Measuring the Development of Knowledge-Based Economy in Taiwan*

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The progress of information and communication technology (ICT) has been regarded as one crucial factor bringing about the phenomenon of knowledge-based economy, while other factors such as human resource development, and related institutional settings have also played important roles behind the scene. Our measurement reflects Taiwan's potential knowledge-based economy (KBE) development, which nevertheless indicates considerable room for improvement. Except for ICT investment, the other knowledge investment indicators supported the perspective of Taiwan's KBE development. However, the knowledge diffusion is perhaps the weakest part of Taiwan's KBE development; Taiwan needs much improvement in order to stay close to the developed countries. Finally, as for the knowledge output and application, Taiwan's outstanding performance in research publication and patents is consistent with that in research and development (R&D) of human resources, but the obviously weak performance of knowledge-intensive service sector might have resulted from Taiwan's relative disadvantages indicated by the measurement of the knowledge diffusion. Given the above status of Taiwan's KBE development, Taiwan will inevitably encounter the following two major challenges: one is related to the difficulty in upgrading Taiwan's science and technology (S&T), and the other is related to the noted issues of digital divide and economic stability.

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INTRODUCTION

For the era of knowledge-based economy (KBE), Organization for Economic Cooperation and Development (OECD) members, while strengthening their policies for promoting science and technology (S&T) research and development (R&D) and innovation, have also been working on establishing a better indicator system for national innovation capability so that policy-makers could receive timely information and make policy adjustment accordingly. As a part on the world competition, Taiwan needs to advance along with the others for better survival. Motivated as such, this paper aims at (1) providing a measurement framework with several widely used indicators, and (2) presenting and interpreting the measurement results. It is our hope that our measurement would provide some useful information for our government as well as researchers so that better policies for the related field could be made in Taiwan.

This paper is organized as follows: first, the concept and the emergence of the KBE will be briefly discussed, and then an indicator system will be proposed and the measurement result of the development of KBE in Taiwan will be presented, followed by our interpretation and conclusion.

KBE AND ITS EMERGENCE

About ten years ago the world witnessed the economic prosperity in Japan and some South East Asian countries, which were believed as rising stars in the near future. However, the Japanese economy has since suffered and the South East Asian countries were hard hit by financial crises. Their perspectives seem no longer bright. In contrast, the economy of the United States has experienced ten-year long prosperity, with the record-breaking continual economic growth, and low unemployment and inflation rates.

The surprising performance of the U.S. economy has caught the world's attention, and numerous researches were done for the possible reasons and answers for such long-lasting prosperity. In 1996 OECD published an article entitled, "The Knowledge-Based Economy," defined as "economies which are directly based on the production, distribution and use of knowledge and information." Subsequent researches by European Community (EC) (2000) and Asia-Pacific Economic Cooperation (APEC) (2000) refined the concept of KBE as "knowledge-driven economy (KDE)," and argued that the impact of knowledge creation, diffusion, and its use does not reach only a few "hi-tech" industries, but all economic sectors.

The KBE can be characterized statically by the large output proportion of so-called "knowledge-intensive industries" in GDP, and dynamically by the speeding of innovations. Knowledge-intensive industries mean high intensity of knowledge as a factor

of production and transaction. OECD used such criteria as expenditure on personnel education and training, R&D, and software for identifying knowledge-intensive industries. The efforts lead to the following: (1) knowledge-intensive manufacturing industries include high-technology industries such as manufacturing of aircraft, office and computing equipment, drugs and medicines, radio, TV and communication equipment, and medium-high-technology industries, such as manufacturing of motor vehicles, professional goods, electrical machinery, chemicals and so on; (2) knowledge-intensive service industries include financial industries, insurance industries, telecommunication services, asset-evaluation services, business services, and social and personal services.

The phenomena of KBE are usually attributed to the non-rivalrous nature of knowledge; i.e., the use of knowledge in principle is not limited by location and time, in contrast to most of the other factors of production. Moreover, the non-rivalrous benefit of knowledge has been tremendously enhanced by the information and communication technology (ICT), since the knowledge diffusion has become much easier and less expensive, facilitating R&D and innovation activities, resulting in faster accumulation of human knowledge stock.

It is our argument, therefore, that ICT as an enabling technology for KBE rests on three reasons: (1) ICT applied in production raises the net value of production (direct productivity up and cost down); (2) ICT reduces the transaction costs, resulting in a higher degree of specialization and labor division, which additionally enhance productivity; (3) faster innovation activities and knowledge accumulation also help greatly the progress of technology, making feasible the continual rise in productivity. The almost simultaneous emergence of prosperous Internet and the U.S. economy might serve as one piece of the supporting evidence.

