National System of S&T Innovation: Dynamics of Manpower Building in a Catching-Up Economy

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ABSTRACT. This study uses the National System of Innovation (NSI) as an analytical framework and introduces it as a catching-up economic perspective with a focus on Taiwan's current and future manpower environment, including the three basic elements of NSI in relation to science and technology (S&T). This study explores Taiwanese S&T manpower flow and distribution, as well as how the government facilitates the development of the technology network, narrowing the gap between catching-up economies and advanced economies through the NSI analysis. This study also investigates how the NSI factors affect one another, and how the interaction among government policy, the academic system, and the industrial sector promote Taiwan's S&T manpower development. Research conclusions and suggestions are also provided.

KEYWORDS. National system of innovation (NSI), science and technology manpower; Taiwan

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INTRODUCTION

In the report titled "Science, Technology and Industry Outlook for 1996," the Organization for Economic Cooperation and Development (OECD) announced the definition of a knowledge-based economy for the first time as "the economy established on the basis of production, distribution and employment of technology and information" (OECD, 1996, p. 1). With the rapid growth of technology and the economic environment, technology innovation will become the key factor in enhancing the competitive power and the development of the organization, especially in highly technology-intensive industries.

The OECD (1996) pointed out that in terms of science, technology, and development, the whole world can be divided into countries with "catching-up economies" and "advanced economies." The important aspect that divides advanced economies from catching-up economies is knowledge gap. According to Persaud (2001), knowledge gap mainly results from innovation and communication gaps. Furman, Porter, and Stern (2002) indicated that manpower is one of the most important determinants of input devoted to innovation and to improve knowledge networking and knowledge flow. According to the knowledge-based economy, manpower is a national innovative capacity that cannot be neglected in the development of science and technology (S&T). In other words, the bridging of the knowledge gap by upgrading manpower becomes an important research subject when catching-up economies intend to keep pace with advanced economies.

In recent years the catching-up economies (like Taiwan) have brought much attention to the fields of S&T and its relations. According to the World Economic Forum's 2003 Global Competitiveness Report, Taiwan ranked second in terms of "innovation competitiveness," and third in terms of "technology competitiveness." These dazzling performances garnered Taiwan international recognition with its achievements in S&T development.

This is especially true in academic circles and in the industrial sector where Taiwan has made excellent progress. According to a National Science Council (NSC; 2004a) research and development (R&D) survey in 2003, Taiwan ranked 18th in the world in terms of number of academic papers with 12,313 in the Science Citation Index (SCI). It was also ranked 11th in the world in terms of papers (7,518), as cited in the Engineering Index (EI) (NSC, 2004a). With regard to Taiwan's performance in the industrial field, the NSC (2004a) summarized that a total of 5,298 U.S. patents were granted to applicants from Taiwan, which gave the country a rank of 4th worldwide.

Taiwan has outstanding S&T industries, such as the semiconductor industry and the Thin–Film Transistor Liquid–Crystal Display (TFT-LCD) industry. In the semiconductor industry, the total output value for semiconductor design was only behind the United States, and the output value of its domestic contract semiconductor manufacturing industry was first in the world (NSC, 2004a). In the TFT-LCD industry, Taiwan maintained technological parity with the rest of the world and was rated 2nd in the world in total output value (NSC, 2004a).

In 2001, statistical analysis from the Lausanne Institute of Management (IMD) proved that Taiwan's S&T manpower has a competitive edge compared with other backward countries (see Table 1).

The main purpose of this study is to introduce Taiwan's innovation system's manpower characteristics via the catching-up economy perspective. To do so, we introduce a novel framework based on the concept of a national system of innovation (NSI).

National system of innovation is widely used in technology management articles in analyzing science- and technology-related situations at the national level (e.g., Chang & Shih, 2005; Patrinos & Lavoie, 1995; Solleiro & Castañón, 2005). However, despite the rising importance of manpower as a source of national innovation, the link between manpower and its contribution to national innovation is not completely understood, especially in research focusing on catching-up technology development.

In light of the above, a demand arises for studies aimed at clarifying how Taiwan can effectively project and utilize S&T manpower to pursue advanced S&T development. In this regard, this article aims to shed some light on the question on a twofold basis. First, we explore how Taiwan's S&T manpower flow and distribution and government improve knowledge networking and flow to narrow the knowledge gap between catching-up economies and advanced economies through the NSI analysis. Second, we explore the methods by which national innovational factors interplay to explain how these three factors—government policy, the academic system, and the industrial sector—upgrade the development of Taiwan's S&T manpower.

