Evolutionary paths of R&D Internationalization: The Case of Taiwanese Transnational Corporations

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Abstract

Based on data from 75 of the top 1000 Taiwanese manufacturers, we examine how these firms establish their overseas R&D centers and connect with global innovation networks over time by conducting both data searching and in-depth interviews. We categorize four paths of internationalizing R&D for Taiwanese firms and explore three types of technology strategies through in-depth interviews with top management. The three technology strategies are 'technology driven strategy', 'cost driven strategy', and 'keeping flexible strategy'. By comparing three financial indexes, we find that firms adopting a keeping flexible strategy gained the highest average performance, and those firms focusing on cost performed the worst. The results provide valuable insights to the top management of firms in developing countries.

Keywords: Developing country, Path, R&D internationalization, Technology strategy

1. Introduction

Innovative capabilities and activities are essential for economic growth and development. With the prosperity of globalization, R&D internationalization has been a great contributor to enterprises' innovation system. In the 1970s, fewer researchers devoted themselves to the field of international R&D investment. Traditionally, R&D activities in TNCs were centralized and concentrated in their home country, mainly because of higher appropriability of R&D efforts [34]. It was not until the early 1990s that the TNCs established an increasing number of R&D laboratories in offshore locations, and researchers also placed greater emphasis on R&D internationalization. A number of studies have examined the issues of foreign direct R&D investment - for example, the determinants of location [6, 14, 20, 22, 23], technology transfer [15], R&D collaboration [8], the phenomena of R&D clusters (e.g., Silicon Valley and Route 128), the management of multinational R&D [10], and the impact of entry mode and experience-based organizational learning on R&D activities [4].

The traditional and main purpose of foreign technological activities is to support foreign production and to service the foreign market [29]. Companies mainly exploit their technological advantage created within their home country. Recently, internationalizing R&D is often advocated as a strategy for fostering the development of technological capabilities [31]. Niosi [26] also argues that the role of the internationalization of industrial R&D is changing from technology transfer to the learning organization [4]. Foreign-based R&D labs have become more involved in technology exploration and advanced development, as opposed to exploitation and adaptation of centrally-advanced, home country-based technologies [19, 21, 30]. Many researchers view international R&D as the key to innovativeness and competitiveness in the global knowledge-based and highly-specialized economy [13].

The following two observations underlie the motivations for this study. First, data and research on R&D in developing countries are relatively scattered and few, although international R&D from developing home countries are increasingly valued. Previous studies have indicated that the overseas R&D expenditure of TNCs is highly concentrated in a handful of technologically-advanced regions/ countries such as North America, Europe, and Japan [9, 22, 38]. This concentration is nicknamed the triad. Numerous investigations on R&D internationalization (e.g., [18, 28, 29, 33]) mainly contributed to the knowledge of developed countries. However, the increased activities in international R&D is not limited to just triad firms. Some evidence has indicated that R&D internationalization increasingly involves developing countries, most notably India and China [9, 38, 41]. Growing numbers of academics and organizations are noticing the rapid increase in overseas R&D activities in the contexts of developing countries. For example, the *World Investment Report 2005* from the United Nations Conference on Trade and Development (UNCTAD) [35] reveals "another new trend whereby developing countries are connecting to global knowledge networks is the emergence and fast growth of foreign R&D activities by TNCs from developing economies." A report from the Goldman Sachs Global Research Centres (GS) also predicts that the BRICs (Brazil, Russia, India, and China) economies could become a much larger force in the world economy over the next 50 years [40].

The second observation is that the topic of the evolutionary trajectories of R&D internationalization from a developing country over time is still less stressed in the literature. A substantial amount of research on international R&D, either in the contexts of developing or developed countries, has been analyzed from a static perspective. Von Zedtwitz [38],

for example, observes the distributions of international R&D from other developing countries in China and proposes two strategies for R&D internationalization from a developing country. One is "Catch up" which describes firms from a developing country conducting R&D in a developed country. The other is "Expansionary" which characterizes a firm in one developing country investing in R&D in another developing country. Nevertheless, von Zedtwitz [38] ignores how these strategies change over time and how these different paths form and evolve. Although based on a dynamic cross-section model, Cantewll and Piscitello [7] discuss more on the interrelationship between the diversification, internationalization and accumulation of technological competence in the U.S.

These two observations mentioned above bring us to the following research questions. What are the different evolutionary trajectories of firms from a developing country extending their R&D centers to other host countries? How do these paths evolve? What kind of technology strategy do these firms employ in order to upgrade the technological capabilities and connect to global innovation networks? To address these questions, this study examines 75 major firms that are among the top 1000 manufacturers in Taiwan through both data searching and in-depth interviews. The unit of analysis in this study comprises Taiwanese firms that have wholly-owned international R&D centers. The results reveal four patterns of path and three types of technology strategies of firms from a developing country — technology driven strategy which refers to those firms from a developing country arranging R&D only in developed countries, cost driven strategy in which firms merely conduct R&D in other developing countries, and keeping flexible strategy which refers to firms conducting R&D activities in developed countries first and then establishing R&D centers in other developing countries later or setting up R&D centers in other developing countries earlier and then entering developed countries at a later date. We find that the keeping flexible firms acquired the highest average earnings per share (EPS), and those firms that adopted a cost driven strategy performed the worst. Moreover, the most attractive destinations for overseas R&D centers have been shifting from the triad economies into the emerging economies (China, India, and Russia).

