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Facilitators of national innovation policy in a SME-dominated country: A case study of Taiwan

Chia-Yi Chen, Yu-Ling Lin* and Po-Young Chu+
Department of Business Administration, National Pingtung University of Science and Technology, Pingtung, Taiwan; *Department of Business Administration, National Chin-Yi University of Technology, Taichung, Taiwan; +Department of Management Science, National Chiao Tung University, Hsinchu, Taiwan

Abstract: *Twenty years ago, Taiwan faced the common constraints of most SME-dominated developing countries in build up scientific and technological capabilities. To facilitate the implementation of national innovation policy, Taiwan government has over time generously supported non-profit R&D institutions which embedded themselves into the triple helix model. Among the institutes, the Industrial Technology Research Institute (ITRI) and Hsinchu Science-based Industrial Park (HSIP) are the most visible. This paper aims to illustrate a case study discussing how ITRI and HSIP have helped SMEs in Taiwan overcome the challenges of technology, human resources, and new business venture when developing a high-tech sector. For other countries seeking to build up innovation capabilities and currently reliant on SMEs, it is worth studying the case of Taiwan.*

Keywords: Hsinchu Science-based Industrial Park (HSIP), Industrial Technology Research Institute (ITRI), national innovation policy, triple helix model, Taiwan

Many developing countries in Southeast Asia, Eastern Europe, and Latin America are currently trying to transform from traditional industry bases to high-tech, knowledge-driven economies. However, small and medium sized enterprises (SMEs) are often the dominant economic structure in these developing countries (OECD, 2004; Wignaraja, 2003). In such SME-dominated economy, few private enterprises are able to afford large, independent R&D expenditures that would generate their own technological capabilities (Chang & Hsu, 1998). Accordingly, the government of a SME-dominated country must build an adequate infrastructure to compensate for the relative scarcity of large-scale private firms possessing large R&D budgets. Most developing countries pursued private sector development strategies skewed toward the needs of large-scale business, including foreign invested ones. However, this type of policy was partly motivated by the rather disappointing results achieved through extensive SME support systems operated in developed countries since the 1970's (OECD, 2004).

Twenty years ago, Taiwan also faced the common constraints of SME-dominated developing countries. Driven by a unique national innovation and diffusion system, the successful development of Taiwan's high-tech industry has been widely acclaimed today. The International Institute for Management Development (IMD) ranked Taiwan's technological and scientific infrastructures fourth and fifth among 61 countries (IMD, 2006). In 2006, Taiwan is the largest TFT-LCD supplier in the world, ranks fourth in semiconductor manufacturing, and is third in information technology.

Taiwan government has over time generously supported non-profit R&D institutions engaged in technological development. These government-funded organizations have embedded themselves into the 'triple helix' model of university, industry, and government to facilitate the implementation of national innovation and technological policies. Jan & Chen (2006) suggested that these government-supported R&D institutes were most likely one of the most important factors in Taiwan's ability to innovate and industrially develop. Among the institutes, the Industrial Technology Research Institute (ITRI) is the most visible and dynamic (Amsden, 2003; Luo, 2001). Hsinchu Science-based Industrial Park (HSIP) has also played a critical role in forming synergistic industry clusters that upgrade Taiwan's domestic industry (Hu, Lin, & Chang, 2005; Lee

& Yang, 2000; Tsai, 2005; Xue, 1997). These institutions have functioned largely like hubs facilitating the triple helix model of technology development in Taiwan by forming a partnership network integrating Taiwan government, universities and firms (Chu, Lin, Huang, & Liu, 2009). For other countries seeking to build up scientific and technological capabilities and currently reliant on SMEs, it is worth studying the Taiwan model. Therefore, in this study we aim to explore the following questions:

1. What common problems a SME-dominated developing country has to deal with when it intends to develop a high-tech sector?
2. What ITRI and HSIP associate with the development of Taiwan's high-tech industry specifically?
3. How could other less resourceful SME-dominated countries learn to facilitate their national innovation policy via non-profit institutes such as ITRI and HSIP?

The rest of this paper is organized as follows. In the next section, we first review germane literature of technology and national innovation policy. Taiwan's national innovation system section gives a brief introduction of Taiwan's technological innovation system. How ITRI and HSIP facilitating Taiwan's innovation policy section describes how ITRI and HSIP facilitating to the development of the Taiwan's high-tech industry. Finally, the conclusions and policy implications of this study are discussed.