THE NATIONAL SYSTEM OF INNOVATION

The concept of the NSI is very important for S&T policy research, and the NSI literature emphasizes S&T policy, education, and country-specific institutions (Furman et al., 2002). The NSI is generally recognized as comprising the complex functions and interactions among various sectors and institutions

TABLE 1. Ranking national Competitiveness and high-tech infrastructure by lausanne institute of management (IMD)

	Taiwan	Singapore	Japan	Korea	China	United States
Overall performance ranking						
National competitiveness	18	2	26	28	33	1
Location attractiveness for R&D	18	3	14	29	40	1
Infrastructure for business	18	5	19	34	29	1
Ranks of science-techology infrastructure in 2001						
Total expenditure on R&D						
R&D expenditure	13	26	2	9	10	1
Total expenditure on R&D per capita	20	16	2	21	44	4
R&D as percentage of GDP	10	14	2	7	28	6
Business expenditure on R&D	13	22	2	10	12	1
Business expenditure on R&D per capital	20	14	3	21	40	4
R&D manpower						
Total R&D personnel nationwide	10	31	1	9	3	—
Total R&D personnel nationwide per capital	13	17	4	21	32	—
Total R&D personnel in enterprise	10	23	1	8	3	—
Total R&D personnel in business per capital	9	15	4	19	31	—
Qualified engineers	20	9	16	36	49	29
Availability of IT skills	12	7	39	24	47	8

Science-technology management						
Technological cooperation	9	9	8	33	49	4
Company–university cooperation	12	4	32	19	42	3
Funding for technological development	18	8	14	28	45	3
Development and application of technology	20	3	21	36	30	5
Relocation of R&D facilities	21	21	22	26	28	1
Research and education						
Nobel Prizes (1950–2000)	24	24	10	24	15	1
Nobel prizes per capita (1950–2000)	24	24	19	24	22	5
Basic research	26	8	16	10	21	1
Science and education	3	1	19	26	32	32
Science & technology and youth	3	2	30	33	42	18
Intellectual property						
Patented granted to residents (1998)	6	43	1	3	12	2
Change in patents granted to residents (1998)	34	45	25	4	16	11
Securing patents abroad (1998)	17	-	2	11	29	1
Patent and copyright protection	23	14	18	32	25	1
Number of patents in force (1998)	9	17	8	21	38	14

Source: IMD (2001).
R&D: research and development; GDP: gross domestic product; IT: information technology.

(Kumaresan & Miyazaki, 1999; OECD, 1999; Smith, 1996). The concept of the NSI was introduced by Freeman (1987) and has since been widely disseminated by Edquist (1997), Lundvail (1992), Nelson and Rosenberg (1993), and Patel and Pavitt (1994). Freeman (1987) introduced the term *NSI* in his study of Japan where he defined it as "the network of institutions of private and public sector, whose activities and interactions initiate, import, modify, and diffuse new technologies" From an evolutionary approach, Lundvail (1992, p. 18) argued that NSI, in a broad sense, could be referred to as "constituted elements and relationships that interact in the production, diffusion, and use, of new and economically useful knowledge" (p. 251) It was also termed "a national system that encompasses elements and relationships, either located within or rooted inside the borders of a national state" (Smith, 1996, p. 43). Nelson and Rosenberg (1993) formally adopted an institutional approach and examined the relationship between the national institutions of finance, education, law, S&T, corporate activities, and government policies with respect to their influence on innovation (Chung & Lay, 1997).

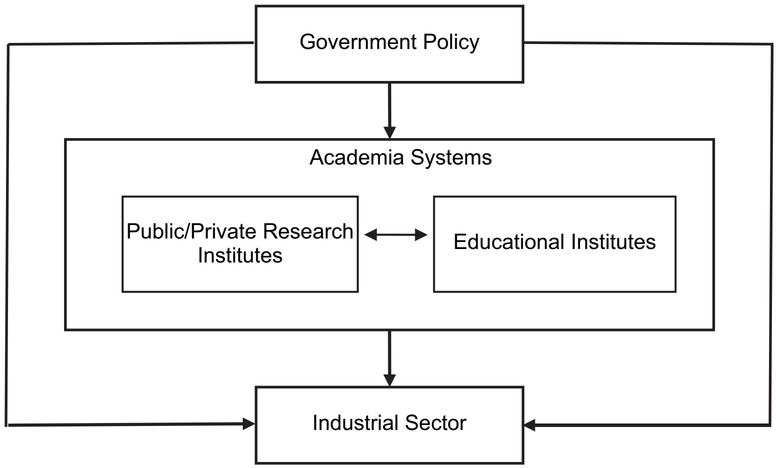
Patel and Pavitt (1994) provided a synthesis of the above-mentioned approaches. They took the concept further and argued that NSI could be defined as "national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning in a country" (p. 12). The role of incentives and strategic capabilities of firms have had a particular impact on innovation and competitiveness.