The remainder of this paper is organized as follows: Section II describes and summarizes a prior literature review. Section III reports the research methodology and the data sample. Section IV represents the findings of this study. Descriptive statistics of firms are disclosed and three technology strategies are explained. Section V concludes the study.

2. Theoretical Background

Motives for Establishing Foreign R&D Units

Traditional overseas R&D laboratories have played the role of adapting products for regional or national markets and technology transfer rather than that of undertaking fundamental research [13, 28]. This function emphasizes more on market orientation, which is consistent with the definition in Florida's [16] study and also echoes Vernon's [37] product life cycle perspective. Elder [13] and Niosi and Godin [27] find that for German and Canadian TNCs technology transfer and adaptation to the local market are still important goals of a foreign R&D establishment.

On the other hand, some research has suggested that internationalization of R&D will in general increasingly become supply-led (e.g., [16, 18, 21]) or technological knowledge sourcing (e.g., [19, 29]). Expatriate R&D also appeared to be at the root of learning processes through which multinational corporations increased their stock of knowledge in foreign markets [12, 24]. Kuemmerle [21] remarks that the 'capability-exploiting motive for foreign direct investment in R&D' has been the dominant view in international business literature, and characterizes the nature of the expatriate technological activities. Granstrand [18] argues that internationalization of R&D will in general become increasingly supply-led for the reasons of technology diversification and emerging technology market conditions.

Recent literature on the motivations for setting R&D abroad has been revisited, considering the relative competitive advantage and complementary factors. When the host country owns the complementary factors that a company needs, but which the home country does not have, the company will establish R&D units in the host country to acquire the complementary factors as well as a relative competitive advantage. For instance, Lu and Liu [24] find that human-capital-augmentation is the major complementary factor for Taiwan's companies in establishing R&D units in China.

The motives of internationalizing R&D can be classified as technology oriented, market oriented, and investment incentives. Technology oriented motives include accessing the advanced technology and excellent engineers in the host country, as well as connecting to the host knowledge network. Market oriented motives comprise supporting the local market and manufacturing site. Investment incentives mean the host country provides the incentives on taxation, infrastructure, and financing. The main title

(on the first page) should be centered, and in Times New Roman 14-point, boldface type, use title case as in the above example.

Strategy of Overseas R&D Activities

Several R&D strategies have been discussed in the R&D internationalization literature. Tracking back to the missions of R&D activities, Ronstadt [33, p. 8-9] investigates 55 R&D units made abroad by seven U.S.-based multinational enterprises and identifies four distinctive kinds of R&D investment abroad: 1) Transfer Technology Units (TTUs) aimed at technical service to the subsidiary; 2) Indigenous Technology Units (ITUs) where new products were developed abroad to service host markets; 3) Global Technology Units (GTUs) where foreign R&D establishments developed products or simultaneous launch in several foreign countries, and 4) Corporate Technology Units (CTUs) where new/basic technology were generated for use by the parent company. Ronstadt finds data showing that most R&D investments were made for manufacturing (TTUs) in order to help transfer the parent's technology and few were for basic research (CTUs).

Bartlett and Ghoshal [3] propose four different types of management in international innovation projects: central-for-global (developing new products or processes at home for the global markets), local-for-local (developing products and processes independently in each R&D establishment around the world for use in the local market of the subsidiary), locally-linked (developing a novelty in each location for global exploitation), and globally-linked (developing a novelty through the collaboration of R&D units located in different countries for exploitation in the world market).

Gassmann and von Zedtwitz [17] develop an evolutionary model of international R&D organization and describe five types of international R&D organizations: ethnocentric centralized R&D, geocentric centralized R&D, the R&D hub, polycentric decentralized R&D, and the integrated R&D network. Based on the drivers by access to markets and access to science, von Zedtwitz and Gassmann [39] offer four archetypical forms of international R&D organization. National treasure R&D represents domestic research and domestic development. Technology-driven R&D refers to dispersed research and domestic development. Market-driven R&D stands for domestic research and dispersed development. Global R&D symbols dispersed research and dispersed development.

Le Bas and Sierra [23] investigate 345 multinational firms with the greatest patenting activity in Europe and propose four types of R&D internationalization: technology-seeking, home-base-exploiting, home-base-augmenting, and market-seeking FDI in R&D. Conducting an empirical study of Japanese R&D investment in the U.S., Iwasa and Odagiri [19] separate overseas R&D into two types, "research-oriented" and "local-support-oriented." Based on the diversification strategy, Niosi and Godin [27] differentiate among three types of expatriate laboratories: related diversification, vertically-integrated firms, and global R&D. They find that diversification into related activities is the overseas strategy of Canadian multinational corporations with foreign R&D activities.

