Theme: Building the innovation markets, places and networks

Structural holes and intermediaries in the evolution of triple helix networks in Thailand with reference to the case of the MNC-dominated hard disk drive industry (HDD)

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Abstract

This paper explores the evolution of the triple helix network and innovation system in relation to the role of innovation intermediaries based on the experience of knowledge network development in Thai hard disk drive industry. The paper attempts to show both conceptually and empirically the development of the triple helix innovation system as an evolutionary process starting from 'pre-existing inter-firm networks', which occur in the form of supply chain-based vertical links and industry or trade associations or cluster-based horizontal links, and progressing through triple helix networks that would be expected to culminate in the establishment of the triple helix innovation system underpinned by network dynamics. Intermediaries are crucial to stimulate the evolution by closing and bridging 'structural holes' or disconnected actors and stimulating network dynamics through playing three roles as: sponsors providing funding for collective actions and 'specific investments'; brokers closing internal structural holes and bridging external structural holes; and boundary spanners facilitating macro and micro knowledge circulation. From the case study, the challenge of knowledge network development is a major hurdle that has yet to be overcome in the long evolutionary process of getting to the triple helix innovation system. Network dynamics have not been seen in the early phase of network

development due to lack of trust and short-term government supports. To promote triple helix innovation system, government should promote market-led intermediaries to provide bridging and closure services in network development in the long term.

Keywords: Triple Helix network; Innovation intermediaries; structural holes; learning; knowledge; Thailand; hard disk drive industry

1. Introduction

The aim of this paper is twofold: to show the development of triple helix knowledge network as a basis for the evolution of the triple helix innovation system; and knowledge intermediaries as policy vehicles for network development through the bridging and closing of 'structural holes'. An important distinction is thus drawn between triple helix as a knowledge network and triple helix as a system of innovation. This is particularly relevant to discussions of triple helix in the context of developing countries, where the focus should be more on the former than on the latter.

The triple helix knowledge network is an evolving phenomenon in developing countries. This is reflected in the growing policy support for the expansion of university-industry cooperation. However, what little university-industry interaction there has been to date in developing countries has for the most part been driven by personal initiatives and conducted on ad-hoc basis. Much of the problem underlying this situation relates to the issue of shortfalls in institutional capacity development in these countries. If this problem is to be overcome, and developing countries are to benefit from the integration of the activities of knowledge creation and knowledge use, the role of policy is crucial in knowledge network development, as it provides, *inter alia,* the missing links that would mitigate institutional rigidities and the

fragmentation of activities in the domains of knowledge production and use. The question, however, remains: how effective are governments in developing countries in playing interventionist roles to leverage the evolution of triple helix knowledge networks? Given the widely acknowledged failure of both governments and markets in the allocation and management of resources in developing countries, the question at stake is how best the mechanisms of intervention can be designed to promote the development of a competitive basis for knowledge production and its use.

In view of the above, this paper aims to look into the significance of the roles of innovation intermediaries in bridging and closing 'structural holes' that disconnect actors in the triple helix network (Burt, 2000, 2001, 2004), with particular reference to the case of the Thai hard disk drive (HDD) industry. 'Structural holes' prevail in the absence of networks, leaving firms to their own devices as potential free-riders driven by opportunistic behaviour. 'Structural holes' also create a barrier against knowledge exchange adding to the transactions cost of firms and making them reluctant to innovate, lest others benefit from their efforts. Where 'structural holes' abound, they disrupt the process of knowledge transmission and constrain the evolutionary process in the development of knowledge networks. While the occurrence of 'structural holes' is a characteristic feature to be envisaged in the development of knowledge networks in developing countries, it is less so where policy has been actively implemented to promote institutional capacity building as a basis for an integrated approach to socio-economic development.

Thailand is one of the rapidly emerging developing countries aspiring to qualify as an 'Asian tiger' economy. In the past, economic growth in Thailand derived from the accumulation of foreign direct investment (FDI) (Diao et al., 2006). However, in recent years, the government has come up with policy initiatives to shift the economy

from an FDI-based to a knowledge-based trajectory. Consequently, the cluster approach has been adopted since 2004 to develop and upgrade technological capability of industry through the promotion of networking within industry and between industry and supporting or complementary institutions, namely universities, research centres and government and non-government agencies. This paper will attempt to invoke a specific aspect of the industrial development experience of Thailand as a point of reference to provide a conceptual and empirical framework for analysing the role of intermediaries in the formation and evolution of triple helix networks that constitute a strategic basis for knowledge creation, knowledge exchange, knowledge use and the development of a triple helix innovation system.

The remainder of this paper is four parts. The part following this introduction discusses the conceptual framework, including reviews of the evolution of inter-firm networks into triple helix innovation system; the characteristics and significance of structural holes in networks; and the roles played by innovation intermediaries in the transformation process. The third part briefly describes the methods used in this study. The fourth part presents a case study drawing on the network experience of the Thai HDD industry. The last part presents the conclusions and policy implications of the issues raised in the paper.

2. Conceptual framework

2.1 Evolution of triple helix innovation system

In principle, triple helix knowledge networks arise from pre-existing inter-firm networks, including vertical supply chain and horizontal industrial association networks (Nakwa et al., (2012). Knowledge networks can be categorised into three dimensions (Pöyhönen and Smedlund, 2004; Nakwa et al., 2012). First, horizontal industrial networks consist of firms in the same industry or at the same level of value

chain. Firms in the same industry with similar knowledge base can reduce costs and lead times of technological development through the coordination of efforts in some common areas (Robertson and Langlois, 1995). Second, vertical value chains involve trading relationships of suppliers, manufacturers and customers. This constitutes supply chain relationships among firms. Both suppliers and customers influence technological development as the manufacturers' end-customers exercise this influence through the expression of their requirements (Gemünden et al., 1996), and suppliers, through the adoption new technologies thereby changing the supply chain dynamics (Freeman, 1991). The third category of inter-firm relationship, which occupies the diagonal space, combines the vertical and horizontal elements as components of the institutional sphere of production and wealth creation. The evolution of this sphere is conditional on its alignment to the overarching knowledge and policy and governance spheres.