Theoretical background

National innovation system

In a knowledge-based economy, innovation has become the principal driving force for the sustainable development of nations, for competitive advantage in industry and in the accumulation of added-value. It is thus recent policy research has seen a growing interest in studying the development of 'National Innovation System' in order to build on a more comprehensive view of innovation and technical change (Freeman, 1987; Lundvall, 1992; Nelson, 1993). Freeman (1987) defined a national system of innovation as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies. There have been different approaches to National Innovation System in the past decade of scholarly work. According to Ergas (1987), technology policy of a nation can be either mission-oriented or diffusion-oriented. The former concentrates on a small number of technologies in early phases of their life cycle, whereas the latter aims to create large base technological capabilities within the entire industrial base of small, medium and large firms. It has been suggested that the diffusion of new knowledge in a National Innovation System require dynamic interactions among innovative institutions within an economy, including public and private institutions (Lundvall, 1992). Rothwell and Zegveld (1982) also proposed that innovation policy tools generally can be grouped under three main categories:

(a) Supply: Provision of financial, manpower and technical assistance, including the establishment of a scientific and technological infrastructure.
(b) Demand: Central and local government purchases and contracts, notably for innovative products, processes and services innovative products, and processes and services.
(c) Environment: Taxation policy, patent policy and regulations (economic, worker health and safety and environmental), that is those measures that establish the legal and fiscal framework in which industry operates.

Based on the foregoing studies, it is suggested that the successful development of an economy's high-tech sector requires two policy inputs. The first is usually public sector-led in the form of public infrastructure, favorable tax statuses, investment incentives, and academic resources. The second aims at fostering the technological advantages that an industry or firm needs to survive and compete.

The triple helix model

In a national innovation system, there are various organizations or systems assisting the development and expansion of new technologies innovation, including universities, research institutes, government departments, and private firms. Etzkowitz and Leydesdorff (2000) proposed the 'triple helix' model to capture the evolution of innovation systems. The triple helix model stated that three institutional spheres (government as public, industry as private, and university as academic) form the critical elements in a knowledge-based economy's innovation process (Leydesdorff & Meyer, 2003). Etzkowitz and Leydesdorff (2000) introduced three types of triple-helix policy models and suggested that most countries are presently trying to attain some form of the third model (illustrated in Figure 1) where university spin-offs, tri-lateral initiatives for knowledge-based economic development, and strategic alliances among firms, government laboratories, and academic research groups abound (Etzkowitz & Leydesdorff, 2000). In the triple helix model, the functions of state and academia usually implemented by public sector, while the function of industry is carried out by private sector. To accelerate industrial improvement, all three spheres collaborate closely, represented in the model by the intersection of the circles.

However, the triple helix system may have some possible shortcomings for developing country, because these countries' technological development is learning-oriented rather than innovation-oriented (Jan & Chen, 2005; Viotti, 2002). There are some limits to the extent to which government and academia can cooperate with and assist private sector efforts in developing technological capabilities. First, the public sector typically has less information than the private sector about the market. Second, industrial policy designed to help private investors venture into new activities can unfortunately end up serving as a mechanism for rent transfer to less scrupulous businessmen and more self-interested bureaucrats (Rodrik, 2004). Last, the research results of academia are often difficult to link with industrial production (Chang & Hsu, 1998). Thus, in order for government and academia to more effectively support and promote technology policy and development, innovation policy-making should embed itself into a network of linkages with private groups, and shield public officials from too-close interactions with businessmen.