Von Zedtwitz [38] summarizes four types of the previous research path in international R&D research. Type 1 concerns the "traditional" R&D internationalization among developed countries, i.e. mostly within the triad of North America, Western Europe, and Japan. Type 2 is the "modern" category of research. The modern form of R&D internationalization became popular in the late 1990s, driven in part by improved economic conditions in Southeast Asia, China, and Eastern Europe, in part by strategic considerations of parent companies to set global standards and build global brands, and partly by a growing understanding and financial commitment of TNCs to support local sales with local R&D efforts. Type 3 is "Catch-up" which describes firms from a developing country conducting R&D in a developed country. These firms are naturally attracted to using developed countries as R&D bases, partially in order to acquire local technology and science, to some extent in order to support local product development. The Type 4 strategy of R&D internationalization is "Expansionary," which may be to support second-generation technology transfer, or to support other local business activities.

Based on differences in operational patterns between home and host R&D units, Lu and Liu [24] propose three categories of R&D activities of Taiwanese IT companies in China: home-base-integration, host-base-integration, and product-life-cycle. Home-base-integration means that home R&D units define the production specifications, design the system structures, and integrate system components to the final products. Host-base-integration refers to the situation where home R&D units define the production specifications, design the system structures, but the host R&D units do the system integration. The product-life-cycle is the case where home R&D units are responsible for the development of advanced technologies, and the old generations of a product are transferred to the host R&D units.

Most of these typologies mentioned above are concluded from data of the triad economies, (i.e. research discusses the categories of TNCs from the triad economies which have set up their foreign R&D activities in developing or/and developed countries.) Only a few empirical studies (e.g., [21], [31]) focus on R&D internationalization from developing countries.

Moreover, all research studies on international R&D, either in the context of developing or developed countries, have analyzed this from a static perspective. Thus, the dynamic and evolutionary process of R&D internationalization over time is still ignored in the literature. Von Zedtwitz [38], for example, observes the distributions of international R&D from other developing countries in China, while ignoring how these different paths and strategies form and change over time. Practically, R&D internalization of developing countries should consist of four evolutionary paths described in the following section.Author names and affiliations are to be centered beneath the title and printed in Times New Roman 10-point, non-boldface type

Overseas R&D Activities of Taiwanese Firms

The R&D expenditures by Taiwanese enterprises are highly concentrated in the manufacturing industry, especially in electronics and IT. Most enterprises still set up their R&D centers in their domestic markets. The R&D expenditures as a percentage of sales to Taiwanese enterprises in the manufacturing sector are low by international standards. Thus, compared to developed countries, Taiwanese R&D activities are less globalized [24].

The overseas activities of many Taiwanese firms have shifted from exporting, with direct investment in marketing and distribution, to overseas manufacturing, and then, particularly in the high-tech industries, to the start of overseas R&D activity. Generally, most of Taiwan's major sectors are characterized by their vertical disintegration and the pursuit of original equipment manufacturing (OEM) and original design manufacturing (ODM) contracts for brand marketers, without direct access to the final market. The OEM/ODM relationships have also created pressures that have forced the Taiwanese firms to extend their production capability to improve cost advantage rather than to increase their technology innovation capability. Thus, firms based in Taiwan undertook more 'D' than 'R', and they lack systems integration capabilities [9, 24]. However, Taiwanese firms have benefited from OEM/ODM relationships with leading firms and have acquired production engineering capabilities over time.

In the 1990s, a few large firms started to internationalize their R&D activities. Some companies which have gone on to build up their own-brand products set up their R&D establishments in the developed countries. Giant and Acer are valid examples, which established their foreign R&D affiliates in the Netherlands and the United States, respectively. Accompanying their industrial upgrades, in the late 1990s some companies in the semiconductor and IT industries conducted their overseas R&D labs in the United States. Some companies have established their foreign R&D activities in Japan, Germany, and England. The major missions of these units are to access the local science and to absorb know-how of global value. Since 2000, China has been the most attractive location for most Taiwanese firms. The rapid internationalization in recent years has helped Taiwan obtain a strong position in the list of top 100 developing-economy TNCs. Fifteen companies have entered the list, and all are privately owned and mostly focused in computers and electronics [36].

Evolutionary Path of Overseas R&D

Extending from the previous studies and considering the trajectory of R&D internationalization from a developing country, we propose four patterns of overseas R&D path in the host countries. Table 1 demonstrates these four evolutionary paths of R&D internationalization from a developing home country.

The first pattern refers to those firms from a developing country arranging overseas R&D only in the developed countries, which is consistent with the technology-seeking strategy defined by Le Bas and Sierra [23]. Foreign R&D is used as a vehicle to move closer to the industries of host country with technological advantages. In comparison with their developed-country counterparts, firms from developing economies have generally been technological followers. To improve their competitiveness, especially in terms of seeking to compete in global markets, firms based in emerging economies may be forced to enter developed countries by acquiring new resources and capabilities [5, 38] or by exploration to build up potential absorptive capacity, but not on immediate performance [41]. Firms from the developing home countries have conducted innovative (asset-seeking) R&D abroad in the developed countries in order to tap other centers of innovation and overcome the constraints of their domestic economy [11]. However, the primary stimulus of this R&D internationalization is to "catch-up" [38, p. 3] with developed countries, such as R&D sites of Taiwanese semiconductor companies in the US. Typically, enterprises under this pattern tend to be more technological innovation orientated.