Vertical and horizontal inter-firm networks predate triple helix networks and are referred to in this paper as pre-existing networks. Such networks offer limited scope for growth and deep cooperation for lack of heterogeneity in the community of firms and limited exposure to sources of knowledge and new ideas. However, network development through knowledge exchange has its own dynamics, which cuts across boundaries to involve heterogeneous players and occupy the diagonal space. Thus emerges the triple helix knowledge network, integrating horizontal industrial networks, vertical value chain networks and other supporting institutions from the knowledge and policy and governance spheres (see Figure 1).

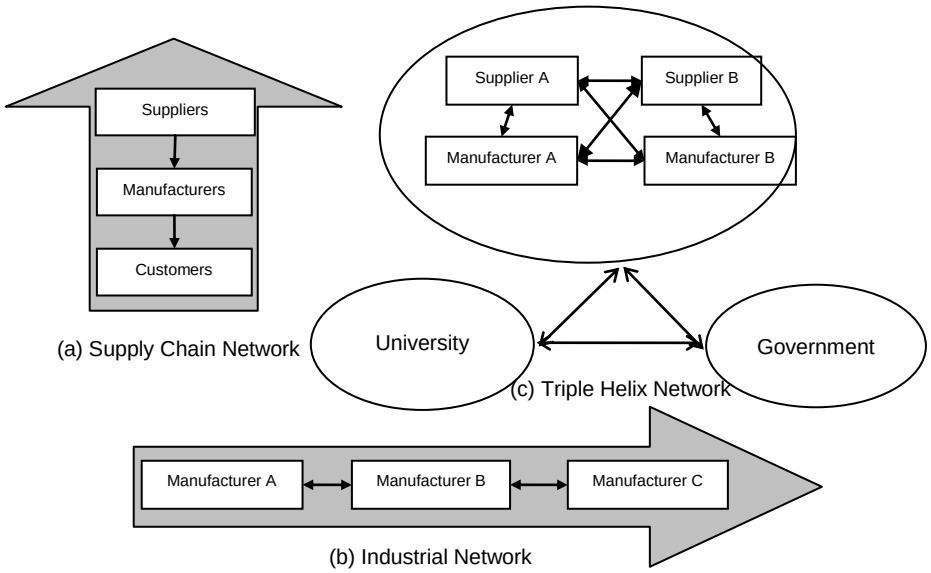

Figure 1 Innovation networks (a) Supply chain network (b) Industrial Network (c) Triple helix network

This type of knowledge network can create network dynamics as a result of the exposure of firms to a wide range of actors with a diverse set of knowledge, experience, competencies and resources (Nakwa et al., 2012). Networking of firms corresponding to different value chains and industries with different technological paths can open new technological opportunities that provide the basis for radical innovation (Pyka, 2002). Apart from inter-firm cooperation, the interactions along the diagonal space would be expected to involve other institutions, such as universities and government agencies, these being two of the essential actors in the triple helix network, the other actor being industry and business. Universities are knowledge producers feeding networks with new knowledge categories. Business and industry use the knowledge acquired to create wealth; and the role of government is to provide resources and policy and institutional mechanisms to stimulate and optimise the cross-fertilisation effect of the diagonal inter-firm networks (Gemünden et al., 1996). The combination of diverse knowledge along the diagonal space generates network

dynamics that are capable of bringing forth new technological paradigms and trajectories (Dosi, 1982; Menzel and Fornahl, 2007).

Networking between triple helix institutional actors enhances the learning process and contributes to the development of a dynamic culture of creativity and innovativeness. This happens because networking allows the convergence of diverse knowledge streams, which is necessary for the synthesis of ideas culminating in innovation (Balthasar et al., 2000; Madill et al., 2004; Knorringa and van Staveren, 2006; Capaldo, 2007; Menzel and Fornahl, 2007). Network dynamics is reflected in the process of the synthesis of knowledge deriving from a wide range of sources.

According to Nonaka and Takeuchi (1995), knowledge creation involves the application of four processes of knowledge conversion from tacit to explicit knowledge: socialisation; externalisation; combination; and internalisation. Through these four modes, the knowledge of individuals can be combined to create group, organisational and inter-organisational knowledge with new and larger loops occurring in a spiral mode. At each loop, learning occurs through the combination of the knowledge streams of heterogeneous actors, thus successively increasing the knowledge stock of networks (Bell and Albu, 1999; Gilsing, 2005). At the same time, networking offers opportunities for combining diverse and non-redundant knowledge streams and competencies of heterogeneous actors, leading to radical innovation (Beckman and Haunschild, 2002).

In the knowledge exploration process, firms can search for and combine knowledge from ‘strong ties’ with cognitive closeness. This, at best, results in incremental innovation. On the other hand, ‘weak ties’ with cognitive distance can be sources of significantly new knowledge categories that are capable of opening opportunities for radical innovation, considered as network dynamics (Gilsing, 2005).