However, the development of ICT does not come from nowhere. The progress and wide-spread use of ICT are tremendous time-consuming process for human resource development (HRD), both in quality and quantity. On the other hand, institutional establishment for promoting intellectual property, R&D, and innovations also serves as the prerequisite for technology progress in a society, since personal spontaneous interests in R&D and innovation cannot be a reliable driving force. In other words, the emergence of KBE could not be fostered without the support of HRD and related institutions.

Finally, the emergence of KBE can also be attributed to the promotion and advancement of free international trade. From General Agreement on Tariffs and Trade (GATT) to World Trade Organization (WTO), more and more countries have taken part in international trade, and the subsequent participation of developing economies such as South East Asia, China, East Europe, and India, have resulted in excess supply of the low skill labor and labor-intensive products. The fact has led to the situation where the key competitive advantage in the global market does not rest solely on the inexpensive labor and other physical resources, which are now largely available to all countries, but also relies increasingly on the technological strength.

THE MEASUREMENT FOR THE DEVELOPMENT OF TAIWAN'S KBE

Description of the Proposed Indicator System

The system of KBE indicators proposed in this paper is formed according to the following criteria of indicator selection:

- (1) **Commonness.** The indicators selected into our system will be among those widely used by many countries in the world. The more comprehensive studies in the KBE measurement include OECD (1999), APEC (2000), U.K. (1999), and Australia (2000), which provide important references for the indicator system proposed in this paper.
- (2) **Comparability.** A thorough measurement has to include self-evaluation as well as international comparison so that the relative ranking and status of competitiveness among nations in the world can be explicitly shown. Indicators also require the same definition as the comparison basis.
- (3) **Data availability.** Besides the same definitions of indicators, data availability constitutes an important factor or constraint for international comparison.

TABLE 1.1. SUMMARY OF THE PROPOSED INDICATOR SYSTEM

Types	Indicator Set	Indicators
Resource	Knowledge investment	<ul style="list-style-type: none"> • Educational investment • R&D investment • ICT investment
	Human capital/resource	<ul style="list-style-type: none"> • Citizen educational level • Human capital in labor force • Human capital in R&D researchers
Process	Knowledge diffusion	<ul style="list-style-type: none"> • ICT infrastructure and use • Social innovation capital
	Innovation institutional settings	<ul style="list-style-type: none"> • Legal settings • Financial settings
Output	Direct knowledge output	<ul style="list-style-type: none"> • SCI Publications • EI Publications • Patents granted in the U.S.
	Knowledge application	<ul style="list-style-type: none"> • Ratio of exported knowledge goods • Ratio of knowledge-intensive industries • Ratio of knowledge workers

The indicator system proposed in this paper consists of three sets: resource indicators, process indicators, and result indicators. The set of resource indicators serves as the

proxies of measuring knowledge input level, including mainly knowledge investments (e.g., educational investment, R&D investment, and ICT investment) and human capital or resources. Secondly, the set of process indicators serves as the proxies of measuring knowledge diffusion level, including ICT infrastructure and use, social innovation capital, and several institutional factors. Finally, the set of result indicators serves as the proxies of measuring knowledge output and application, including the number of Science Citation Index (SCI) and Engineering Index (EI) publications, the number of patents granted in the U.S., the ratio of exported knowledge-intensive product to GDP, the ratio of knowledge-intensive industries to all industries, the employment ratio of knowledge workers, and so on. The indicator system is summarized in Table 1.1.

The Result of Measurement

(1) Knowledge Investment

It is difficult to measure knowledge investment, not only because of the absence of clear definition of the term, knowledge investment, but also because of data differentiation. The most common definition for knowledge investment is from OECD (1999), which involves R&D expenditure, educational expenditure, and software investment as the major indicators. The indicators for knowledge investment are summarized in Table 2.1.

TABLE 2.1. SUMMARY OF KNOWLEDGE INVESTMENT INDICATORS

Type	Indicators	Reference
Educational Investment	<ul style="list-style-type: none"> Public education spending/GDP National education spending/GDP 	<ul style="list-style-type: none"> OECD, "Education at Glance" UNESCO Ministry of Education, R.O.C. http://www.edu.tw/resource/8-1.htm
R & D Investment	<ul style="list-style-type: none"> Gross Expenditure of R&D (GERD) GERD/GDP GERD composition 	<ul style="list-style-type: none"> OECD, ANBERD database OECD, MSTI database OECD, "STI scoreboard 1999" Indicators of S&T, R.O.C.
ICT Investment	<ul style="list-style-type: none"> ICT spending/GDP Software spending/GDP 	WITSA & IDC "Digital Planet 2000"

Note: ANBERD Analytical Business Enterprise Research and Development; MSTI Main Science and Technology Indicator; STI Science and Technology Indicator; WITSA World Information Technology and Service Association; IDC International Data Corporation.

a. Educational Investment

In theory educational expenditure includes that of formal education and on-the-job training, but owing to data availability, in this paper only public expenditure in

education is used as the sole indicator for international comparison.

