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Knowledge Flow and Industry Innovation*

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CONTENTS

SUMMARY

1.Overview

Se-Hwa Wu

2.A Study of Policies Related to Innovation Networks —A Parallel Study to OECD

Feng-Shang Wu

3.The Technology and Area Study In Industril/Research Institute Cooperation And Industril Innovation

Jen-Fang Lee

4.The Cross Country Studies on Technology innovation & Diffusion System and Industrial Innovation --A Comparative Analysis of Chinese Taipei and Mainland China

Chang-Yung Liu

5.Comparative Studies of Interorganisational Learning between South Korea and Taiwan -- A View from National Systems of Innovation

Se-Hwa Wu & Frederick B. Hsu

6.The Relationship of Foreign R&D Unit in Taiwan and Taiwanese Knowledge Flow System

Shih-Chieh Fang

7.Modeling Knowledge Distribution on the Internet

Wen-Ching Liou

Theme II. Knowledge flow and industry innovation: Summary of research findings and future prospects

The APEC-STPRC research project ('Establishing the S&T Policy Research Center Project') of the first three-year period has come to an end. 'Knowledge flow and industry innovation' is the second theme under exploration in this project. Broadly speaking, this theme coordinated and captured various exploratory efforts of a team of talented researchers which transformed into a three-stage study plan. In the first year as the first stage, the team started to look out for 'facts' about knowledge exchanges in Taiwan. Namely, inter-company knowledge exchanges (including channels for knowledge exchanges), and statistics on industrial innovations were examined. In the second year as the second stage, contributions of knowledge exchanges through differing channels to industrial innovations, and contextual factors (e.g., ways of companies networking with each other, the roles of research institutes, government and universities) which facilitate knowledge exchanges were explored.

Our research projects after two years of efforts, culminated at cross-border comparisons made based on previous findings. Countries selected for our studies included Australia, Mainland China, New Zealand and South Korea. Prof. F. S. Wu, one of our research team members also joined OECD's third phase focus group project: innovative firms and networks. Based on the comparisons, practical implications for companies and policy implications for government in Taiwan were drawn for the purpose of enhancing the effectiveness of knowledge flows.

Specifically, under the second theme, several lines of enquiry have been conducted which resulted in fruitful outcomes. The lines of enquiry and the outcomes are summarised as below.

1. An exploratory study into policies which impact inter-firm collaboration in technology development¹. The study seeks to extract out of a wide array of literature on university-industry, research-institute-industry, or inter-firm knowledge exchanges policy implications and suggestions for governments of APEC countries. A research framework was also developed in order that firm cases in Taiwan could be studied as to their knowledge exchange processes. This study is parallel to a concurrent OECD focus group research project titled innovative firms and networks.

¹ Hosted by Dr. Wu, Feng-Shang.

2. The impacts of industry-university collaboration on industrial innovations². This study's purpose is to observe industry cases collaborating with research institutes, especially government-affiliated ones. For example, was explored. Specifically, this study aimed to answer the questions listed below:
 - a. How technology characteristics influence and shape modes of knowledge transfer from research institutes to industries?
 - b. How technology characteristics influence and shape modes of communication between research institutes and industries?
 - c. How technology characteristics influence and shape problem solving processes during the industry-research-institute cooperation?
3. The impacts of spin-off companies of research institutes on industrial innovations³. The study seeks to establish the importance of spin-off companies in fostering industrial innovations. It is discovered that spin-off companies in Taiwan have been taking the lead in generating industrial innovations. What Taiwan needs to do now is to enhance the roles played by universities in fostering industrial innovativeness, and to strengthen university-industry collaboration.
4. Inter-firm knowledge flow and industrial innovations⁴. The research team discovered that high-tech companies as represented by semiconductor manufacturers and IC design houses in Taiwan showed strong motivations in learning. They sought mainly large MNCs for the transfer of technology needed for their development. However, these high-tech companies were still engaged in OEM as their major businesses. In the long run, in order to secure and acquire new sources of competitive advantage, our high-tech industries should develop their own R&D capacity. The government should subsidise and encourage collaborative research between industries and government-affiliated research institute, i.e., ITRI, and between industries and universities.
5. Transnational knowledge exchanges and industrial innovations⁵. This study aims to explore a) factors which encourage foreign companies to or deter them from engaging in R&D in Taiwan, b) the type of R&D activities foreign companies in Taiwan engage themselves in, and c) the impact of these R&D activities on the knowledge flows in Taiwan. The findings offer suggestions for both companies and

² Hosted by Prof. Lee, Jen-Fang.