From the above NSI-related literature discussion, we know that the NSI is a scientific analysis that combines technological ability and a suitable competitive situation framework. The major concern of the NSI concept is how one can formulate an effective national setting of major innovation actors. Furthermore, there is the issue of information flows among them that generate and appropriate innovation effectively. An economy depends not so much on how specific organizations perform, but rather on how well their manpower interacts with one another. Therefore, this research, aimed at expounding the situation of the NSI framework and the interaction among its factors, seeks to present a further explanation regarding S&T manpower in Taiwan. In the next section, we provide a framework to describe the content of our research.

THE ANALYSIS OF THE NATIONAL INNOVATION SYSTEM FOR TAIWAN'S S&T MANPOWER

To provide a context for discussion, consider Figure 1. This is a representation of the NSI for the Taiwan's S&T manpower analytical

FIGURE 1. Research Framework.



framework. The main elements of the innovation system are (1) government policy; (2) academic systems, including the public and private research institutions and the educational institutes, and (3) the industrial sector. These three elements for S&T manpower distribution situations and interactions were introduced in this study.

Government Policy

The difficulties and challenges are even tougher for countries and regions catching up by developing their S&T industries. In a catching-up economy, owing to the shortage of fundamental resources and the insufficient production of industries, governments have to play a critical role in the efforts that focus on the development of its advanced S&T industries in a short time.

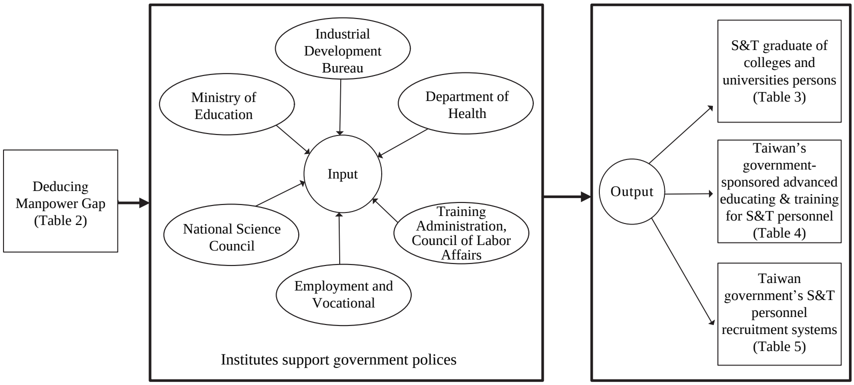
In Taiwan, government policy is implemented with the help of institutes, and to promote S&T manpower, the government comes up with a policy to address manpower gap (see Table 2) and further develop S&T. Therefore, from the input–output perspective, the current research explores how the government sector inputs S&T innovation manpower resources (see Figure 2). Concerning the deducing manpower gap, government rolling survey analysis on the short-term supply and demand of technology manpower in the industry will be conducted yearly by observing the movement trend of talents to systematically grasp the situation of

TABLE 2. Survey and deduction result of technology manpower for the industry

		2005			2006			2007		
		Demand	Supply	Gap	Demand	Supply	Gap	Demand	Supply	Gap
Semiconductor	Conservative	5,200	6200	—	3,800	7700	—	4,800	7,900	—
	Unbiased	9,700	—	3,500	6,400	—	—	9,200	—	1,300
	Optimistic	2,700	—	6,500	10,600	—	2,900	14,100	—	6,200
Color image display	Conservative	4,200	5,000	—	4,100	5,400	—	6,800	5,900	600
	Unbiased	5,800	—	800	6,100	—	700	6,900	—	1,000
	Optimistic	7,400	—	2,400	7,900	—	2,500	10,500	—	4,600
Communication	Conservative	2,700	5,400	—	4,300	6,400	—	2,100	6,900	—
	Unbiased	5,200	—	—	6,300	—	—	3,400	—	—
	Optimistic	1,1200	—	5,800	11,200	—	4,800	7,900	—	1,000
Digital content	Conservative	6,600	3,300	3,300	6,500	3,800	2,700	6,300	4,300	2,000
	Unbiased	7,000	—	3,700	6,800	—	6,800	6,600	—	2,300
	Optimistic	7,300	—	4,000	7,100	—	3,300	7,000	—	2,700

Source: IEK-Industrial Technology Research Institute, Institute for Information Industry.
Survey on the digital content industry was lead by the Industrial Development Bureau of the Ministry of Economic Affairs.

FIGURE 2. Processes of Government Policy Contributions on Science and Technology (S&T) Manpower.



the supply and demand of talents, and further put forth a measure to make up the manpower gap.

First, Figure 3 describes the Taiwanese government's plan and implementation of its policy regarding S&T manpower. Taiwan's government policy planning and execution figure significantly with regard to the training and implementation of S&T manpower in the country. From the NSI perspective, the basic duty of governments is to stipulate definite policies related to the

FIGURE 3. S&T Manpower Promotion of the Division of Manpower in Government.