Pattern 2 represents firms from a developing country that conducts overseas R&D only in other developing countries. The overseas R&D centers under this pattern exhibit the characteristics of the technology transfer units (TTUs) of Ronstadt's typology. These centers may support second-generation technology transfer (e.g., [9, 33, 38]) or in acquiring human capital [24] – for example, Taiwanese IT companies in China. In this type, companies are active in foreign locations in technical fields where they are relatively strong at home. Moreover, von Zedtwitz [38] argues that firms of developing countries will internationalize R&D into other developing countries

opportunistically, i.e. when following local customer requests. As a consequence, they may reap long-term first mover advantages in less privileged regions of the world.

Under Pattern 3, firms conduct R&D in developed countries first and then establish R&D centers in other developing countries later. Companies in this pattern develop the R&D network's capabilities by conducting cutting-edge technology development and absorbing know-how from developed countries, and then passing on the absorbed technologies refined for use in other developing countries.

Pattern 4 describes firms arranging R&D in other developing countries earlier and then entering developed countries later. Companies under this pattern are mostly in a mature industry which will set up R&D centers in other developing countries to take a cost advantage. However, those firms would like to upgrade their technology level to acquire higher profit margin. Moving R&D activities to developed countries is a feasible way to achieve this goal. This is similar to intersectional upgrading, which applies the competence obtained in a particular function to move into a new sector. In this pattern, technological capabilities in the developed host location become increasingly important over time. Basic research is the most important mission of the units, and thus the cost of the host location is not a major concern in the location decision.

Only a few studies (e.g., [38]) discussed pattern 1 and pattern 2, while pattern 3 and pattern 4 are neglected in the prior literature on R&D internationalization. Based on the proposed patterns, we investigate the distributions of patterns that Taiwanese firms demonstrate, and the detailed evolutionary path and the technology strategy of their R&D internationalization.

Table 1: EVOLUTIONARY PATHS OF R&D INTERNATIONALIZATION

Pattern	Evolutionary paths	
	Home country	Host country
1.	Developing	→Developed countries
2.	Developing	→Other developing countries
3.	Developing	→Developed countries→Other developing countries
4.	Developing	→Other developing countries→Developed countries

3. Research Methodology

Data Sample

To observe the evolutionary process of R&D internationalization from a developing country over time, the sample in this study consists of Taiwanese firms that possess wholly-owned R&D centers in the host countries. The R&D center is viewed as an affiliate with autonomy that contributes to providing design, research, development, experiment or R&D services which relate to the improvement of industrial science and technology, and is operated independently for the long term. Thus, R&D centers can help firms to improve, upgrade, and accumulate their innovative capabilities.

Data for this study were collected through a combination of secondary data searching, telephone interviews and in-depth interviews. Based on the database of a well-known Taiwanese business magazine, Business Weekly, this study first conducted secondary data searching and telephone interviews. Locations of R&D centers were compiled by means of company publications, company websites, and third-party databases. Unclear information was resolved in follow-up telephone interviews with company spokesmen or R&D managers. We find that 564 companies out of the top 1000 manufacturers in 2005 were involved in overseas business activities. Among them, 80 have set up their foreign R&D centers in other developing and/or developed countries. Two companies closed in 2006. Three firms present a random path on R&D internationalization. Thus, 75 firms were chosen for further examination.

In-depth interviews were conducted to further comprehend the details of locations of R&D centers, and the motives of overseas R&D activities and technology strategies. We developed a semi-structured interview guideline focusing on the issues mentioned above. 21 of these 75 companies accepted follow-up interviews with their top management and senior R&D managers. Each interview took 1.5 hours to 2 hours. Interview questions included: How many international R&D centers does your company have? When and where were these R&D centers built up? What were the determinants for their location and establishment? What is the technology strategy of R&D internationalization for your company? Table 2 shows the demographical characteristics of the sampled firms. In this paper company names are not disclosed as this was promised in advance, because the interview questions involved sensitive issues (e.g., a company's strategy and government policy in Taiwan).

Table 2: Demographics of samples firms in 2005

Item	Scope (US$ million)
Capital	12.13 to 5962.5
Assets	29.88 to 10712.5
Sales	294.91 to 21046.9
Initial Public Offerings	Yes: 59; No: 16

US$: NT$ = 1: 32

4. Results

Based on data collected from secondary data searching and telephone interviews, the following sections first present the distributions of four patterns to further understand the details of the number and proportion of each pattern, the evolutionary process over time and the principal product group of the firms. Finally, according to the results of in-depth interviews, we categorize the technology strategy of R&D internationalization and then compare the management performance.

Table 3: Patterns of R&D internationalization of 75 firms

Patterns	Number of firms	Percentage (%)
Pattern 1 (Taiwan→Developed countries)	20	26.7
Pattern 2 (Taiwan→Other developing countries)	32	42.7
Pattern 3 (Taiwan→Developed countries→Developing countries)	21	28.0
Pattern 4 (Taiwan→Developing countries→Developed countries)	2	2.7
Total	75	100