³ Hosted by Prof. Liu, Chang Yung.

⁴ Hosted by Prof. Wu, Se-Hwa. Dr. Hsu, Frederick B. did not join this project until toward the start of the second half of the second year.

⁵ Hosted by Dr. Fang, Shih-Chieh.

government. Companies should upgrade their technological levels so that their learning effectiveness could be enhanced once technology transfer takes place from their foreign counterparts to them. The government should seek to upgrade the level of sophistication of the market demand so that subsidiaries of multinational companies would upgrade their R&D efforts here in Taiwan.

6. The Research of 'Technology Innovation' Web Site Contents⁶. 'Technology Innovation' Web site is one which releases information on technological innovations of a country. However, the state-of-the-art technology only allow Web pages to adopt non-structural natural languages. This causes information retrieval, which contains a wealth of information and knowledge on the Web, cannot be fully utilized. Therefore, the purposes of this study are to establish a 'Technology Innovation' Web site information retrieval mechanism, and to provide a feasible Internet resource discovery method.

The research projects in the past three years have amounted to another three year project wished to continue the lines of quest in the previous years. There we wish, with re-organisation of our research teams, to explore several topics as below. We wish the project in the short run will be conducted under the sponsorship of National Science Council.

- a) The fit among types of infrastructure, types of knowledge-based innovation, and types of technological development.
- b) The changing roles of incubators in knowledge economy.
- c) The roles of venture education and business games in knowledge economy.
- d) The roles of research institute in knowledge economy - using Industrial Technology Research Centre (ITRI) as an exemplary case.
- e) Management of innovation processes - Exploring the developmental process of software-based innovations.
- f) A study into the relationship between organisational learning and innovations.
- g) Strategies for knowledge management in high-tech industries.

⁶ Hosted by Dr. Liou, W.

APEC-STPRC: Knowledge Flow and Industry Innovation

Theme II. Knowledge Flow and Industry Innovation

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A Study of Policies Related to Innovation Networks

—A Parallel Study to OECD

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Abstract

It has become a trend for most of the companies to rely on the external networks to complement their own internal innovation capabilities and to gain competitiveness. These networks are also important parts of a country's national innovation system (NIS). Thus, government should play a key role in making its NIS solid. Despite the importance of the issue, very few countries have well prepared for employing appropriate policy measures to reach the goal. In addition, little research has been completed regarding the issue of policies for innovation networks. The study develops a holistic framework to integrate the policy measures and the networking process. The model is empirically tested based on the case studies in Chinese Taipei. It is also a part of the joint effort in participating the research of OECD Focus Group Network of 3rd phase national innovation system (NIS) studies.

Key words: innovation network; policy measures; university/academia-industry cooperation

1. Introduction

Chinese Taipei has been working hard to change the situation from labor-intensive to knowledge-intensive economy. Nevertheless, one can still recognize that its current capabilities for innovation is not solid enough, i.e., its “national innovation system (NIS)” is yet well-constructed. For example, Taiwan is placed on top 3 in the world in computer-related product areas in terms of outputs, but the corporations’ profits and value added are not sufficient compared with those in developed economies. In addition, very few new products are originally developed from the firms based in Taiwan.

New technology is critical to the industrial corporations’ competitiveness. Companies can develop their technical capabilities and products either based on internal research and development (R&D) or outsourcing. Although it remains necessary to build own internal R&D capacity, getting the external sources of technologies through the networks have become more and more important (Fusfeld & Haklisch, 1987; Sen & Rubenstein, 1989; Berman, 1990; Wu, 1994; etc.). The issue is particularly important in Taiwan from the following two aspects:

- (1) Chinese Taipei is currently still in the “investment-driven” stage so that she must pay much attention to upgrading her innovative capabilities in order to move to innovation-driven stage. In fact, because of lack of the aforementioned capabilities, the performance of most corporations in Chinese Taipei are not good compared to those of foreign ones.
- (2) In general, high-level of researchers and engineers are not sufficiently available in the industries in Chinese Taipei. For example, there were about 15,947 engineers with doctoral degree in Chinese Taipei in 1998. Among them, there are only about 11% working in industry. In addition, most of firms in Chinese Taipei are small & medium-sized enterprises (SMEs) and don’t have much resources for advanced innovation, in turn need the support from governments. Therefore, industrial companies can benefit a lot if they are able to leverage the technical resources through the innovation networks. This summarized report is to explore the policies for innovation networks based on deep case studies.