Research Levels	Promotion of Government
Basic research Applied research	Academia Sinica; Science & Technology; Advisory Group; National Science Council
Experimental development Commercialization	Ministry of Education; Department of Health; Environmental Protection Administration; Ministry of Economic Affairs; Council of Agriculture; Ministry of Transportation and Communications; Atomic Energy Council; Council of Labor Affairs; Ministry of National Defense.

Source: NSC (2004a).

development of advanced S&T industries. The Taiwanese government has a more detailed plan regarding various units and their responsibilities.

Taiwan's government has four main policies regarding S&T development: education, training, recruitment, and rewarding of S&T manpower. Taiwan has been able to form a pool of high-quality S&T manpower mainly due to its educational policies, social value systems, public training systems, and the return of overseas experts (Arensman, Brown, & Wilson, 1991; Shyu and Chiu, 2002).

The main objectives of these Taiwan government policies are the improvement of the research environment, technology transfer and diffusion, the establishment of an intellectual property rights system, and the encouragement of private sector research and development.

All of these government policies play essential roles in the development of S&T and increase the operational efficiency of public research institutes in generating knowledge and wealth (Chang, Chen, & Yang, 2006). We respectively expound on these practices and its effects in the following sections.

The Education and Training of S&T Manpower

The Taiwanese government has adopted the following three approaches to the education and training of S&T manpower: education in colleges and universities, advanced studies in Taiwan and overseas for personnel selected by government agencies, and training by vocational and professional training institutions (NSC, 2004b).

The total number of graduates from colleges and universities has continuously increased from 1999 to 2002. During these academic years, 4,408 persons had received an S&T-related (including natural sciences, engineering, medicine, agriculture) PhD degree, 57,282 had received a master's degree, and 559,683 had received a bachelor or a technical associate's degree (see Table 3).

Table 4 presents the statistics concerning the number of S&T personnel sent by the government for further education and training in Taiwan and abroad, and Taiwan's chief technical manpower training systems and their accomplishments in 2003. There were 108 people who received overseas training funded by the government in that year. In that same year, the number of people participating in government-funded training programs on human resources in the industrial sector reached 39,422, and those undergoing vocational training topped 762,000. From this we can see that in terms of S&T talent training, the government had has put much emphasis on human resources in industrial technology and vocational training.

TABLE 3. The graduate of colleges and universities persons related S&T (Unit: FTE)

Degree	PhD Degree	Master Degree	Bachelor Degree[a]	Total
1999	1033	11079	126463	138575
2000	1017	13079	134168	148264
2001	1093	15442	146908	163443
2002	1265	17682	152144	171091
Total	4408	57282	559683	621373

Source: National Science Council (2004a).
Following Organization for Economic Cooperation and Development's definition that full-time equivalent (FTE) is the total manpower engaged in a R&D project is counted by the equivalent number of full-time persons. For instance, a researcher who spends 50% of his or her time on teaching and the rest on R&D should be considered as 0.5 FTE (or 0.5 person-year). Researcher who spends full-time on R&D (250 working days per year) is one FTE.
[a]includes the persons who received a technically associated degree.
S&T: science and technology; FTE: full-time equivalent; R&D: research & development.

TABLE 4. Taiwan's government-sponsored advanced educating and training for S&T personnel in 2003

Institute	Item	Person-Times
Ministry of Education	Government scholarship for overseas	108
Industrial Development Bureau	Human resources in industrial technology	39,422
Department of Health (National Health Research Institutes)	Medical oncology training programs	4
	MD/PD and DDS/PhD predoctoral fellowship	5
	Postdoctoral fellowship awards	4
	Medical, surgical, and gynecological oncology training programs	4
National Science Council	S&T personnel selected for research and advanced study locally and abroad	182
	Postdoctoral research subsidies for specific-topic projects	10
Employment and Vocational Training Administration, Council of Labor Affairs	Vocational training	762,000
	Skill testing	238,839

Source: National Science Council (2004a).
MD: medical doctor; PD: Physics Doctor; DDS: doctor of dental surgery: S&T; science and technology.

The Recruitment of S&T Manpower

The Taiwanese government has adopted simultaneous long- and short-term approaches in recruiting S&T manpower. For the various types of recruiting programs and their results, see Table 5. To (1) balance the demand for qualified manpower, (2) improve the quality of manpower, and (3) shorten new manpower training times, the Hsinchu Science Industrial Park (HSIP) sponsored training programs with the Industrial Technology Research Institute (ITRI) and nearby universities.