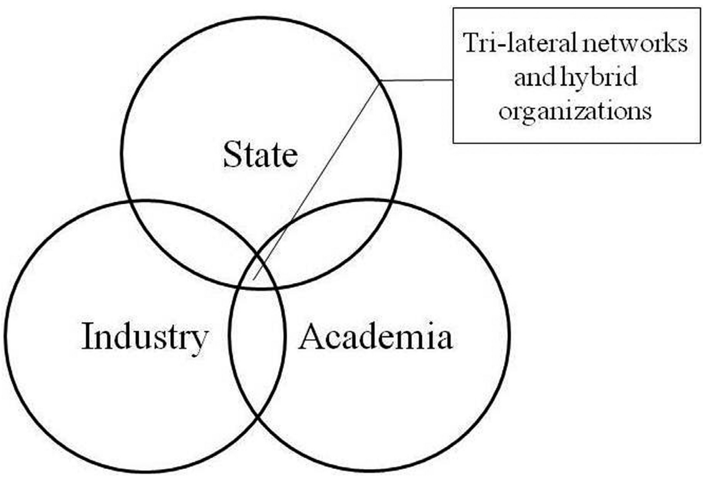

FIGURE 1: THE TRIPLE HELIX III MODEL

Taiwan's economic structure

Compared to countries like Korea which promoted the growth of large private conglomerates (*chaebol*), the Taiwanese government's relationship with industry was more distant. This resulted in an industrial structure dominated by SMEs: at the end of 2006, Taiwan had around 700,000 registered SMEs. Companies with a workforce of less than 200 people accounted for 97.8% of all enterprises at the end of 2005. The total number of persons employed by SMEs was 7.64 million, accounting for 76.9% of all employed persons. SMEs contribute more than 55% of Taiwan's manufactured exports (Ministry of Economic Affairs, 2006).

Due to Taiwan's industrial structure based on SMEs, the development of high-technology industries is somewhat handicapped (OECD, 1988). SMEs typically lack the market information, risk tolerance, as well as financial resources necessary to venture into new businesses. In studies conducted by Mahmood and Singh (2003), unlike South Korea where large business groups (*chaebols*) dominate and unlike Singapore which has relied heavily on foreign multinationals for developing innovative capabilities, Taiwan's national system of innovation has a much great role for SMEs. With a lack of large-scale funding from public and private sources, Taiwanese technology policymakers focused on building government research assets that would compensate for the lack of endeavors by private firms.

Taiwan's national innovation system

Although other countries have also incorporated non-profit institutions and industrial parks to facilitate national innovation policy (i.e., Korea Institute of Science and Technology, KIST; Japan's National Institute of Advanced Industrial Science and Technology, AIST; China's Shanghai Zhangjiang High-Tech Park), few have played as prominent a role as in Taiwan. For other countries seeking to build up scientific and technological capabilities and currently reliant on SMEs, it is worth studying the Taiwan model. Therefore, in the following, Taiwan is used as a case study to explain how government-supported institutions facilitating the implementation of national innovation policy in a SME-dominated country.

National innovation policy of Taiwan

During the early years of Taiwan's industrialization, industrial policy encompassed import protection, direct credit, FDI selectivity, support for indigenous skill and technology development, and strong export promotion (Brautigam, 1995; Wade, 2004). The government attracted FDI into activities in which domestic industry was weak, and used a variety of means to ensure that MNCs transferred their technology to local suppliers. In this period, Taiwan's primary goal was to foster labor-intensive import-substituting industries in pursuit of stability and self-sufficiency. In the 1970s, Taiwan's labor-intensive sectors were still a main driver of national competitiveness.

In the 1980s, with land and labor costs surging, the government recognized many of Taiwan's the comparative advantage steadily slipping away. The only avenue open was for industries to upgrade to a higher technological level, with capital and technology intensity replacing the no-longer-viable labor intensity of the past. Taiwan government thus set out to formulate an export-oriented strategy fuelled by high-tech industrial development (Hsu & Chiang, 2001). At that time, however, there was no high-tech industry in Taiwan to speak of, nor any infrastructure that would be a source of creating and manufacturing breakthrough technologies and products. Therefore, the main challenge facing Taiwanese economic planners was how to move from the *status quo* of little know-how, inadequate institutions where trained scientists and engineers were in short supply to a high-tech-based economy.

Due to an economy largely made up by SMEs, Taiwan's private sector R&D capabilities were quite insufficient. Few domestic enterprises were able to afford the type of personnel and expenditures that would generate their own technological breakthroughs. In order to compensate, the government established semi-state institutions (of which ITRI and HSIP were the most effective) to take on the responsibilities and functions usually assumed by industry per the triple helix model (shown in Figure 2).