2. Background and Literature Review

2.1 OECD’s Project

The section describe the major themes related to OECD’s third phase of its project on National Innovation Systems (NIS). This phase builds on the preceding phase, which was reported to OECD(1999). The continuation in the third phase covers the

work of focus groups for targeted studies of key areas for innovation policy as endorsed by the OECD working party for Technology and Innovation Policy (TIP) in June 1999.

The NIS project aims at improving the knowledge necessary for policy makers to design and implement policies in an environment of constant change. Knowledge creation, dissemination, and use represent significant sources of economic growth and new policies need to be based on constant updates of the understanding of how the economy operates, and what roles various forms of knowledge play. The main insight from the previous phase of NIS project was therefore the very role of governments change.

The NIS approach promises new insights into the foundations for and formulation of technology and innovation policy. The previous phase represented one step ahead in this respect. The 3rd phase of the NIS project and the work of the focus groups will need to bring the approach further. While there is still need for empirical and conceptual work, specifically so in the context of the emerging knowledge economy, the concentration of OECD 's activities into three focus groups (FG) illustrates the expectation of exploring key policy issues in further detail. These three focus groups include FGs Mobility, Clusters, and Networks. The FG Mobility aims to benchmark mobility rates across countries, and to study trends of international mobility including "brain drain, gain and circulation". The FG Clusters aim to compare innovation practices and innovation styles in selected clusters, refinement of methodologies for studying clusters, and deriving at implications for policy. This report conducted in Chinese Taipei is a joint effort of participating the FG Network whose major themes are listed in Table 1.

Table 1. Major Themes to be Studied by FG Network

<p>(a) Collaboration and Co-operation in Manufacturing: Three major subjects will be explored: (i) Science-Industry Relationship (ii) Domestic-foreign collaborations (iii) The service sector as a contributor to product innovation</p> <p>(b) Collaboration in R&D Analysis of CORDIS data to explore patterns of partnerships in the EU framework programme: (i) Emphasis on science-industry relationship (ii) Patterns of national and sectoral involvement in R&D partnership</p> <p>(c) Dynamics of Networks: Analysis of CIS II and other data sources to explore forms of</p>

co-operation, collaboration and networking

(d) Policies For Facilitating Networks:

Rationales and recommendations based on typologies of market/ coordination failures and selected policy case studies

(e) Capacities in the Innovative Firms

(i) Link the capacity approach to the policy measures that help firms develop progressively these capacities

(ii) Deepening the understanding of the role of government in enhancing these capacities

(iii) Assessment of the impacts of proposed policy measures

Source: OECD Workshop of FG Network, November 1999

2.2 The Role and Characteristics of Networks

The characteristics of, and comparisons among, markets, hierarchies, and networks have been studied recently. Many of the corresponding researches were based on the transaction cost theory of Coase and Williamson. They mentioned that the economic activities are organized according to the transaction cost characteristics and argue: (1) the “markets” can efficiently induce economic activities characterized by low transaction costs; (2) hierarchies are superior with high transaction cost activities; and (3) “networks” or “hybrids” have a comparative advantage with activities characterized by intermediate levels of transaction costs (Coase, 1937; Williamson, 1985 & 1991). Although it seems there have been some improvement in interpreting and understanding the network, there remain some critiques about the transaction cost theory.

Hamalainen & Schienstock (2000) summarize the aforementioned criticism in five ways: (1) the definitions of “transaction” and “transaction cost” have been very vague; (2) the transaction cost theory has paid disproportionate attention to transaction in comparison to production and coordination issues; (3) the unit of analysis in the transaction cost theory is an individual transaction. This neglects the costs and benefits that a particular transaction may cause in other parts of the interdependent production system; (4) the static approach of the transaction cost theory has little say about the dynamics of technological and organizational innovations (Porter, 1985; Dunning, 1988; Demsetz, 1991; Simon, 1991; Kogut & Zander, 1992; Ring & Van de Ven, 1992). They both further indicated the technological, political, institutional framework of value-adding activities varies among different industries, geographical locations, and historical time periods in ways that influence the comparative advantage of different organizational arrangements.

2.3 Types of Networks

The term “network” has been widely used in recent years. While various versions of definitions are provided, so far, there is not which is universally acceptable. The lack of a common definition may pose an obstacle to the further advancement of “network” studies and generalizations.