However, in the search for the combination of knowledge from other institutional actors with different cognitive backgrounds, firms need capability improvement investments in terms of equipment, machinery and human resource development, so-called 'specific investments' (Gilsing, 2005). These would enable them to create common cognitive framework and to build trust and mutual understanding. Through such investments, socialisation takes place allowing, if informally, the exchange of tacit knowledge of different institutional actors as well as the building of trust and mutual understanding between the actors. When the cognitive distance of actors in networks decreases, these actors can combine their organisational knowledge into inter-organisational knowledge. The newly combined knowledge can contribute to economic development as it is internalised into routine operation through commercialisation process, generating economic value. These four loops of knowledge creation are presented in Figure 2.

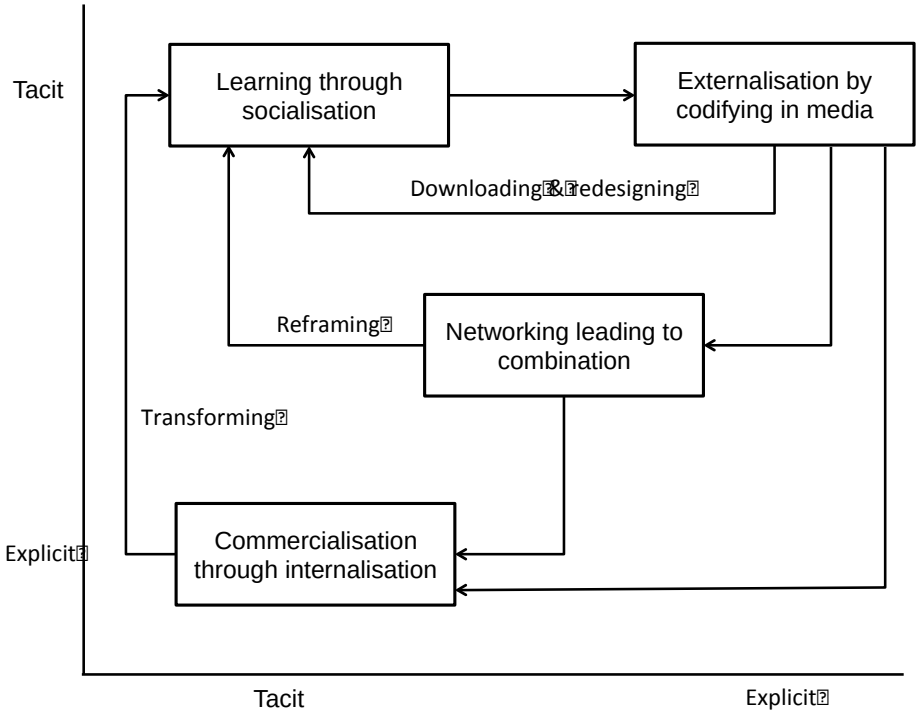

Figure 2 Four loops of inter-organisational knowledge creation process

Source: Modified from Nonaka and Takeuchi (1995) and Pahl-Wostl (2009)

2.2 Structural holes: closure and bridging

In developing countries, the combination of knowledge deriving from heterogeneous actors is constrained by differences in the culture and knowledge base of institutional actors. Thus, while the potential for new knowledge creation is well afforded by the heterogeneity of actors, the scope for the realisation of innovation is constrained by institutional rigidities in these countries caused by the prevalence of structural holes. This constraint is mitigated by the introduction of the role of intermediaries whose task it is to close and bridge structural holes through the formation of strong ties and weak ties (Burt, 2001).

Where structural holes abound, they can be exploited as sources of new knowledge, particularly if they knowledge spill-over that can be had without costs. But the generation of such benefits is unsustainable as firms responsible for the knowledge spill-over would shirk. Of more concern, however, are the negative externalities, where structural holes prompt opportunistic behaviour in firms. This too is unsustainable as firms would sooner or later react to reduce their exposure to potential free-riders. In the former case involving knowledge spill-over, Burt (2004) proposes bridging structural holes through brokerage to tap into new and diverse knowledge sources. In the latter case, the suggestion is to close structural holes in order to reduce opportunistic behaviour of disconnected firms. The former relate to internal structural holes, and the latter to external structural holes (Burt, 2001; Gilsing, 2005).

Internal structural holes refer to disconnected actors within a network; external structural holes involve disconnected actors outside the network. In the context of triple helix networks, internal structural holes can be considered as disconnected actors within each institutional sphere; and external structural holes, as disconnected

actors between institutional spheres. Internal structural holes arise within an institutional sphere to avert the opportunistic behaviour of homogeneous actors with similar knowledge bases. In contrast, external structural holes arise due to differences in culture, resources, competencies and knowledge bases between actors in different institutional spheres, impeding connection and collaboration. Although these external structural holes can offer benefits to the networks in forms of diverse and non-redundant knowledge, a focal firm may hardly exploit such knowledge spillovers due to problems of cognitive distance and lack of absorptive capability.

Internal structural holes can lead to sub-optimal level of technology development of actors within institutional spheres (Johnson, 2009). What would be required in such circumstances is action for structural hole closure to mitigate opportunistic behaviour among players within institutional spheres (Ahuja, 2000). In the process of structural hole closure, trust is the main factor to increase social capital of networks within institutional spheres. Consequently, these internal structural holes can be transformed into strong ties, in which homogeneous actors are connected (Burt, 2000) (see Figure 3). Apart from mitigation of opportunism, network closure within institutional spheres also facilitates communication, micro knowledge circulation and coordination within institutional actors (Etzkowitz and Dzisah, 2008). Knorringa and van Staveren (2006) called this closure process as ‘bonding social capital’. Network closure cannot happen where there are differences in culture and knowledge bases.