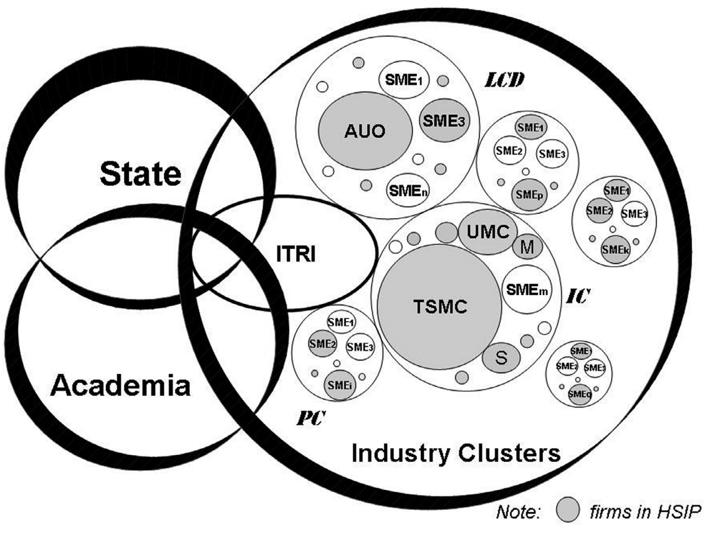

Figure 2: Taiwan's adaptation of the triple helix model

Introduction to ITRI

ITRI is a non-profit R&D organization founded by Taiwan's Ministry of Economic Affairs (MOEA) in 1973 serving as both a public policy arm and technical resource center for private enterprises. By 2005, the ITRI staff had grown to more than 6,000 people. In Taiwan's transition from a traditional industry economy to a technology-based one, ITRI has played a vital role in providing and disseminating research and technical services.

To build up SME R&D capabilities, the government has played an important financing role. In 1979, MOEA's Department of Industrial Technology (DOIT) launched the Technology Development Program (TDP). DOIT's major task is to formulate industrial development policies and to identify promising areas for future technological developments. DOIT has distributed TDP funding to create and sustain non-profit research institutions which then subcontract with universities in compliance with the program's requirements. Of these TDP-funded research institutions, ITRI is one of the most visible and dynamic – the program's total budget in fiscal year 2004 was US$542 million, approximately half of which went to ITRI. Under government leadership and cooperation from the industrial sector, ITRI develops new technologies required by industry and regularly spins them off to enterprises. In 2005, ITRI's research projects were grouped into five technology groupings (Communication and Optoelectronic, Advanced Materials and Chemical Technology, Precision Machinery and MEMS Technology, Biomedical Technology, and Sustainable Development Technology) so as to facilitate further integration of ITRI's intellectual capital.

Introduction to HSIP

The HSIP was the first high-tech industry development center in Taiwan established by the government in 1980 under the guidance of the National Science Council (NSC). The objective of HSIP is to attract a critical mass of high tech industries and individuals to form synergistic industry clusters so as to elevate Taiwan's domestic industry base. Entirely government-funded, as of 2005 HSIP has received investments totaling approximately US$1.79 billion for infrastructure, hardware and software development, and construction. HSIP offers a range of special benefits to participating firms, such as low-interest government loans, R&D matching funds, tax benefits, commodity and business taxes, special tariff exemptions, and government-subsidized purchases of foreign technology.

The HSIP has a strong cast of supporters, including ITRI, National Chiao Tung University (NCTU), and National Tsing Hua University (NTHU). NCTU and NTHU are both advanced science and technology universities in Taiwan, especially in electronics and information technology (Hsu, Shyu, Yu, Yuo, & Lo, 2003). They furnish the HSIP with talent enforcement activities, high-quality human resource, and R&D support. The HSIP also houses three national laboratories: the National Centre for High-performance Computing, the Synchrotron Radiation Research Centre, and the National Space Program Office (Lai & Shyu, 2005). By the end of 2005, HSIP hosted a total of 382 high-tech firms, providing employment for nearly 40,000 people, and the Park's sales revenue reached US$33.59 billion. In 2005, Park businesses invested US$2 billion in R&D, or 6.8% of their total sales (HSIP, 2005). The infrastructure provided in and around HSIP has proved to be especially valuable feature for technological development in Taiwan's SME-dominated economy.