Nahapiet & Ghoshal (1998) mentioned that network relationships usually take a long time to develop. However, they tend to be characterized by mutual interdependence, intensive communication, reciprocity, and high levels of trust once established. Hamalailen & Schienstock (2000) indicated networks have been analyzed by researchers from many different disciplines with various interests and research approaches. They have focused on either different aspects or different level of network formation. Some researchers put emphasis on structural approach and may focus on the configuration, number and quality of network ties. Others may emphasize the issues of interpersonal relationships for productive cooperation, economic efficiency and innovativeness (Granovetter, 1973 & 1995). In fact, there exist various types of networks. They can be categorized into vertical and horizontal networks according to the activities of value chains by Michael Porter. The former ones integrate firms or production activities along a particular value chain; the latter ones integrate individuals and organizations in particular business functions. In addition, the linkage between the public and private sectors has been emphasized recently particularly for the purpose of building a solid national innovation system. Networks can also be differentiated by their geographical scope. Thus, one can distinguish between local, regional, international and global networks. Lundvall & Borrás (1997) classify the networks in terms of the formality of network relationships, and thus have them from highly informal, flexible, and trust-based relations toward more formal and rigid connections. Similarly, the duration of networks can be also different; from the short-term cooperative project to joint ventures, consortia, and associated organizations with longer term objectives.

Hämäläinen & Schienstock (2000) also indicated that the boundary of a network can be more or less clear-cut. In many cases, we can hardly find the clear boundaries between its environment. In addition, it is sometimes difficult to say whether a certain individual or organization belongs to a particular network or not. In this regard, we can differentiate networks according to their degree of openness or closeness. Furthermore, networks can differ according to the degree of centrality, i.e., some networks may rely on a few powerful members for decision making, while the members of other networks may have approximately equivalent power and rights (Rugman & D’Cruz, 1996.) Also, the stability of networks may differ greatly. In general, the types of networks can be summarized on table 2.

Table 2. Types of Network

- Geographical Dimension: local, national, international
- Functional dimension: vertical networks and horizontal networks
- Tightness of coordination: centralized vs. decentralized
- Organizational vs. human/expert networks
- Formal (contract-based) vs. Informal (trust-based) networks
- Virtual (ICT-based) networks vs. networks of physical contact
- Temporary networks vs. long-term networks
- University-Industry-Research-Institute networks

Source: Hämäläinen & Schienstock (2000)

2.4 The Networking Process

This section describe the practical problems in networking in solving them at different stages of the networking process, which include: (1)awareness of network possibility; (2)search for partners; (3)building trust and shared knowledge base; (4)organizing the network; and (5)active cooperation. (Hämäläinen & Schienstock, 2000)

Awareness of Network Possibility

Although there has been wide media coverage and active promotion by policy makers, the characteristics and potential benefits of network are not always well known particularly among small and medium-sized enterprises (SMEs). Normally, they spend much time to search for new market, to improve the production process, and to serve for the customers and may not want to lose competitive advantages to potential partners. This kind of problem may reduce the possibility of organizational adjustment among corporations which could benefit firms through active networking and cooperation. In fact, governments can help promote companies' awareness regarding the network and networking. Setting up a network inherits benefits and costs. Only when the benefits exceed the cost will a firm participate in network formation.

Search for Partners

Finding out potential networks and partners is not easy and thus, requires deep knowledge about firms' specific strengths and weakness and how they could complement each other. Lundvall & Borras (1997) indicated that governments can support firms' own search for networking partners with information, brokerage and matching services. These kind of services can include seminars, fairs, and some information-technology based show. Some scholars suggest that the search for partners should take place very close to firms at local and sectoral levels.

Building Trust and A Shared Knowledge Base

Once the suitable partners have been found, there might still be many “mental barriers” to effective cooperation. In fact, the mental rigidities and traditional behaviors are often the biggest hurdle to effective networking. Potential partners need to learn more about each other’s world view, beliefs and attitudes, values and business models. This can only be done through an intensive and open discussion by which the participants gradually build trust and a shared knowledge base. In this regard, government, as a neutral and trusted third party, can often help reduce the suspicions and reservations that firms have toward closer cooperation. Building shared understandings and trust takes time. Therefore, governments should favor policies which provide firms adequate incentives to continue participating in the networking process long enough to build the necessary shared knowledge base.

Organizing the Network

Once firms understand and trust each other enough, they can start to build a shared vision and behavioral rules for the network. A shared vision of the future and a common strategy are important coordinating mechanism where the market and hierarchical coordination mechanism can not be relied on . However , the coordination mechanisms do not emerge automatically. Instead, some people have to provide leadership in their development. This role is often played by a strong “flagship firm” which has a strong interest in the success of the network (Rugman & D’cruz, 1996; Hämmäläinen & Schienstock, 2000). Therefore, governments can focus on finding such flagship firms in the search stage of network formation. Even in the absence of a flagship firm, governments can help develop contract models and arranging consulting service for forming the network.