Overseas S&T Manpower Introduction

Nowadays, the development of information technology continuously takes on a faster pace. Keeping a sufficient inventory of human capital occupies a very important position in innovative and technically oriented economic growth. Regardless of where these developments are made in Taiwan, there still remain questions regarding the insufficiency of scientists

TABLE 5. Taiwan government's S&T personnel recruitment systems and results in 2003

Institute	Item	Person-Times
Academia Sinica	Recruitment of post doctoral researchers, overseas consultants, experts and scholars	11
National Science Council	Recruiting S&T personnel	101
	Recruiting postdoctoral research personnel	884
	Recruitment of research scholars with subsidies	20
	Inviting important S&T researchers from Mainland China for short-term visits	12
	Recruiting S&T researchers from Mainland China for research works	100
	Funding of trips to Mainland China for the purpose of short-term scientific and technological	120
	Research by specialists and scholars specialists visiting from Mainland China for S&T activities	505

Source: National Science Council (2004a).
S&T: science and technology.

and technicians. To solve the shortage of domestic R&D capacity, the Taiwanese government has recruited overseas experts and scholars who have brought the knowledge of advanced technology, market information, and equipment procurement information. The Taiwanese government seeks to introduce S&T manpower via an international pipeline to satisfy a phenomenon of short-term domestic shortage.

Academic Systems

Taiwan's academic system mainly comprises two main kinds of institutes: educational institutes and research institutes. In terms of function, the educational institutes focus on intensifying the basic research ability of S&T talents and provide proper educational personnel. Although research institutes put more emphasis on applied research and experimental development and effectively employ the fruits of the research into industries.

Furthermore, we discuss the roles of educational institutes and research institutes in S&T manpower development, as well as in NSI.

S&T High Educational Institution Manpower

In recent years, the educational quality in Taiwan has been upgraded markedly and the total number of teachers has likewise quickly increased. The average growth rates for teachers who have master's degrees or higher, are 15.6% and 14.4%, respectively (NSC, 2004a). From 1999–2001, the annual average growth rate was 3.0%, with the population of engineering teachers growing quickest at 3.6%.

Public/Private Research Institutes

In Taiwan, the main research-performing academic organizations include the Academia Sinica, universities, and university research centers (NSC, 2004b). All of these are public S&T research institutes.

Due to the fact that almost all main S&T research institutes are public, Taiwan's S&T development depends heavily on government-owned and-operated laboratories and facilities (Schoening, Souder, Lee, & Cooper, 1998). As such, the public research institutions are the most vital sectors among the academic institutes. Until 2003, S&T manpower for Taiwanese public research institutes consisted of 20,478 persons, whereas private and nonprofit research institutes invested in S&T manpower of 14,249 persons (NSC, 2004a). From 1995 to 1998, the public S&T research institutes' population average growth rate was 11%, whereas that of the private and nonprofit S&T research institutes was 13.14%. From 1999 to 2003, the public S&T research institutes' population average growth rate was only 7.85% but still maintained positive increase. Although that of the private and the nonprofit S&T research institutes was negative at 1.51% (see Table 6). In recent years, Taiwan government agencies have not only greatly increased their S&T-related budgets, but have also worked hard to develop related S&T manpower.

As a whole, research institutes are dominated by government organizations and funded by the government. Researchers in public research institutions have long-term stable growth as compared to researchers in other institutions and will continue to act as the national driving force for the advancement of S&T.

Industrial Sector

In Taiwan, S&T manpower in the industrial sector increased yearly from 1994–2004. In particular, professional researchers (including researchers and technicians) have accounted for over 90% of all the S&T manpower personnel. In contrast, the percentage of technology support staff fell year by year (see Table 7). The main reason is that with the improvement of educational quality as a whole, people with high degrees were unwilling to take jobs at grassroots-level institutes or industries.

TABLE 6. R&D personnel of S&T research institutes (Unit: FTE)

Year	Public		Private & Nonprofit		Total
	Number	Growth Rate %	Number	Growth Rate %	Number
1995	11,068	6.33	11,803	25.72	22871
1996	12,306	11.19	13,957	18.25	26263
1997	14,859	20.75	14,147	1.36	29006
1998	15,707	5.71	15,169	7.22	30876
1999	15,570	–0.87	13,819	–8.90	29389
2000	15,618	0.31	13,301	–3.75	28919
2001	15,975	2.29	13,612	2.34	29587
2002	20,478	28.19	14,249	4.68	34727
2003	22,387	9.32	13,976	–1.92	36363
Each period growth rate:					
During 1995–1998		10.99		13.14	
During 1999–2003		7.85		–1.51	

Source: National Science Council (2000, 2001, 2002, 2003).
R&D: research and development; S&T: science and technology.

TABLE 7. Overall S&T manpower employment distribution in industry sector from 1995 to 2004 (Unit: %)

Year	lResearchers		Technicians		Supporting Staff		Total
	Number	%	Number	%	Number	%	Number
1999	31,474	45.0	32,871	47.0	5,642	8.1	69,987
2000	31,975	45.7	32,434	46.4	5,493	7.9	69,903
2001	35,298	48.7	32,138	44.3	5,033	6.9	72,469
2002	37,527	50.4	32,185	43.2	4,803	6.4	74,514
2003	40,530	51.3	33,737	42.7	4,808	6.1	79,075
2004	45,591	51.7	37,455	42.5	5,059	5.7	88,106

Source: National Science Council (2000, 2001, 2002, 2003, 2004a).
S&T: science and technology.