How ITRI and HSIP facilitating Taiwan's innovation policy

The role of ITRI in the development of Taiwan's high-tech industry

Government-funded ITRI and HSIP have created huge knowledge externalities that have been critical to the island's successful high-tech industry. In the following, we will illustrate how ITRI and HSIP have helped SMEs overcome three main challenges in developing high-tech capabilities, which are **technology**, **human resources**, and **new business venture**. We will also discuss in more depth how ITRI and HSIP have facilitated the implementation of national innovation policy in Taiwan.

Technology

The mission of ITRI is to implement mid and long-term national applied research projects that are comprehensive, progressive and cutting edge. ITRI plays a critical role in introducing, assimilating, and improving foreign technology and generating new technology in Taiwan. In line with government measures, ITRI has advised SMEs and participated in state enterprise R&D projects to help optimize national research resources (Hsu & Chiang, 2001). ITRI's laboratories have also conducted R&D projects for pre-competitive and applied technology development sponsored by the MOEA. In addition, ITRI has collaborated with academic institutes, HSIP businesses' R&D departments, and non-Park firms. Once projects are completed, technology is diffused via non-exclusive technology transfers, seminars, workshops, and industrial services (Jan & Chen, 2006). Although ITRI is a government-supported R&D institution whose assets are public goods, it still seeks to develop promising technology and product lines for commercial use. Thus, ITRI not only works with major institutions in basic research, but also closely collaborates with technology recipient firms. By working closely with industrial partners, ITRI has facilitated an accelerated commercialization process of transferring technology to SMEs in Taiwan and bringing about new business opportunities for them.

Since 1999, these institutes have, on average, licensed 50 technology transfer cases to 40 domestic IT companies and filed more than 100 patent applications annually. In 2005, it transferred technology for 663 items to 581 companies in Taiwan, and obtained 2,149 patents (928 domestic and 1,221 foreign) (Industrial Technology Research Institute, 2007). By 2003, ITRI obtained 7,248 granted patents (domestic and overseas), held 13,227 seminars, and conducted 14,088 commissioned and joint research projects obtained 821 patents (459 domestic and 362 foreign), hosted over 1,189 conferences and training courses, Over 26,000 companies received services of some kind from ITRI (Chu, Lin, Hsiung, & Liu, 2006).

Human resources

Human capital is any R&D institution's key asset because it is the source of innovation and strategic renewal (de Pablos, 2002). Although ITRI is not an educational institution, it is one of the main suppliers of industrial leaders for Taiwan's high-tech sector. ITRI provides both on-the-job training and development programs for employees. In addition, each year ITRI organizes and runs over 1,000 professional training services in the form of lectures, workshops, seminars, and symposia. ITRI also offers over 300 basic and advanced classes, covering both technical and management topics.

ITRI has 4,300 engineers striving to match the best that the West, Japan, and Korea can offer in fields such as microelectronics and optoelectronics. Since its establishment in 1973 and as of 2003, ITRI has transferred 16,401 personnel to other sectors, including 13,246 to the business sector, 660 to government institutions, 1,673 to academia, and 822 to pursue advanced studies. Among former ITRI employees who have transferred to the industrial sector, 40% of them entered private electronics, semiconductor, computer and telecom enterprises, approximately one-third of which are located in HSIP. A recent survey showed that a total of 55 companies were found to have had previous presidents or board chairmen transferred from ITRI, and approximately 13 have incumbent presidents or board chairmen transferred from ITRI (Chu et al., 2006).

Taiwan's technological competence today is derived largely from highly-qualified HSIP personnel (Luo, 2001). HSIP is one of the deepest reserves of high-tech talent in the world. According to statistics on detailed R&D manpower, there were 10,770 researchers participating in R&D activities in HSIP in 1999, a number which has only grown with time. Among that 1999 figure, 4,849 hold Master's degrees and 579 hold doctorate degrees (National Science Council, 2000).

Developing new high-tech industries

Within the government's efforts to develop new strategic industries, ITRI has played a vital role. ITRI helps to move a product from the laboratory to pilot production or to spin it off as a new company. By absorbing a new technology, testing and using it, and making improvements upon it, these firms successfully elevate their technological capabilities. The creations of such spin-offs have created an industry ecosystem that further stimulates technological investment and economic development. ITRI has incorporated 12 spin-off companies in accordance with the '*ITRI Spin-off Organization Procedure*' (Chu et al., 2009). Chu et al. (2006) also found that as of 2003 new R&D discoveries by the five TAIEX-listed and OTC-listed ITRI spin-offs generated NT$6.56 of revenue and NT$1.57 of profit for each NT$1 originally invested by ITRI. Including human diffusion, each NT$1 input by ITRI produced NT$13.96 of revenue and NT$2.15 of profit for the industrial sector.