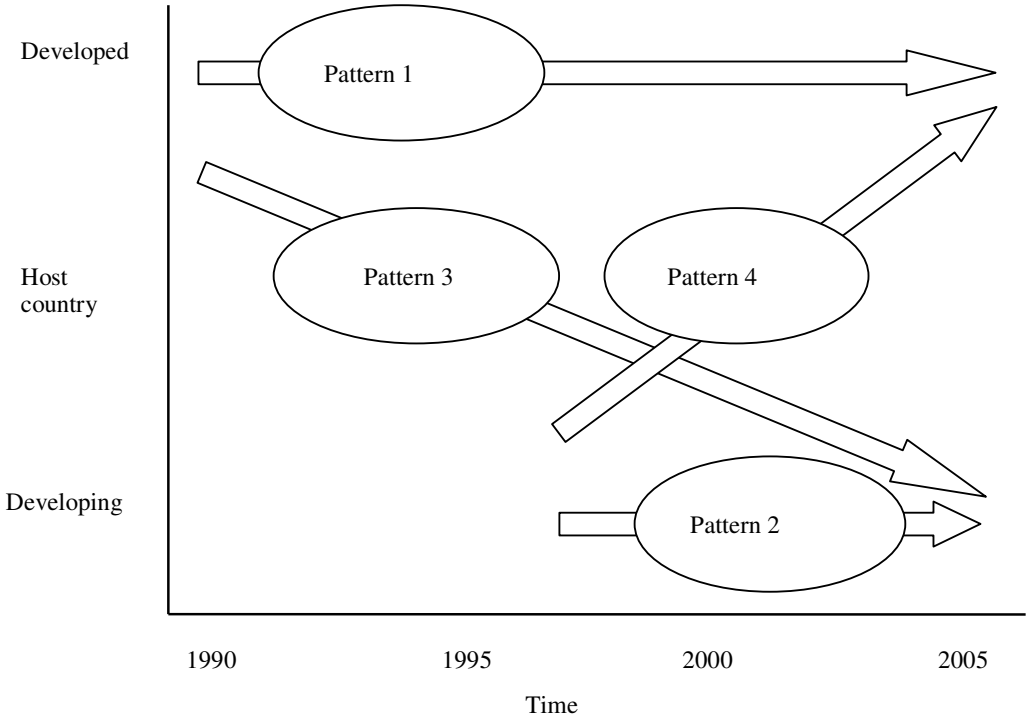

Fig. 1. Paths of R&D Internationalization from 1990-2005

Distributions of Four Patterns

Table 3 and Figure 1 present the details of four paths of R&D internationalization over the period 1990-2005. We find that since the early 1990s, 20 (26.7%) out of 75 firms under path pattern 1 have located their foreign R&D centers only in developed countries. Thirty-two (42.7%) firms belong to path pattern 2, which have started to set up R&D units in other developing countries since the late 1990s. Twenty-one (28%) firms, classified under path pattern 3, established their international R&D centers in developed countries in the early 1990s and then shifted their next R&D centers in the developing countries. Only 2 (2.7%) cases adopted path pattern 4,

which built up overseas R&D centers in other developing countries in the late 1990s and recently established R&D sites in developed countries. The results support the facts that internationalization of R&D has spread to developing countries, and firms from the developing countries are themselves investing in R&D either in other developing countries or developed countries.

Table 4 lists the sampled 75 firms according to the pattern and principal product group. In terms of the industrial distributions, we find that over half (54.7%) of the firms are from the IT industry, followed by 14.7% from the semiconductor industry, 9.3% from the electric equipment industry, and 6.7% from the photoelectric industry. The findings imply that R&D activities in the IT industry are more internationalized than those in the other industries. In the IT industry, 24 out of 41 firms are under pattern 2, followed by 12 firms under pattern 3. In the semiconductor industry, 6 out of 11 firms take path pattern 1, and 4 firms are under pattern 3. Table 5 reveals the details of four paths of international R&D centers in the host countries.

Under pattern 1 we find that 15 out of 20 firms have set up their R&D centers in the United States. Two companies first established their R&D centers in the United States and later in Germany. Two firms and one firm built up their international R&D centers in Japan and Denmark, respectively. Under this pattern, we find that the most attractive location of R&D centers in developed countries is the U.S. followed by Germany and Japan. The U.S. attracted 17 out of 20 firms to set up their foreign R&D centers, especially those in the IT, semiconductor, and pharmaceutical industries. The results reveal the close technological relationships between Taiwan and the United States.

Table 4: Distribution of patterns and principal product group

Product group	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Total (percentage)
IT	4	24	12	1	41 (54.7)
Semiconductor	6	1	4	-	11 (14.7)
Electric equipment	2	2	3	-	7 (9.3)
Photoelectric	2	1	1	1	5 (6.7)
Pharmaceuticals	3	-	-	-	3 (4.0)
Automotive and Transportation	-	2	1	-	3 (4.0)
Chemicals	1	1	-	-	2 (2.7)
Rubber	1	-	-	-	1 (1.3)
Furniture	-	1	-	-	1 (1.3)
Food	1	-	-	-	1 (1.3)
Total	20	32	21	2	75 (100)

Under pattern 2, Table 5 shows that 27 out of the 32 companies set up their R&D centers directly in China, and most are categorized in the IT industry. Four companies in the IT and automotive industries established their overseas R&D centers first in China and then subsequently in Southeast Asia (i.e. Malaysia, Vietnam, and Thailand). Only 1 automotive company situated its R&D center in Vietnam. Since the mid-1990s, electrical and electronic equipment manufacturers in Taiwan have improved their competitiveness by investing in China in association with production, followed by investment in R&D. We observe that, overall, 31 firms have set up their international R&D centers in China. Among them, we find 17 companies with single-site R&D center and 14 with multi-site R&D centers in China. These R&D centers – mostly established in Beijing, Shanghai, and Tianjin, as well as Guangdong and Jiangsu provinces – permit firms closer access to their large Chinese customer base.