Although the tables above show that S&T manpower has grown year by year, two industries shortages still exist. The first shortage is the imbalance in the industrial sector. The ITRI indicated that Taiwan's S&T manpower did not have a sufficient supply (National Science Foundation, 2002), and the government emphasized the key professional person's cultivation. The government then established the Semiconductor Institute, Digital Content Institute, the Professional Training Project for Color Image Display Industry, and the Communication Cooperation Project. Especially in the biotechnology and information industries, there existed a high "quantity" of manpower matter, but its "quality" still needed to be improved (NSC, 2004a).

The second shortage is that of the insufficiency of the industrial sector. The government set up to eliminate this insufficiency status via planning a project to increase master-level industrial R&D manpower, and general technological manpower training for industry. The primary goal of this project is to promote effective support for domestic science development, and increase the manpower quality by enriching R&D activity with on-the-job engineers in high-technology industry.

The concentration of regional industry innovation has made a great contribution to the development of S&T economics, and as a result, knowledge networking and the NSI play increasingly important roles in economic development. Building the NSI and technology-intensive industry groups will become an important method for countries around the world to develop their S&T industry. Following radical economical and environmental changes, Taiwan gradually stepped up with the development in the capital-intensive and technology-intensive industries. The

Taiwan government now especially promotes the "Challenges 2008 Year-National Developments Plan," and the "Two Trillion and Twin-Star Industries Development Plan," to improve Taiwan S&T development.

INTERACTIVE EFFECT OF NSI IN TAIWAN S&T

In this section, we discuss the interactions among sectors and their dynamic effects on NSI. First, we study how the interaction of government policy and the academic system improve the development of Taiwan's S&T manpower. Second, we discuss the effects on the development of Taiwan's S&T manpower caused by the interaction of the academic system (including the research institutes and educational institutes) and the industrial sector.

The Interaction of Government Policy and the Academic System

As mentioned above, for catching-up countries without abundant resources, the government plays an important role in the development of S&T. Therefore, no matter how academic institutes or research institutes perform, the Taiwan government has an important influence on the development of S&T. A column on Table 8 shows that, from 1999 onwards, government sponsorship represented more than 84% of the research and development expenditure every year. Half of the funds had been spent on the academic system, as shown in Column B of Table 8.

With regard to the academic system, from the mid-1990s onward, the national and many competent regional authorities passed a large number of laws and regulations that facilitated academic S&T innovation; for example, the Taiwan government implemented the Science and Technology Basic Law in January of 1999.

The Effect on the Development of S&T from the Interaction Between the Academic System and the Industrial Sector

The bridge institute between the academic institutes and the industrial sector is the ITRI, with highly ranked talent engaging in research. In the past, the ITRI put emphasis on technology development and mixed patent technology transfer. Nowadays, however, the institute has adopted more flexible methods of popularizing and transferring technology, such as industries participating in research in advance, international cooperation, commissioning of research with one another, and so on. As an important

TABLE 8. Academia system R&D expenditure by source of funds (Unit: Million NT$)

Year	Government (A)	% (A/C)	Others[a] (B)	% (B/C)	Total (C)
Panel A	Higher Education R&D Expenditure by Source of Funds				
1999	19163	85.8	3171	14.2	22334
2000	20463	85.1	3584	14.9	24047
2001	21631	84.8	3890	15.2	25521
2002	23628	85.5	4009	14.5	27637
2003	24573	85.1	4317	14.9	28890
2004	25316	83.4	5034	16.6	30350
Panel B	Sources of Research Funds for Research Institutes				
1999	737	52.9	655	47.1	1392
2000	874	62.8	518	37.2	1392
2001	855	60.0	570	40.0	1425
2002	948	62.0	582	38.0	1530
2003	1004	66.5	506	33.5	1510
2004	902	60.8	582	39.2	1484

Sources: National Science Council (2000, 2001, 2002, 2003, 2004a).
[a]Include the business enterprise, private R&D organizations and abroad organizations.
R&D: research and development; NT: New Taiwan Dollar.

impetus for the development of S&T in Taiwan (NSC, 2004a), ITRI's technology transfers have increased yearly, enabling research results to be applied to industries. Through the coordination of a unified system and incentive measurement, manpower and intellectual resource can play full roles, and at the same time, research results can be effectively converted into industrial profit.