Taiwan's integrated circuit (IC) industry is one of the best examples illustrating ITRI's contributions. After the IC industry was selected by the Taiwanese government as a strategic industry, ITRI was responsible for introducing, assimilating, and improving IC technology (Chang & Hsu, 1998). United Microelectronics Corporation (UMC Group) and Taiwan Semiconductor Manufacturing Company (TSMC), which together command approximately 60% of today's worldwide dedicated chip foundry market, are both spin-offs from timely ITRI research projects. Their services have promoted the explosion of fabless companies and created other niches in the value chain for Taiwanese IC design, assembly, and testing firms (Fuller, 2002). These firms are now internationally-renowned participants in the global semiconductor industry. Taiwan is now a world-class player in the semiconductor industry.

ITRI's contribution to SMEs in Taiwan

How should ITRI's external effects be evaluated in terms of SMEs in Taiwan? Taiwan's traditional industries are mainly comprised of SMEs so government assistance mostly took the form of information provision, human resource training, automation transformation guidance, technology guidance, etc. ITRI's role in fostering traditional industry upgrades lay in the expansion of available technology and information, as well as in providing primary guidance and demonstration work. The former is mainly in the area of industrial technology information provision, professional technologist training, tour exhibits for technology results, and R&D results transfer. As for the latter, in view of the wide variety of industries and the huge number of manufacturers it had to attend to, ITRI first selected the line of business and screened manufacturers; then it defined the detailed plans and implemented full-scale automation, technology consultation, technology transfer, R&D, and production improvement counseling. Relevant technologies were introduced and demonstrated to the industrial sector to expand effects.

In the technology service and exchange with industries, ITRI devoted around 65% of its services to SMEs, and around 35% to publicly-listed and OTC-listed companies. SMEs are the lifeblood of industries and are the important source of employment opportunities. ITRI fully cooperated with the government in counseling on R&D and the transformation of manufacturers. The related innovation awards, such as the Bedrock Award, Innovation Award, etc., manifest its contribution results. Of the eleven Bedrock awards held (123 manufacturers), 27 of the ITRI technology transfer recipients (e.g., FALCON, Hitron Technology, NH Enterprise), and nine of the ITRI counseling recipients (e.g., Chi Mei Food, NH Enterprise), or a total of 29% of ITRI beneficiaries became award recipients. In the nine Small & Medium Enterprise Innovation Awards held (355 manufacturers), 11 of the ITRI technology transfer recipients and one ITRI counseling recipient, or 3.38% of ITRI beneficiaries became award recipients.

ITRI started operating its Open Lab in 1996. It provided joint research and start-up enterprise incubator services. The establishment of the Open Lab was aimed at improving the R&D environments of industries, accelerating product realization processes, and realizing exchanges between corporate R&D facilities and the R&D of businesses. The Lab is open to companies that have joint research projects with ITRI. The Incubator provides technology enterprises with the resources they need. Although the beneficiaries of the Open Lab and Incubator are different, they still belong to industrial services. As for the Open Lab, it has attracted high tech companies and self-made entrepreneurs since its establishment in 1996. It has had over 4,000 users and had a total of 176 resident manufacturers. A total of over NT$4 billion for projects has been poured in, and accrued project funds received have exceeded NT$1.48 billion. It has assisted and fostered the establishment of 99 new companies; and total paid in capital has exceeded NT$39 billion. Twenty-nine of these companies are in the science park.