In contrast, external structural holes with cognitive distance or non-redundant knowledge bases can benefit a focal firm within an institutional sphere when there is combination of diverse knowledge. Bridging such structural holes and transforming external structural holes into weak ties offers the focal firm an opportunity to combine

existing knowledge with new knowledge (Burt, 2000), enabling macro knowledge circulation between triple helix institutional actors (Etzkowitz and Dzisah, 2008). In the bridging process, 'specific investments' have to be made to reduce cognitive distances and differences, thus increasing social capital (Gilsing, 2005). This bridging process can be used to connect heterogeneous actors in different institutional spheres when 'bonding social capital' between homogeneous actors reaches a critical level. As can be seen in Figure 3, a triple helix network contains both strong and weak ties. Strong social capital within institutional spheres facilitates communication and collective actions, and complementarity of heterogeneous actors with different knowledge bases leads to radical innovation (Pyka, 2002; Knorringa and van Staveren, 2006).

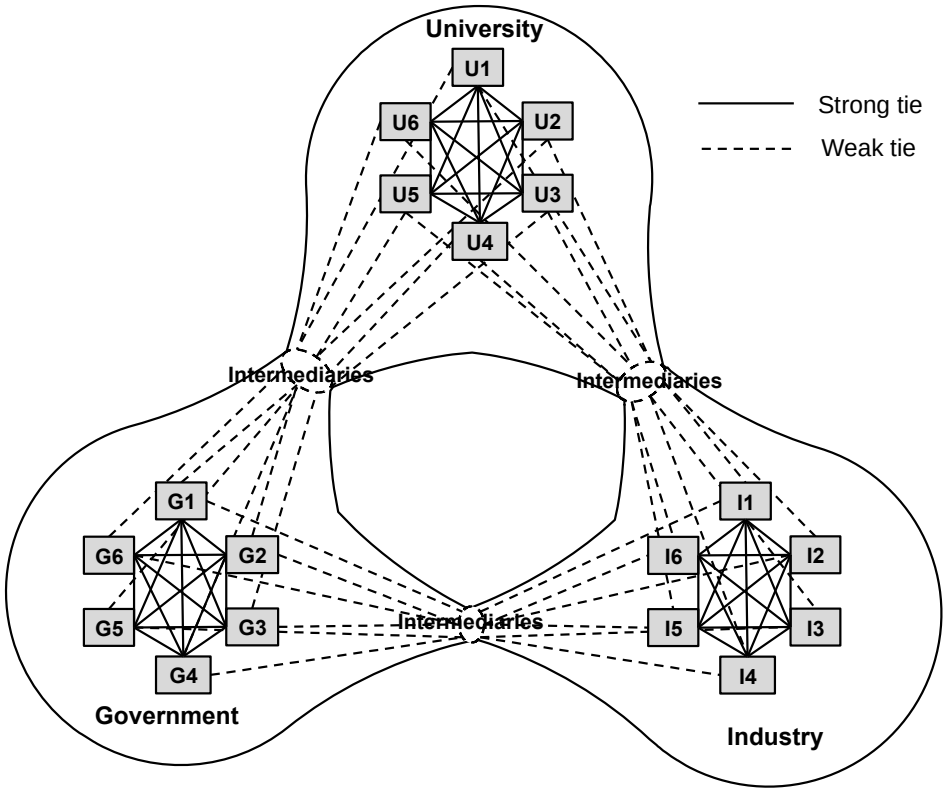

Figure 3 Network closure within institutional actors and brokerage between institutional actors in triple helix

2.3 Roles of intermediaries in closing and bridging structural holes

In developing countries, triple helix networks are generally dysfunctional because of structural bottlenecks or the prevalence of 'structural holes' that constrain communication between the triple helix institutional actors. In such cases, innovation or knowledge intermediaries play an important role in mitigating the effects of 'structural holes' by linking the principal triple helix actors through bridging and closing mechanisms, so that they can engage in conversations as to how they can work together to solve specific problems and to identify options for the way forward.

Intermediaries are necessary to transform inter-firm networks into triple helix networks by attracting other institutional actors, i.e. universities and government agencies, to participate in pre-existing inter-firm networks (Nakwa et al., 2012). In this transformation process, intermediaries play roles as: sponsors providing policy guidelines and funds to promote network development; brokers linking actors and building collaboration mechanisms; and boundary spanners providing operational services to facilitate knowledge circulation. Intermediaries can also play these roles in the evolution of triple helix networks into triple helix system by stimulating network dynamics through closing and bridging structural holes.

Intermediaries play a sponsoring role by providing funding to create collective actions for building trust, thus closing internal structural holes and stimulating 'specific investments' for reducing cognitive distance and differences between actors in different institutional spheres, thus bridging external structural holes. They play a brokering role by connecting internal structural holes and creating collective actions within institutional spheres; and also by connecting external structural holes through 'specific investment' programme. They play a boundary-spanning role by providing operational services to facilitate the exchange of tacit knowledge embedded in actors

within institutional spheres through socialisation; to convert tacit knowledge shared between strong ties within institutional spheres (transformed from internal structural holes) into explicit knowledge through externalisation; to help upgrade technological capability of actors across institutional spheres to reduce cognitive distance between weak ties (transformed from external structural holes), thus stimulating combination of diverse knowledge of heterogeneous actors; and to help commercialise newly combined knowledge into innovation, thus creating economic value through internalisation (Nonaka and Takeuchi, 1995; Nakwa and Zawdie, 2012).

In addition, intermediaries play a role in creating network dynamics through iterative transformation within triple helix knowledge networks. It is argued that weak ties and strong ties benefit a focal firm in exploration and exploitation of new knowledge, respectively (Capaldo, 2007; Harryson et al., 2008). In the exploration process, firms search for new diverse knowledge and creativity from structural holes, opening their boundaries for knowledge from other networks (Harryson et al., 2008). Intermediaries can stimulate socialisation to transform 'compartmentalised networks' with structural holes into 'loosely connected networks' with heterogeneous weak ties through brokerage (Gilsing, 2005) (see Figure 4).