The ITRI' s Incubator Center was named the 2006 Randall M. Whaley Incubator of the Year at the National Business Incubation Association's (NBIA[1]) 20th International Conference on Business Incubation in St. Louis, Missouri, United States. The Whaley award, the NBIA's most prestigious honor, recognizes overall incubator excellence. In 2004, the ITRI owned 712 technology results in all and transferred them to industries 825 times, accounting for 36.9% of the total research results. In 2003, it had 520 technology results and transferred them 641 times, accounting for 28.7% of total research results. Apart from technology transfers, the ITRI also provides technology cooperation and service. It has an average of 4.2 commissions and cooperative researches per day (see Table 9). The ITRI provided industry technology services 50,260

TABLE 9. Industrial technology research institute provides technology cooperation and service summary

Year	Cases	Growth%	Companies	Growth%
Panel A		Technology Transferred to Industry		
2001	337	—	471	—
2002	414	22.85	542	15.07
2003	520	25.60	641	18.27
2004	712	36.92	825	28.71
Panel B		Contract Research		
2001	933	—	1010	—
2002	788	–15.54	836	–17.23%
2003	1094	38.83	1038	24.16%
2004	1176	7.50	1237	19.17%
Panel C		General Services to Industry		
2001	57,142	—	30,427	—
2002	51,696	–4.28	25,812	–15.17
2003	55,443	1.37	25,846	0.13
2004	50,260	–9.35	27,282	5.56

Sources: National Science Council (2001, 2002, 2003, 2004a).

times in 2004, with 27,282 factories benefiting from these services and 111.4 factories obtaining services on a per-day basis (see Table 9).

From the resources-based viewpoint, this study posits that manpower is an important and valuable resource (Ordóñez de Pablos, 2002) and proceeds to explain ITRI investments in manpower contribution. First is the ITRI gathering of S&T manpower (high-technology researchers). During the 1970s, Taiwan suffered from the lack of high-technology researchers. By 2003, ITRI had become operational, comprising 6,193 members. A doctoral or master's degree background has become the main qualification of its members, increasing from 18.66% in the initial period to 62.7% in 2003.

Second are the main suppliers of high-technology leaders. One of the objectives of ITRI is to distribute technology among private enterprises, and this objective is achieved by turning ITRI researchers into industrial technologists. ITRI has provided the gateway to help researchers improve on their own knowledge as they contribute to local and global advancements in technology. In addition, chief executives are appointed by the government, such as Guo-Ding Li, Yun-Xuan Sun, and the like, who were excellent leaders in Taiwan. Meanwhile, some talented people selected high-technology careers in ITRI overseas.

Third are on-the-job training and development programs for employees. Although ITRI is not an educational institution, it is one of the main suppliers of industrial leaders—especially in high-technology sectors—in Taiwan. ITRI set up ITRI College as an industrial academy to propagate its knowledge and accelerate the training of human resources required for the knowledge-based economy. ITRI also offers systemized programs to preserve and enhance industrial competitiveness, including strategic technology, new knowledge, and customized and specialized management courses.

CONCLUSION AND RECOMMENDATIONS

Taiwan's government also provided huge amounts of research funding to give S&T-related institutions the ability to carry on with manpower training and implementation (Schoening et al., 1998). Taiwan can effectively transfer its industrial structure into a high-technology oriented industry based on high quantities and qualities of S&T manpower.

This research uses the analysis of the NSI to completely and correctly display the S&T manpower of Taiwan at the present development and challenge situation. The study likewise aspires to deeply understand the successful S&T manpower development experience of Taiwan as well as discount some pitfalls. Therefore, the following four feasible recommendations are proposed.

First, the Taiwanese government must conduct a comprehensive plan regarding the shortages of manpower in the S&T industry and help supply surplus-related manpower to reform other industries. This will further help in the promotion of industrial upgrades and manpower balance. Previously, the government spearheaded S&T manpower development that is the most important among NSC factors in Taiwan. Regardless if it is the academia or industrial sectors, when it comes to S&T manpower demand and supply, all appreciate the government's resource input.

Second, the government should enhance its NSC role. According to Taiwan's S&T manpower development characteristics, the Taiwanese government is aware of the increases in investment resources in S&T day by day. Therefore, it is important that the S&T manpower gap be addressed, and, aside from considering the resource investment, the quality of S&T manpower should be checked. An example is the establishment of a professional license certification system that maintains and enhances S&T manpower quality.

Third, in the future, the Taiwanese government might also find the need to establish a standard for issuing professional or technical licensing certifications through their administrative institutions and encourage enterprises to implement professional certifications or to grant firms the ability to license technical certifications. These strategies will also boost the image of professional and technical license authorities.