Cluster effect within HSIP

Industry cluster formation in HSIP is another success factor of Taiwan's high-tech industry. First, the industrial cluster effect of HSIP rapidly and effectively diffuses technology. Knowledge spillovers have provided new opportunities for other business and attracted additional foreign investment. HSIP has also created incentives for imports of new technologies (Tsai, 2005; Xue, 1997). Second, the integration of upstream and downstream industries reduces costs and increases the nimbleness of high-tech industries and companies. For example, within the IC industry cluster, HSIP IC design companies are always able to secure needed timely support from foundry and assembly/testing houses. Information about corporate capabilities and needs are readily circulated and known. Physical proximity and the ease of working together encourages a higher level of inter-dependency, enabling more technological diffusion, facilitating tighter communication and cooperation, and supporting the development of new ICs. This is why a successful cluster effect continues to positively reinforce growing Park sales. Third, the diffusion of personnel and networking within clusters are very robust, particularly in semiconductor and computer sectors. In summary, the externality effect of relationships and dependency within the HSIP clusters comes mainly from the density of experienced workers, technological spillovers, and cost reductions for individual firms (Eriksson, 2005).

HSIP solves the public goods problem that individual firms face. By providing the physical infrastructure that allows firms to be physically located in the same vicinity, HSIP facilitates the horizontal and vertical integration of the industry and creates competitive advantages for individual firms (Hu et al., 2005). For example, IC design houses cannot flourish without the support of wafer foundry providers; equipment makers cannot afford very expensive upgrades if not for platform leaders like TSMC or UMC; no Soc or IP vendors can exist without growing IC design house. The collaboration between foundries and design houses are the core source of positive externalities to reinforce each other, and thus create the world's most prominent IC design houses, along with premier foundry service providers in HSIP (Saxenian, 2001).

ITRI and HSIP as facilitators of national innovation policy

To develop a high-tech sector within an economy, both the public sector's build out of infrastructure through less-discriminating industrial policy and the private sector's market knowledge and entrepreneurship are needed. Lacking a private sector base to carry out core R&D, in SME-dominated countries government and academia may try to compensate. However, this is sub-optimal because private firms inordinately have better information about what the market needs and will accept. Relative to other developing countries with successful technology-driven growth during the last 30 years, Taiwan has uniquely utilized semi-government institutions. These institutions have been public sector-like in their role of building out infrastructure and bearing the financial and manpower risks of R&D development; at the same time, they have been private sector-like, maintaining flexibility and an entrepreneurial nature (Jan & Chen, 2005, 2006). This is what we mean by their role as facilitators of industrial policy and technology policy.

ITRI is like a hub, forming a partnership network that integrates and plays to the respective strengths of Taiwan government, academia, and industry. Within that network, HSIP and the clusters within it strengthen the inter-connections among R&D-oriented institutions, mass production-oriented firms, and related service providers (Hu, Lin, & Chang, 2005). Figure 3 illustrates ITRI and HSIP's interrelationships with government, academic institutions, and industry. As shown in Figure 3, ITRI draws upon central government support to collaborate with academic institutes and private business R&D departments (of which many, but not all, are located in HSIP). Successful technological innovation requires much more than entities engaging in fundamental research. By closely working with industrial partners, ITRI has transferred technology for further development

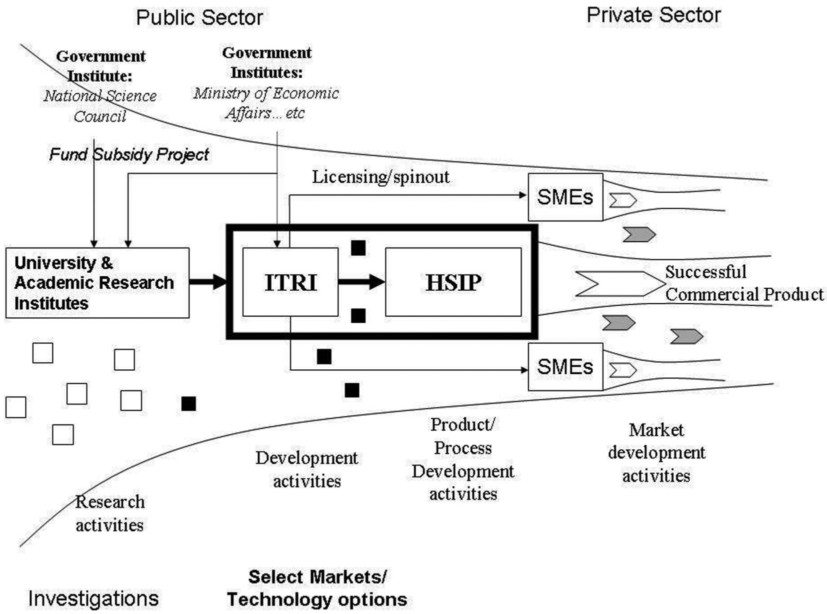

FIGURE 3: STRUCTURES OF RELATIONSHIPS AMONG ITRI, HSIP AND COLLABORATIVE PARTNERS

to Taiwan SMEs leading ultimately to commercial products. ITRI has not only generated commercializable R&D results, but it has significantly reduced technological uncertainties and risk of manpower shortages (Jan & Chen, 2005).

