68 and HDD is HS 847170.
Sources: Author’s Compilation from UNComtrade database

Figure 4
Market Share of Major HDD Exporters, 1990-2008

Notes: HDD is referred to HS847170 and 6 major exports consist of China, Thailand, Malaysia, Singapore, Ireland and the Philippines
Sources: Author’s Compilation from UNComtrade database
Figure 5
Export Unit Value of Major HDD Exporters in East Asia

Notes: HDD is HS 847170.
Sources: Author’s Compilation from UNComtrade database

Figure 6
IPNs and Industrial Clusters in Thai HDD Industry

Source: developed by Author
## Appendix 1
### Characteristics of Interviewed Samples

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HDD Makers</td>
</tr>
<tr>
<td>2</td>
<td>HDD Makers</td>
</tr>
<tr>
<td>3</td>
<td>Non-electronics Parts + Foreign Firms</td>
</tr>
<tr>
<td>4</td>
<td>Electronics Parts + Foreign Firms</td>
</tr>
<tr>
<td>5</td>
<td>Core Parts+ Foreign Firms</td>
</tr>
<tr>
<td>6</td>
<td>Ministry of Science and Technology</td>
</tr>
<tr>
<td>7</td>
<td>NECTEC</td>
</tr>
</tbody>
</table>