Table 5 also demonstrates the distributions of pattern 3 of foreign R&D centers. Twelve companies conducting R&D in the triad economies (Europe, North America, and Japan) in the beginning have built up their next R&D centers in China. Three firms situated their R&D centers in the U.S., followed by China and India. Two firms set up their R&D in the U.S., China, and then later in Malaysia. One set up an R&D center in the U.S. and then invested in Singapore. Two of the three companies establishing R&D centers in the triad economies first set up their follow-up R&D centers in Russia and another one in India. Overall, 20 firms have set up their international R&D in Russia, India, and China and the result reveals that BRICs (except Brazil) are the most attractive emerging countries for Taiwanese firms to internationalize their R&D centers. In-depth interviews disclose that Brazil is too far away for Taiwanese firms and lacks incentives to set up an R&D center there.

Table 5 shows only two cases of pattern 4. These two firms are in a mature product line of the electronics industry and upgrade their technology capabilities to enter another new industry through mergers and acquisitions (M&A). One of the firms is originally a mobile display company which set up its foreign

R&D center in China and acquired another photoelectric firm and its overseas R&D centers in Japan and Netherlands. The other one, which is primary a cell phone keyboard manufacturer, conducted its overseas R&D in Malaysia and China first and then obtained an R&D center related to the telecommunications industry in Japan.

After summarizing and integrating the data collected in semi-structured in-depth interviews, we categorize three kinds of technology strategy for R&D internationalization of Taiwanese firms: the technology driven strategy, the cost driven strategy, and the keeping flexible strategy. Technology driven strategy describes when firms set up overseas R&D centers to access the leading technology, and thus firms started up their R&D only in developed countries. The cost driven strategy emphasizes lowering R&D cost. For this reason, companies arrange their foreign R&D units only in other developing countries. The third one is a keeping flexible strategy, in which firms consider the optimization of the R&D cost and technological abilities. Some companies that have the technology gap with the advanced countries first move their R&D centers into host developed countries to upgrade their technology level and then switch to other developing countries to decrease their R&D expenditure. The other companies in the industries which allow low-level technology establish their first R&D centers in other developing countries to support local markets, and then set up their next R&D centers in developed countries to access scientific knowledge as soon as they have found the technical know-how is insufficient to meet the customers' needs.

The following section describes the details of in-depth interviews with top management and senior R&D managers, focusing on the reasons, determinants, paths and technology strategy of R&D internationalization.

Table 5: Paths of R&D centers in the host countries

Patterns	Number of firms
Pattern 1	
United States	15
United States→Germany	2
Japan	2
Denmark	1
Pattern 2	
China (including Hong Kong)	27
China→Malaysia	2
China→Vietnam	1
China→Thailand	1
Vietnam	1
Pattern 3	
United States→China	7
United States→China→India	3
United States→China→Malaysia	2
United States→Singapore	1
Canada→China	1
Japan→China	3
Netherlands→United States→China	1
Germany→Russia	1
Germany→Japan→United States→Russia	1
England→India	1
Pattern 4	
China→Japan/Netherlands	1
Malaysia→China→Japan	1
Total	75

Technology Driven Strategy

From in-depth interviews, we find that firms under pattern 1 insist on pursuing the leading scientific and technological knowledge or recruiting high-quality researchers. These firms establish R&D centers in the developed countries, because of the shortage of domestic technologies and the leading position of the advanced host countries in some technological fields.

To improve their competitiveness, especially in terms of seeking to survive and grow in global markets, firms enter developed countries for access to local centers-of-scientific-excellence and because of the relative scarcity of scientific personnel at home. A senior R&D manager from an IC design company mentioned, "America is the technology leader in the IC design industry, especially in the field of analogy design. At the same time, there are numerous Chinese students studying there and thus it is no difficulty for Taiwanese companies to recruit high-quality manpower. Therefore, we choose Silicon Valley to set up our overseas R&D centers." Another top manager in an optical equipment company stated, "The technologies of Japanese companies in the photoelectric industry are in the lead as well as we keep close business relationships with Japanese companies, so we built up our first R&D center in Japan to improve our design abilities in optical lens." A top manager from the pharmaceutical industry which has overseas R&D centers in America and Germany said, "America and Germany are in the leading positions in pharmaceutical technology, and our company built up R&D centers in these two countries to pick the best technology respectively."

Companies mentioned above are active in foreign locations in the technical field where they are relatively weak at home. The host-country scientific infrastructure is the main determinant and thus overseas R&D units are established in advanced countries for leading technologies rather than in other developing countries for low R&D cost. We categorize it as the technology driven strategy.

Cost Driven Strategy

In general, firms from a developing country that set up R&D units in other developing countries seem to emphasize more on transferring the technology to support local manufacturing or adapting products for regional or national markets. However, Lu and Liu [24] argue that local effective human capital provided by China is the major complementary factor for their R&D extensions for two reasons. The first is immediate local support. The second is that China offers Taiwan well-educated local engineers, which are cost effective and share geographical and linguistic proximities.