2.5 Science and Technology Policy Measures

To conduct scientific and technological innovations always need requisite resources and incur great risks. Therefore, most of countries enact some policy measures/tools to encourage the investments and efforts for research and development (R&D). The policy measures could be authoritative (regulation, permission, and inhibition), incentive-oriented (budget, award, and penalty), capacity-oriented(information, education, and training), and symbolic(value, idea, and direction). Thus, seven types of science and technology(S&T) policy tools are available and are simply described below:

S&T Organization

Governments can help setup the ST-related organizations to either conduct research & development or to facilitate the innovation and technology transfer process. Also, the organizations can be established either domestically or abroad.

S&T Education

Governments can assist in institutionalizing the systems for cultivating and recruiting high level researchers and technical professionals. In addition, they can help modify the current education system to facilitate the technological innovation and entrepreneurship process.

S&T Information

The scientific and technical information is very important to researchers for absorbing and internalizing external knowledge. Therefore, policy-makers can help organize the technical information centers, library, websites, networks and data.

S&T Resources

The resources for scientific and technological development may include funds, equipment, people, and information. The former two item are emphasized here. Governments can provide financial loan, incentives and subsidies.

S&T Law

The assistant legal tools from governments may include patent law, intellectual property rights (IPR), taxes, duties, customs, exchange rate and accounting system.

S&T Procurement

Government can help through the procurement of technologies, hardware, software, components, products, and systems particularly for emerging technologies and industries.

S&T Infrastructure

In additional to the six policy measures above, governments can also help build the better infrastructure such as convenient traffic, regional science park, and telecommunication network.

2.6 University/Academia-Industry Linkage⁷

⁷ While there are many types of networks, the research will choose the university/academia-industry network for the study.

University/academia-industry research cooperation is still a new issue in Taiwan, but its related practices have been faced in developed countries for a long time.

Several main reasons, which are claimed to motivate the industry to increase university-industry cooperation, have been provided by Atlan (1990) and Peters and Fusfeld (1982). They are: (1) access to manpower, including well-trained graduates and knowledgeable faculty; (2) access to basic and applied research results from which new products and processes will evolve; (3) solutions to specific problems or professional expertise, not usually found in an individual firm; (4) access to university facilities, not available in the company; (5) assistance in continuing education and training; (6) obtaining prestige or enhancing the company's image; and (7) being good local citizens or fostering good community relations.

On the other hand, the reasons for universities to seek cooperation with industry appear to be relatively simple. Peters and Fusfeld (1982) have identified several reasons for this interaction: (1) Industry provides a new source of money for university; (2) Industrial money involves less "red tape" than government money; (3) Industrially sponsored research provides student with exposure to real world research problems; (4) Industrially sponsored research provides university researchers a chance to work on an intellectually challenging research programs; (5) Some government funds are available for applied research, based upon a joint effort between university and industry.

As far as the types of university-industry (U-I) interactions are concerned, there has not been a universally accepted classification. Nevertheless, we still can simply categorize university-industry interactions into (1) general support; (2) contract research; (3) research centers and institutes; (4) research consortia; (5) industrial associate/affiliate programs; (6) new business incubators and research parks.

3. Research Framework and Methods

3.1 Research Framework

According to the research background and literature review, a research framework for the study can be developed and is shown on Figure 1.

* The events within the networking process here are adopted from Hämäläinen & Schienstock (2000). However, the author thinks the additional finishing stage and maintenance stage (if the network is a long-term organization) also need to be considered.