Finally, this study follows the NSC framework to analyze Taiwan's S&T manpower and finds that cross-trained S&T manpower does not realize each NSC factor's full value. To cross-train scientists and technicians, the government should encourage various universities and colleges to develop cooperative S&T programs and mutually acknowledge school grades throughout the system. This will aid students in practicing diversity and obtaining needed scientific and technical knowledge and skills. Furthermore, the enhancement and continuous improvement of high-quality staffs should become the priority of enterprises. Firms should develop goals based on their future. Moreover, they should strengthen their staffs' on-the-job training to respond rapidly to changing market demands.

NOTE

1. The NBIA is the world's leading organization advancing business incubation and entrepreneurship. Each year, the NBIA Incubation Awards honor the business incubators, client companies and graduates that exemplify the best of the industry.

REFERENCES

Arensman, R., Brown, G. C., & Wilson, D. (1991). Asia turns on to R&D. *Electronic Business*, *17*(24), 14–16.

Chang, P. L., & Shih, H. Y. (2005). Comparing patterns of intersectoral innovation diffusion in Taiwan and China: A network analysis. *Technovation*, *25*(2), 155–169.

Chang Y. C., Chen, M. H., Hua, M., & Yang, P. Y. (2006). Managing academic innovation in Taiwan: Towards a "scientific-economic" framework. *Technological Forecasting & Social Change*, *73*, 199–213.

Chung, S., & Lay, G. (1997). Technology policy between "diversity" and "one best practice"—A comparison of Korean and German promotion schemes for new production technologies. *Technovation*, *17*(11/12), 675–694.

Edquist, C. (1997). *Systems of innovation: Technologies, institutions and organizations*. London: Pinter.

Freeman, C. (1987). *Technology and economic progress: Lessons from Japan*. London: Pinter.

Furman, J. L., Porter, M. E., & Stern, S. (2002). The determinants of national innovative capacity. *Research Policy*, *31*, 899–933.

IMD (2001). *The World Competitiveness Yearbook*. Switzerland: Lausanne Press.

Industrial Technology Research Institute (ITRI). (2003). A Study of Taiwan's Digital Content Industry, Taipei, Industrial Technology Research Institute (ITRI)/Industrial Economics and Knowledge Center (IEK). Available at http://int.iek.itri.org.tw/eng/index.jsp?orgcd=20.

Kumaresan, N., & Miyazaki, K. (1999). An integrated network approach to system of innovation - the case of robotics in Japan. *Research Policy*, *28*, 563–585.

Lundvail, B. A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (1st ed.). London: Pinter.

National Science Council, (2001). *Indicators of science and technology*. Taipei, Republic of China: Author.

National Science Council. (2002). *Indicators of science and technology*. Taipei, Republic of China: Author.

National Science Council. (2003). *Indicators of science and technology*. Taipei, Republic of China: Author.

National Science Council. (2004a). *Indicators of science and technology*. Taipei, Republic of China: Author.

National Science Council. (2004b). *Yearbook of science and technology*. Taipei, Republic of China: Author.

National Science Foundation, Division of Science Resources Statistics. (n.d.) *National Science Board (NSB) science and engineering indicators, 2002*. Available at: http://www.nsf.gov/sbe/srs/seind02/,.

Nelson, R.R., & Rosenberg, R. (1993). Technical innovation and national systems. In R. R. Nelson (Ed.), *National innovation systems: A comparative analysis* (pp. 3–21). New York: Oxford University Press.

Organization for Economic Cooperation and Development. (1996). *The knowledge-based economy, technology and industry outlook*, Paris.

Organization for Economic Cooperation and Development. (1999). *Managing national innovation systems*. Paris: Author.

Ordóñez de Pablos, P. (2002). Evidence of intellectual capital measurement form Asia, Europe and the Middle East. *Journal of Intellectual Capital*, *12*(3), 287–302.

Patel, P., and Pavitt, K. (1994). Why they are important, and how they might be measured and compared. *Economics of Innovation and New Technology*, *3*, 77–95.

Patrinos, H. A., and Lavoie, M. (1995). Engineers and economic development in Greece. *International Journal of Manpower*, *16*(10), 39–56.

Persaud, A. (2001). The knowledge gap. *Foreign Affairs*, *80*(2), 107–117.

Schoening, N., Souder, W. E., Lee, J., & Cooper, R. (1998). The influence of government science and technology policies on new product development in the USA, UK, South Korea and Taiwan. *International Journal of Technology Management*, *15*(8), 821–835.

Shyu, J. Z., & Chiu, Y. C. (2002). Innovation policy for developing Taiwan's competitive advantages. *R&D Management*, *32*(4), 369–374.

Smith, K. (1996). *The Norwegian National Innovation System: A Pilot Study of Knowledge Creation* (STEP Report). Oslo, Norway: STEP Group.

Solleiro, J. L., & Castañón, R. (2005). Competitiveness and innovation systems: The challenges for Mexico's insertion in the global context. *Technovation*, *25*(9), 1059–1070.

World Economic Forum [WEF] Global Competitiveness Report [GCR] 2001–2002, 2003.