Intermediaries can assist absorptive capability improvement through specific investments. Absorptive capability is necessary for actors to assimilate new diverse knowledge (Kim et al., 2010). To reduce cognitive distance, learning of actors can occur through human resource development and new equipment adoption. Intermediaries as sponsors funding for collective actions and specific investments transform the loosely connected networks within institutional spheres into strongly connected networks ready for the combination and internalisation of knowledge (see Figure3).

In the exploitation of knowledge, intermediaries can facilitate network closure by playing role as either itinerant broker mediating within an intuitional sphere from outside or coordinator mediating within their own spheres (Fernandez and Gould, 1994). In this process, knowledge can be combined after specific investments are made. Newly combined knowledge can contribute to economic development through commercialisation of new knowledge by internalising it into operational routines of production sphere (Nonaka and Takeuchi, 1995). Intermediaries thus set in motion the network dynamics in which existing 'strongly connected networks' turn of their own drive into 'compartmentalised networks' in order to search for new 'structural holes' of networks to continue combining knowledge (see Figure 4).

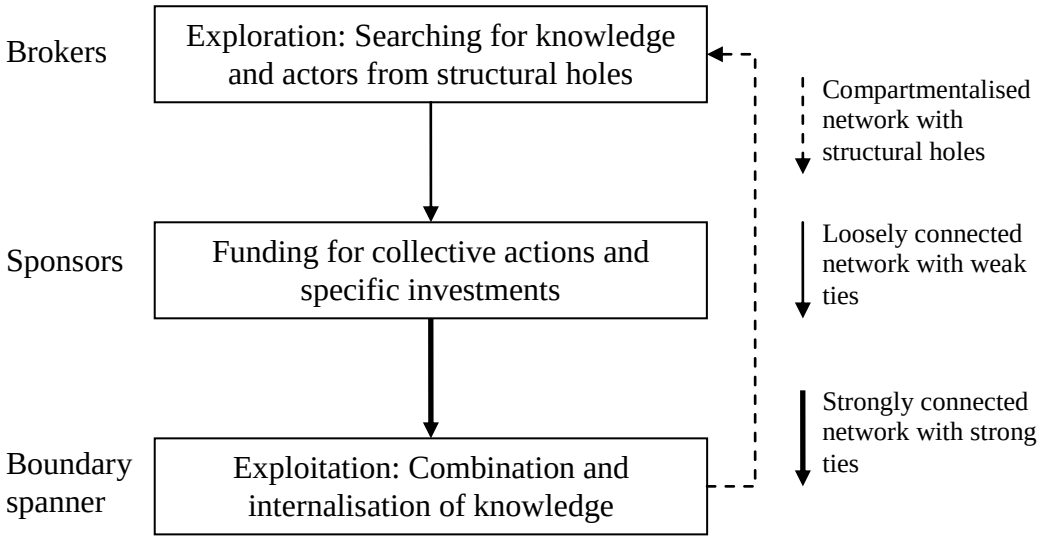

Figure 4 Roles of intermediaries in stimulating network dynamics through structural holes

3. Methodology

This paper is part of a larger study on knowledge network development in Thailand funded by the Thai Royal Government, which culminated in the completion of a PhD project by the lead author of this paper. In this paper, the hard disk drive (HDD)

industry in Thailand is used as a case study. In the Thai HDD industry, policy aimed to internationalise local SMEs into global value chains of MNCs was implemented through the intervention of intermediaries. Data collection was conducted through interviews from February 2011 to August 2012. Key persons from academic, government and industrial sectors were interviewed about network formation, operation and actors. Data were analysed through descriptive case study based on conceptual framework developed in this paper.

4. The case of HDD industry in Thailand

4.1 Current status of Thai HDD industry

Thailand is the largest manufacturing base of the world HDD industry. In 2010, it held a 42 per cent market share of world production with export value at 596,677 million baht (approximately 20,000 million USD) (see Table 1). As seen from Table 1, HDD products and parts account for about one-third of the export of the electronics industry, which is the second largest industry of Thailand. In addition, other than its contribution to industrial employment and output, the HDD industry contributes to the Thai economy in the terms of the development of technological capability. The HDD industry and its supporting industries create approximately 150,000 jobs.

Table 1 Production and export of Thai HDD industry

	2006	2007	2008	2009	2010
Production volume (million pieces)	152.8	204	247.2	258.2	280.6
Production growth (%)	-	33.5	21.2	4.4	8.7
Export of HDD products and parts (million Baht)	559,739	597,059	605,314	545,468	596,677
Proportion of HDD export to electronics export	35.7	36.2	37.4	37.6	35.2
Market share (%)	N/A	N/A	N/A	44	42

Source: Cluster and Programme Management Office, NSTDA (CPMO, 2011)

Although Thailand has long been the manufacturing base of most HDD makers, the value added created in the country is a small fraction of sale, accounting for only 1.12 per cent of export value (Kohpaiboon, 2009). Most HDD makers and the first tier suppliers are MNCs taking advantage of the low wage labour in the country. Local firms do not have the capability to produce HDD parts due to lack of infrastructure for high precision technology. In promoting value added creation, the government has focused on supporting industries, such as jig fixture, automation and indirect materials.