Moreover, ITRI has successfully institutionalized a business model that facilitates technology diffusion via spin-offs and which in Taiwan brought about new business opportunities for other SMEs in HSIP. The externalities created from the clustering in HSIP and other science-based parks (in Tainan, for example) have been pivotal to stimulating Taiwan's economic growth through increased innovation and technological development. The clusters created by HSIP with technology support from ITRI have nurtured many of the high-tech start-ups to which Taiwan owes its outstanding performance on the global IT stage (Saxenian, 2001). ITRI and HSIP have functioned like the central nervous system of Taiwan's national R&D, providing human talent, market knowledge, technology and other resources to HSIP manufacturers. If historically Silicon Valley is the greenhouse for the US's high-tech sector, then ITRI and HSIP have been the cradle for the Taiwanese high-tech industry.

CONCLUSION AND POLICY IMPLICATION

The successful development of an economy's high-tech sector requires not only public sector-led in the form of infrastructure, investment incentives, and academic resources, but also private sector-fostered advantages that an industry or firm needs to survive and compete. In the triple helix model, government and academic institutions play an important role in basic science and technology research but ultimately need to rely on the private sector for successful product commercialization. In the Japanese and South Korean models, the private sector is comprised mostly of large firms which are able to bear the risks and burdens of technology and product commercialization. However, Taiwan's SME-dominated economy did not have this ability of sponsoring expensive R&D projects. Consequently, in order to develop the high-tech industry necessary for the economy's continued growth, the Taiwan government created non-governmental research institutes (such as ITRI) with close ties to industry, which through clustering (such as in HSIP), could easily absorb and disseminate knowledge. ITRI and HSIP made it possible for SMEs to overcome manpower and technological constraints, implementing innovation policy and building up the nation's high-tech capabilities particularly in semiconductors. Clustering created further benefits of rapid knowledge diffusion and quick adaptation to changing market circumstances.

The trend of globalization has created not only great market opportunities but also enormous pressure for survival for companies especially resource-constrained. How to continuously innovate and align with evolving global open ecosystem challenges many paradigms. Neither individual enterprise nor single economic entity has sufficient resources and capabilities to dictate the development of technologies and industries. Not the largest or the most resourceful but the most adaptable ones could survive and prosper. In this situation, modeling the Japanese and South Korean models is one option, where the government promotes the development of and channels the majority of resources to large-scale enterprises. However, this may not suit all countries and Taiwan offers an attractive alternative of creating semi-government institutes which have the public sector's R&D and manpower support but are also market and private sector-oriented. This national innovation system facilitates collaboration between companies along the value chain via the clustering effect and by giving SMEs a bigger role, retains the advantages of an entrepreneurial and flexible marketplace.

The valuable lessons to policy makers and academics from ITRI and HSIP in Taiwan are summarized as follows:

1. Most developing countries are dominated by SMEs and the high-tech knowledge sector is the most promising direction for their economic development. SME growth and survival in high-tech deserves exploration by both academics as well as policy makers.
2. Taiwan has shown remarkable achievement in developing its high-tech sector, growing many SMEs into global companies. The unique development process via ITRI and HSIP is an interesting case study.
3. Taiwan's ability to develop high-tech ability provides insight for technology strategists and policy-makers concerned with resource-constrained entities. Facilitators such as ITRI and HSIP are an effective and efficient way to address the limitations faced by these entities.
4. Policy makers in developing countries are suggested to refer to Taiwan's model to design a national innovation system for incubating high-tech sectors. Government could generously support non-profit R&D institutions (such ITRI and HSIP in Taiwan) which are complementary to firms' proprietary technology development. Less resourceful firms could leverage those policy facilitators to obtain R&D technologies with manageable expenses and low technology uncertainty.

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Received 29 September 2009 Accepted 29 February 2012