This study shows those Taiwanese firms establishing their international R&D centers in China and Southeast Asia (Malaysia, Thailand, and Vietnam) focus on low R&D cost rather than on technology learning. Interviewees in pattern 2 dictate that the technological level at the home country is more advanced than that of the host countries. These firms utilize cost reduction to secure the OEM/ODM business.

An R&D manager in a motherboard company remarked, "Taiwanese motherboard firms are in the leading positions of the world. The main reason to build up R&D units in China is to access the abundant well trained cheap manpower. In the motherboard industry, companies have to meet different customers' requests immediately. The R&D units in Taiwan concentrate mainly on the fundamental product design, and different product varieties are conducted in China." Another interviewee from a leading electron dictionary supplier noted, "The development of electronic dictionaries requires a significant amount of engineering resources. New versions need to be updated constantly and the price competition is very intense. We have to rely on the abundance of cheap human resources in China to strengthen our company's competitiveness." A senior manager in a consumer electronics firm mentioned, "In the consumer product industry, providing plentiful choice is one of the key success factors. We need many R&D engineers to develop derivative products. China and Southeast Asia satisfy our requirements, so we locate our overseas R&D centers there to support the manufacturing."

During the interviews, we queried why firms do not set up their foreign R&D centers in developed countries to seek advanced technologies and know-how. The interviewees in this pattern responded, "The technological level we have is enough to satisfy market needs. It is not necessary to seek technology from the developed countries. The first priority for the companies is to enhance cost advantage. Therefore, the optimal destinations for R&D centers abroad are in other developing countries rather than developed countries." However, one senior manager said, "We will learn advanced technical know-how from developed countries if our technological abilities are insufficient. But now is not the best time and not cost effective." Summarizing the results of the in-depth interviews, we categorize this international R&D strategy as the cost driven strategy.

Keeping Flexible Strategy

Several companies started their overseas R&D into the triad economies to enhance the technological capability. When their capabilities upgrade to certain level, they extend the overseas R&D activities to developing countries to optimize overall performance. The responsibility of R&D centers in the developed countries is to access advanced technology. On the other hand, the R&D centers located in the developing countries try to fully utilize the knowledge learned from the developed countries. For example, one company in the transportation industry set up its R&D center in the Netherlands in 1986 followed by one in the U.S. The purpose of the R&D units is to learn the pioneering technology from

these countries and then to pass the learned knowledge and technical know-how to its parent company. Recently this company created a new R&D center in China to support local production.

We also find that several companies in the IT industry seem to be the first movers to internationalize their R&D into the triad economies and try to improve their own brand. In the host-developed countries, these firms moved up the value chain to create their brands, thus gradually becoming a global brand. Recently, these firms have committed to R&D inputs in other developing countries.

Companies will eliminate R&D centers from developed countries as soon as it cannot create economic benefits. We find that two companies closed their R&D centers in the U.S. Top management of these companies provided two explanations for this phenomenon. The first is the high operating costs of the R&D centers in the U.S. while the performance cannot be realized for a long time. The second is the rapid emergence of BRICs which have improved their technological capabilities gradually and provided well-educated human capital.

Some companies are in the industries which require only a low level of technology capabilities but face high competition, and so these companies arrange their first foreign R&D activities in other developing countries to lower the cost and to support local manufacturing. Following that, as these companies have enough capital to upgrade their technology level to enter another new industry, they will set their next R&D centers in developed countries. Other companies transform into another high value-added industry through mergers and acquisitions (M&A). A senior manager indicated that the exploitation of synergy effects is the principal motivation for M&A activity. The M&A route is more attractive where speed in accessing the technology or innovative strengths in a host developed economy are primary benefits. For example, one company in the mobile display industry completed a merger in 2005. Two partners were involved: one partner from the Netherlands has been in the display business for more than 45 years and the other partner, from Taiwan, successfully pioneered LTPS (Low Temperature Poly Silicon) technology in the flat panel industry. Through the combined strengths and synergies, the company has evolved into an industry leader in the global mobile display industry. This finding also reveals that Taiwanese firms are able to enter a new technological field through M&A.

No matter when looking at path pattern 3 which refers to firms' overseas R&D sites first in developed countries and later in other developing countries or path pattern 4 which describes firms' international R&D centers in the other developing countries first and then in developed countries, these two patterns emphasize the importance of maximizing management performance. These companies adjust strategy to cope with the changing external environment, not persisting in seeking excellent technology or lowering cost. Thus, we label it as the keeping flexible strategy.