Cluster development policy has been pursued since 2006 to promote the development of the HDD industry. Following research for developing HDD cluster, the Hard Disk Drive Institute (HDDI) was established as a hybrid organisation, which emerged from the interaction of industry, government agencies and universities to formulate policy, create collaborative mechanisms and manage the HDD cluster. In the first phase of the HDD cluster (2006-2010), emphasis was put on three technological development activities, including human resource development, R&D and supply chain development (see Figure 5). Human resource development was the major activity of technological development in the HDD sector as the sector afforded the highest support both from government and industry. The goal to be achieved over the first five years was to upgrade the technological capability of firms in the HDD and supporting industries. It can be seen from Figure 5 that the government supports for R&D and supply chain development activities were more than matching supports from industry. In the second phase, the aim of government support is to achieve deeper technological development in HDD production and also in automated equipment production of supporting supply chain industries in order to create more value added to Thai economy (CPMO, 2011). The case study of an alliance analysed

in this paper is a pilot project to develop supply chain or supporting industry to serve MNCs.

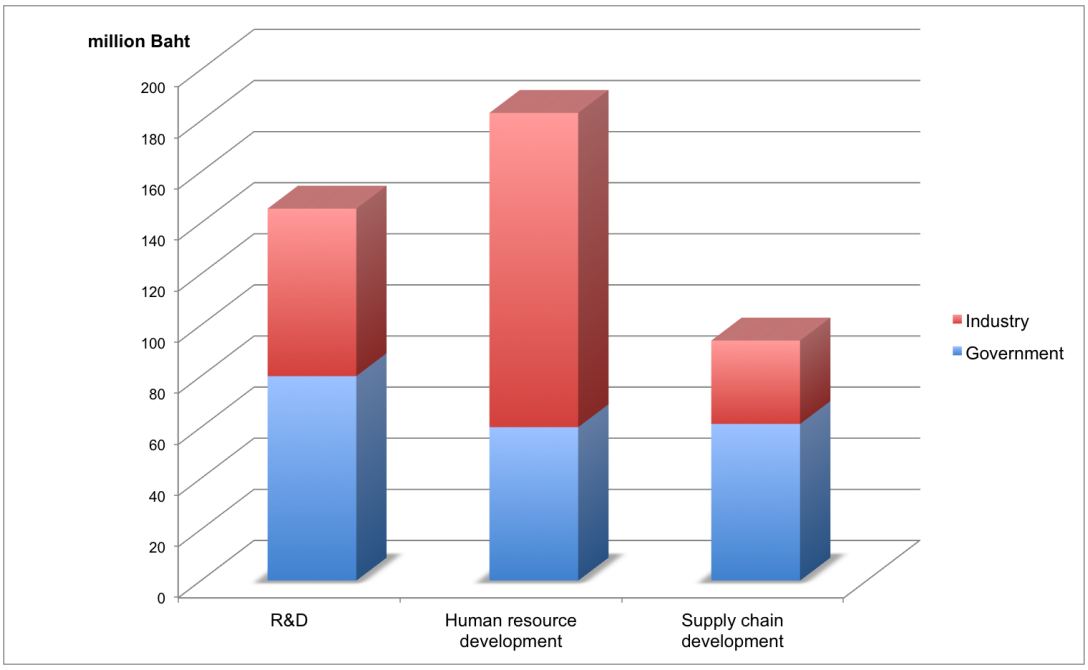

Figure 5 Supports of government and industrial sectors in HDD industry

Source: Cluster and Programme Management Office, NSTDA (CPMO, 2011)

4.2 Case study: TH Alliance as a triple helix network

4.2.1 Establishment of TH Alliance

The role of intermediaries has been found to be crucial for MNC-dominated industries in Thailand to stimulate the backward linkage effects, thus increasing the value added to economy. In the past, this role was executed by government agencies based on the so-called 'local content requirement policy', a protectionist policy aimed at promoting use of locally produced materials instead of imported ones. This policy of import substitution is now abandoned and replaced with a strategy for global sourcing. While this strategy may appeal to inward foreign direct investment (FDI), the government's insistence to generate the maximum possible value added sets a challenge that local producers have to contend with. However, in this change of

policy direction, the government's position is based on the belief that for sustained increase in value added due to FDIs, MNCs would need to make substantial contributions to the technological capability development of local firms. In other words, growth in value added should be based not merely on the employment of more and more of primary resources (capital, labour, land and land-based resources), but more importantly on technological progress.

TH alliance is a pilot project involving the horizontal integration of four SMEs in automation products. It was initiated as a cluster of local firms by the Hard Disk Drive Institute (HDDI) as supporting industries for HDD industry, such as machinery and equipment, thus accounting for the backward linkage effect of the HDD industry. To implement cluster development of local firms to support the activities of the HDD industry, the HDDI created Industry/University Cooperative Research Centres (I/UCRCs) as brokering intermediaries in three universities.

The Institute of Field Robotics (FIBO) in King Mongkut's University of Technology Thonburi, one of the three I/UCRCs, identified a list of potential local firms with the basic capability to manufacture automation products. It provided the list to an HDD maker to select potential suppliers to establish an alliance company by integrating production lines of local firms to realise economies of scale in the process of specialisation. Four SMEs were selected to establish TH Alliance to provide automation products for an HDD maker – some of the SMEs with comparative advantage in manufacturing capability and others in design capability. Each firm in TH Alliance had to invest in the setting up of production and testing lines in which it has comparative advantage, so that its outputs can be effectively integrated into the whole automation production system. These four SMEs set out their machines in particular lines to form a joint station at a site near an HDD maker. Then, as a

boundary-spanning intermediary, the FIBO, facilitated knowledge circulation between MNCs and local SMEs, by providing research support to local firms, thus offering them access to opportunities for reverse engineering and the acquisition of knowledge that would enable them to replicate some imported machines and develop their technological capabilities in the process.