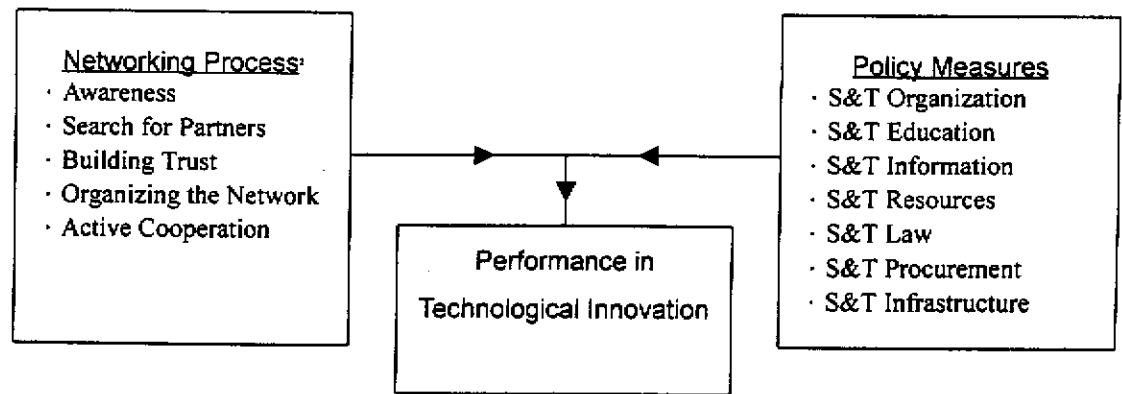


Figure 1. Research Framework for the Study

3.2 Research Methods

Although the study is a joint effort in participating the research of OECD FG Network and thus the conceptual framework has to be consistent with the FG's direction, the investigators are allowed to use their home-based background for the study. In addition, the area of public-private partnership, particularly university/academia-industry linkage is emphasized as the most of the developed countries are oriented toward knowledge economy. Furthermore, the study is exploratory per se. Therefore, the research eventually choose some representative university/academia-industry networks in Chinese Taipei for the study.

4. Research Results

4.1 University/Academia-Industry Linkage in Taiwan

University-industry interaction in Chinese Taipei began to be approved by the Ministry of Education in the early 1980s. Before that time, universities were not allowed to actively cooperate with industrial firms. The degree of interactions can be further understood by a recent survey which is a part of the "Chinese Taipei's National Innovation System" study. As mentioned earlier, the company can develop its technological capabilities either based on internal R&D or external sources of technologies. For the latter ones, they may include sources from universities, research institutes, foreign companies, suppliers and customers. Table 3 lists the survey results about the sources of technological innovation of Taiwanese corporations based on a Likert's 1-7 scale. We can see universities are not major sources of innovation in Taiwan. In addition, 68% of the respondents indicate the foreign companies are either very high or extremely high important to them as the sources of innovation. However, only 2.4% of respondents mention to university at the same level of importance. In the early stage, Nevertheless, there remained two formal organizations: Taiwan University's Tjing-Ling Industrial Research Institute (TLIRI) and Tze-Chiang Foundation of Science and Technology (TCFST), which have been involved in

university-industry cooperation since early 1970s. The latter one, TCFST, will be described in the following section. On the other side, the National Science Council (NSC) of Taiwan thought the lack of good U-I interactions could be one of the reasons why Taiwan is always not able to catch up in the emerging technology areas. Therefore, it initiated a "University-Industry Research Cooperation" Program in 1991, and started to implement in February of 1992. Until March of 1999, there have been more than 140 companies and 14 universities involved 95 U-I Cooperative Research Projects. For the Program as a whole, the NSC has supported the Program with 60 million US\$. Until January of 1998, there were 91 patents and 27 technologies from the Program being transferred or licensed. A deep case study from the Program will be elaborated below. In addition, the university incubator program is also a hot topic in Taiwan recently. It is the Department of Small & Medium-sized Enterprises (DSME) of the Ministry of Economic Affairs that has been supporting and been helping set up more than 50 incubators in the past 5 years. Most of them are located in university campus for a few centers. Furthermore, some academic institutes such as Silica Academia are urged, or at least encouraged, to actively interact with industry. In fact, there have already existed some successful cases.

The following sections will describe the four aforementioned programs.

Table 3 Degree of importance of the Sources of Technological Innovation

	Internal R&D	Foreign Companies	Customers	Other Industries	Suppliers	Research Institutes	Universities
Rank (Average)	5.7	4.8	4.1	3.6	3.6	3.4	2.7

*7:extremely -high important 1:extremely-low important

Source: Wu & Wu (2000)

4.2 Tze-Chiang Foundation of Science and Technology (TCFST)

Tze-Chiang Roundation of Science and Technology (TCFST), a non-profit organization, was founded in 1973 by alumni of National Tsing-Hua University (NTHU). The primary goal of TCFST is to build up connections among academic, research, industrial and governmental institutions in order to promote economic growth, upgrade the industry, popularize human and social science as well as speed up modernization of industrial and business management. TCFST is thus devoted to cooperative research and professional training programs by utilizing academic expertise and facilities as well as obtaining the support of the government.

TCFST was set up as a semiconductor-based laboratory. With the success in semiconductor technology, TCFST was expanded into a science and technology