The Comparison of Management Performance

Finally, this study explores the differences of management performance among these three technology strategies of R&D internationalization. The evaluation index is average earnings per share (EPS) of the firms. We analyze the respective average EPS of the firms under the technology driven strategy, cost driven strategy, and keeping flexible strategy and find the same trend in 2005, 2006, and over 2001 to 2006. Table 6 demonstrates the capital and EPS of the three international R&D strategies. Firms that choose the technology driven strategy possess the lowest average capital (US$219 million) and acquire a medium average EPS (from NT$1.93 to NT$2.44). Firms that adopt the cost driven strategy own the highest average capital (US$532 million) but the lowest average EPS (range from NT$1.35 to NT$1.63). Firms that utilize the keeping flexible strategy have a medium average capital (US$358 million) and obtain the highest average EPS (from NT$3.24 to NT$3.66). The results disclose that companies adopting keeping flexible strategy achieved a far higher EPS than the other two strategies for 2005, 2006 and over 2001 to 2006. The cost driven companies perform the worst. The outcomes reveal the fact that in a highly competitive environment, an unchangeable strategy is not the best choice and a company's strategy should be adjusted to the constantly changing environment to create the highest economical effects.

Table 6: Performance of different strategies

Strategy	Capital (US$ million)		Average EPS (NT$)		
	Range	Average	2005	2006	2001-2006
Technology Driven	12.13 to 1093.75	219.22	1.94	2.44	1.93
Cost Driven	30.19 to 5940.16	532.13	1.35	1.63	1.35
Keeping Flexible	17.41 to 1562.25	357.88	3.66	3.24	3.48

5. Conclusions

The purpose of this study is to shed new empirical light on the internationalization of R&D activities by analyzing the overseas R&D investments of Taiwanese firms. The most important potential home-country gain from outward R&D investments is the improved competitiveness and performance of the firms and industries involved. Although the overseas R&D activity of Taiwanese firms may still be in a rather premature stage compared with that of the triad economies, the investigation reveals the fact that foreign R&D activities have been increasing in recent years. Observing 75 manufacturing firms, we categorize four patterns of evolutionary paths of R&D internationalization. We find that 32 firms have only entered other developing countries, especially China, and only two firms arrange their R&D centers first in other developed countries and then in developed countries. The results also show that in the early 1990s, the triad economies were the most important R&D sites for Taiwanese firms. In the late 1990s, the emerging economies (e.g. China, India, and Russia) gradually became the major destinations with Taiwanese overseas R&D affiliates.

To most Taiwanese firms conducting R&D in developed countries, we discover the fact that the most important host country is the U.S., followed by Japan and Germany. The technological capabilities in the triad economies lead those in Taiwan. Thus, Taiwanese firms with innovation orientation tend to choose the triad economies as their first destination. This finding echoes the observations on clustering which indicate that significant economies of agglomeration exist in the geographical location of national scientific capacity [1, 2, 32].

In the other host developing countries, three of the BRICs (except Brazil) are the most attractive emerging countries for Taiwanese firms to internalize their R&D centers. The rapid emergence of BRICs is because these emerging countries have improved their technological capabilities gradually and provided well-educated human capital. Among them, China is the major destination for most Taiwanese firms in the IT industry. Overseas R&D centers in China are concentrated in large cities with skilled human capital, particularly in Beijing and Shanghai. Some managers indicate that strategic foreign R&D in China does exist and is not only involved in short-term production development, but also in long-term fundamental research. The mission of these R&D laboratories in China is to become an international R&D center, rather than a support laboratory serving the local market. Thus, these R&D centers value not only the Chinese market, but also available talents and technological capacities.

Evidence suggests that companies from a developing country, which would like to improve their own brand products, can internationalize their R&D in the triad economies first to enhance their innovation capacities and then commit R&D inputs in other developing countries to serve the local market. Through creating the R&D network's capabilities to understand and conduct original technology development by learning know-how from developed countries, these firms promote along the value chain to construct their brands, thus becoming similar to developed-country TNCs. In the past, international M&A may have existed more when large TNCs from the developed country entered a host developing country and obtained a local company, while the data show that two companies acquired their foreign R&D centers in the developed countries via M&A to upgrade their technological level and transform to another new industry. Thus, M&A is a possible entry mode for TNCs from a developing country to speed up access to the technology or innovative strengths in a host economy.

There are two opposing views regarding the impact of TNC's R&D on the host countries. One view considers inward R&D-related FDI to be beneficial to economic growth, but the counter view argues that R&D activities by foreign firms tend to tap into unique local R&D resources with little or no benefit to the host country [32]. However, countries have individual innovation capacity that influences their R&D activities both at home and abroad [25]. To policy makers, it is important to understand the nature of the country-specific factors that have an influence in creating national technological advantages, including the competitive climate, the financial system, and education, training and basic research institutions. They should develop realistic attitudes as to what kind of R&D foreign direct investment they can attract to their nations and regions.

In summary, this study enriches the understanding of R&D internationalization and makes a contribution to the arena of technology strategy of R&D internationalization from a developing country over time. The results reveal four patterns of path and three types of technology strategy of R&D internationalization from a developing country. Four paths refer to those firms from a developing country arranging R&D only in developed countries, conducting R&D merely in other developing countries, conducting R&D activities in developed countries first and then establishing R&D centers in other developing countries, and setting up R&D centers in other developing countries earlier and then entering developed countries. Through in-depth interviews with top management, we explore three types of overseas R&D strategy for firms from developing countries, including technology driven strategy, cost driven strategy, and keeping flexible strategy. We find that the keeping flexible firms acquired the highest average earnings per share

(EPS), and those firms that adopted a cost driven strategy performed the worst. This result implied that fine strategies should be adjusted to match with the environment. An unchangeable strategy is not likely to create the best performance for a company.

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