4.2.2 Roles of intermediaries in the transformation of the pre-existing networks into the triple helix networks through structural holes closure and bridging

Triple helix networks, consisting of three intuitional spheres i.e. university, industry and government, can be built through the transformation of pre-existing inter-firm networks (Nakwa et al., 2012). The pre-existing networks of the HDD industry in Thailand involve inter-firm networks – i.e. the vertical value chain between HDD makers and MNC suppliers; and a horizontal industrial association represented by the Thai branch of International Disk Drive Equipment and Materials Association (IDEMA), which was established by four HDD makers to develop human resources and share information about global trends of the HDD market. Prior to intervention by the HDDI, MNCs within the production sphere did not trust local SMEs because they are too small with low registered capital. They lacked quality assurance, inspection equipment and the ability to produce very high precision products. Also, the MNCs did not cooperate with SMEs in technology development activity because of the potential risk of high transactions cost arising from SMEs exercising opportunistic behaviour to 'free-ride' in the absence of any institutional and organisational provisions.

With respect to the institutional spheres, a few universities have forged links with MNCs in form of contract research. A government agency, namely the Thailand Board of Investment, provides tax incentives for technology and human development

activities of these MNCs. However, this compartmentalised network with both internal and external structural holes does not promote value creation and technological capability development due to the absence of knowledge circulation. Under such circumstances, the knowledge stock of local firms can hardly be expected to increase (Bell and Albu, 1999); and in the presence of structural holes, they remain disconnected actors disenfranchised from the system of knowledge circulation. However, the aim of policy in Thailand has been stimulate technological capability development in SMEs by integrating them into global supply chain system through association with MNCs and also by actively engaging them in knowledge transactions as network players together with other firms and local institutions. This arrangement, which would benefit SMEs to tap into global knowledge network, is implemented by intermediaries. As noted in earlier sections of this paper, intermediaries play a major role in Thailand linking disconnected actors, or 'structural holes', through bridging and closure processes.

Intermediaries play three roles as sponsors, brokers and boundary spanners in closing structural holes. Prior to the establishment of TH Alliance, there were four SMEs who knew about each other as firms in same industry, albeit informally and without any intention to cooperate. These four SMEs can be considered as internal structural holes. The Thai Government set up the HDDI, which, as a sponsoring intermediary, assigned FIBO as a brokering intermediary to propose the establishment of TH Alliance and to create mechanisms for collaboration. HDDI then provided funding for FIBO to play a boundary-spanning role, providing technical assistance for the Alliance to work in the joint project. Thus by acting as sponsors, brokers and boundary spanners, intermediaries sought to connect internal structural holes through

horizontal integration and incorporate SMEs into a knowledge network that would ensure their knowledge stock continually refreshed.

Intermediaries also bridge external structural holes through the process of knowledge transfer. Prior the formation of TH Alliance, SMEs did not have any links with universities, and in the eyes of HDDI, these would qualify as external structural holes. As a broker, FIBO invited local firms in relevant industries to participate in the supply chain development programme with the aim to identify potential firms to work with MNCs. The selected SMEs were trained by FIBO as a university-based boundary spanner, and were financially supported by the HDDI in order to develop upstream products for the production of HDD. Through this bridging process, FIBO plays an essential role as a broker in transforming external structural holes into 'weak ties' through the formation of a knowledge network between four SMEs, an MNC, FIBO and HDDI. FIBO also operated as a boundary spanner promoting the circulation of knowledge among the SMEs.

4.2.3 Roles of weak and strong ties in creating network dynamics

Network dynamics arise from iterative processes of knowledge creation and combination consequent upon interactions between heterogeneous actors. In the case of TH Alliance, intermediaries played three roles in transforming compartmentalised networks into strongly connected network through structural holes bridging and closure. In its role as a sponsoring intermediary, HDDI supported 'specific investments' to reduce the cognitive distance between the four SMEs, the MNC and FIBO through the collaborative mechanisms created by FIBO as a broker. These specific investments include funding for human resource development to upgrade the technological capability of engineers in the four SMEs. In addition, FIBO exercised a

boundary spanning role by providing training and technology transfer services to SMEs to enable them to participate in the supply chain of the MNC. The MNC was consequently connected to the four SMEs through the specification of its demand for intermediate products. Socialisation between FIBO, the four SMEs and the MNC occurred in these collaborative activities, transforming the compartmentalised network into a loosely connected network.

Other modes of knowledge conversion related to the exploitation of knowledge which occurred through the iterative processes of externalisation, combination and internalisation. With the supportive intervention of intermediaries, these processes would be expected to culminate in the transformation of loosely connected networks into strongly connected networks. As a brokering intermediary, FIBO promoted the creation of links among players including TH Alliance and the MNC and the four SMEs in the alliance. FIBO also used its resources and boundary spanning expertise to facilitate knowledge conversion processes within the production sphere. For example, in the externalisation mode, FIBO helped firms to conduct reverse engineering and claim intellectual property rights (IPR) on it. FIBO researchers conducted the reverse engineering of imported machines used by an HDD maker and transferred this knowledge and blueprint to the four firms in TH Alliance. After improving their technological capabilities through training, the firms designed their own blueprints and built prototypes through replication. Thus, they combined their tacit knowledge from training and explicit knowledge from blueprints to design and develop new machines, and acquire IPR in the form of patents on these. The patents represent internalisation of newly combined knowledge through the commercialisation of newly developed machines. The SMEs integrated their production lines to produce such machines. The HDDI provided financial support for

the building of prototypes. In addition, FIBO provided and assisted in the production of documents for quality certification, since such certification enhances the profiles of local firms and their eligibility to participate in the supply chains of MNCs. At the end of the project, the MNC purchased seven of the ten patented machines produced by the SMEs. Thus, the first loop of knowledge creation saw the individual knowledge of FIBO and the four SMEs combined into inter-organisation knowledge, creating new knowledge and product innovation.

However, there is no evidence of continuity in the knowledge conversion and creation cycle to ratchet in a spiral mode, suggesting that the network dynamics created in the TH Alliance was not robust enough to be sustained. A major problem behind this state of affairs is the lack of trust among players in the network that prompted the MNC not to be readily forthcoming in its relationship with the SMEs. This problem was exacerbated by the reduction of government supports. As discussed earlier, network dynamics can be created as actors keep on searching for new structural holes possessing complementary resources and knowledge, thus enabling the existing strongly connected networks to develop a constellation of weak ties around them in the form of compartmentalised networks (see Figure 3).

After selling its patents to the HDD maker, thus transferring its proprietary right, TH Alliance was unable to reproduce and sell those seven innovated machines to other HDD makers and other manufacturers in other industries. This left TH Alliance with the option to bid for new projects and develop new machines to maintain the operation of the Alliance. However, some members of the Alliance felt that they did not obtain any benefits from the business of the Alliance and were reluctant to continue their operation as members. This could happen because the establishment of TH Alliance was not based on trust but through the administrative fiat of top-down

policy (Murdoch, 2000). Nor was there much trust between the SMEs and the MNC, their client. In other words, the socialisation process in this project did not really reduce the cognitive distance between the SMEs themselves and between the SMEs and the MNC. The system thrived, albeit unsustainably, with knowledge flowing is one way from FIBO to the SMEs. Eventually, when the Government withdrew its support – more, it can be argued, for budgetary reasons than for lack of interest in knowledge network development – the TH Alliance ceased to function as an effective network player in the and the knowledge creation loop was aborted after the first round of activities of socialisation, externalisation, combination and internalisation, which culminated in the sales of the seven innovated machines to the MNC. In the event, the triple helix knowledge network, which appeared to have made a promising start, relapsed into the original inter-firm network position.

Following the cut in government support and the disengagement of the MNC, the SMEs regrouped to develop strong ties and create a new alliance to combine knowledge and innovate. For example, two of the SMEs started a new alliance to bid for new projects from the same HDD maker. Another SME would partner with an overseas company to establish a joint venture as a basis for technology transfer. However, without access to sources of knowledge production, inter-firm networks face the risk of being locked into old trajectories that would make it difficult for firms to engage in the knowledge combination process through the closure and bridging of structural holes. However, for this effort of network development to be effective, the intervention of intermediaries is crucial. Thus, the link the HDDI helped to create between the four SMEs and the university-based intermediary, FIBO, would need to be strengthened, but on the basis of mutual trust and not on the back of government support. Trust would provide the basis for the SMEs to have sustainable access to

sources of knowledge production, and for FIBO to the agent for the development of the entrepreneurial university culture in Thailand.

5. Conclusions and policy implications

This paper has attempted to shed light on significance of the roles of intermediaries in the evolution of triple helix network into triple helix innovation system. As already discussed, this evolutionary process is expected to occur through the bridging and closure of structural holes. In developing countries where triple helix networks are often dysfunctional, intermediaries are necessary to bridge and close structural holes and then transform them into weak and strong ties, respectively. Intermediaries can also stimulate network dynamics through the iterative transformation of compartmentalised networks of heterogeneous players into strongly connected networks.

The case study of TH Alliance discussed in this paper shows that short-term intervention of intermediaries is necessary to create the first cycle of knowledge creation and network transformation, but it may not be sufficient to create the next cycles. Without trust and the provision of government support, the evidence deriving from the case shows that the subsequent cycles of knowledge creation and network transformation would be aborted. It is also apparent from the case that top-down policy could not be expected to create real trust and bonding among network players to provide the basis for the generation of network dynamics. However, the experience of the TH Alliance shows, if in a limited way, the significance of the contributions that players from the knowledge and government spheres in the triple helix network can make to promote the development of industrial activities through the process of knowledge acquisition and transformation. For instance, some SMEs realised the

benefits of engagement with actors on the triple helix network and continued to pursue this engagement in spite of their earlier experience with their MNC client and FIBO, the university-based brokering intermediary. There is, however, no evidence to show that this has proved to be a success. There is nonetheless good reason to believe that network development based on trust and the accumulation of social capital can provide the cornerstone for the development of triple helix networks and their ultimate evolution into the triple helix innovation system. The converse is also true – that lack of trust would fragment networks or render them sterile without the opportunity to learn through the bridging and closure of structural holes.

The problem in developing countries is one of determining where government-driven top-down initiatives should stop to give way to bottom-up initiatives in network development. In either case, intermediaries are necessary to promote network development as sponsors, brokers and boundary-spanners. But intermediaries would be effective in their mission if their ethos related more to the bottom-up than to the top-down culture of decision-making systems. It can, therefore, be argued that governments in developing countries would create less of a burden on themselves and contribute significantly to the development of knowledge network, in general, and triple helix networks, in particular, if they promoted market-led intermediaries to provide bridging and closure services in network development. Thus, for example, venture capital can be called in to serve as sponsors and universities and private consultants, as brokers and boundary spanners. This arrangement would have a transformative effect on the culture underlying the functions of the triple helix institutional actors – industry would aspire to be innovative and competitive in its role as the agent of wealth creation; universities would seek to be entrepreneurial in their role as producers of knowledge; and governments would seek to provide broad policy

frameworks and regulatory measures to enable institutional players interact and exchange knowledge, generating innovation on a sustainable basis.

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