As shown in Table 2.2, the ratio of public expenditure in education to all government spending in Taiwan in 1998 reached its peak of 15.7%. On the other hand, public expenditure in education as the proportion of GDP reached its peak of 6.23% in 1992 up from 4.63% in 1988.

TABLE 2.2. PUBLIC EDUCATIONAL EXPENDITURE IN TAIWAN

(Unit: NT\$ million, %)

Year	Amount	Nominal Growth Rate	Real Growth Rate	Edu Spending/ Gov. Spending	Edu Spending/ GDP	Edu, S&T Spending/ Gov. Spending
1988	163094	-	-	17.39	4.63	13.69
1989	202364	24.08	20.12	17.47	5.14	15.19
1990	247488	22.30	17.88	17.77	5.75	14.93
1991	290020	17.19	12.84	17.86	6.03	15.31
1992	332463	14.63	11.02	18.43	6.23	15.13
1993	350053	5.29	1.64	18.58	5.91	15.24
1994	366902	4.81	2.80	19.36	5.68	15.46
1995	407596	11.09	8.89	19.50	5.81	15.02
1996	420905	3.27	0.15	18.91	5.48	15.06
1997	430676	2.32	0.63	18.54	5.17	15.27
1998	453090	5.20	2.50	18.80	5.07	15.70

Note: Edu. education; Gov. government.

Source: <http://www.edu.tw/resource/8-1.htm>.

TABLE 2.3. INTERNATIONAL COMPARISON OF PUBLIC EXPENDITURE ON EDUCATION AS PERCENTAGE OF GDP

(Unit: %)

Nation	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
U.S.	4.9	6.8	5	5.1	5.2	5.2	-	5.4	5.3	5.4	-	-	-	-
Canada	6.5	6.8	6.7	6.6	6.4	6.8	7.3	7.5	7.2	6.9	-	-	-	-
Germany									4.8	4.7	4.8	4.8		-
U.K.	4.9	4.9	4.8	4.7	4.7	4.9	5.2	5.4	5.5	5.4	5.3	-		-
Ireland	6.4	6.5	6.7	6.1	5.8	5.6	5.7	6	6.2	6.3	6	6	-	-
Italy	5	5	4.9	4.1	3.2	3.1	4.2	5.2	4.9	4.7	4.9	-	-	-
Sweden	7.7	7.5	7.3	6.7	7.3	7.7	8	8.4	8	8.1	8.3	-	-	-
Denmark	7	6.8	7.2	7.4	7.2	7.1	8.1	7.8	7.7	8.1	6.9			-
Netherlands	6.4	6.5	6.9	6.5	6	6	5.9	5.4	5.2	5.2	5.1	-	-	
Australia	5.6	5.4	5.1	4.9	5.1	5.3	5.5	5.9	5.6	5.4	5.5	-		
New Zealand	4.7	5	5.4	5.8	7.9	6.5	7.4	7.4	7	6.8	7.5	7.3	-	-
Japan	5	4.9	4.8	4.6	4.7	4.7	4.7	4.7	4.8	4.8	4.8	-	-	-
Taiwan	4.1	4.2	3.8	4	4.3	4.8	5.3	5.6	5.8	5.6	5.5	5.6	5.4	5.1
Singapore	4.4	4.1	3.9	3.3	3	3	3.7	3.2	3.1	3	3	-	-	-
South Korea	4.5	4.1	3.8	3.1	3.5	3.5	4	4.2	4.4	3.7	3.7	-	-	-

Source: UNESCO, 1998.

Compared with other countries, as shown in Table 2.3, in 1995 Denmark's public expenditure in education as the proportion of GDP was 6.9% leading all other countries, followed by France, Netherlands, Canada, and other North European countries. The ratio of Taiwan in 1995 was 5.81%, higher than the averages of EU (5.1%) and OECD (4.6%). It revealed that Taiwan's public expenditure in education was no less than the average of the developed countries, but the ratio had been decreasing in recent years.

b. R&D Investment

Owing to the absence of data for the spending on innovations in Taiwan, only R&D-related data is used for self-evaluation and international comparison. As shown in Table 2.4, in 1999 national R&D expenditure as the proportion of GDP was 2.05%, higher than that (1.98%) in 1998, showing a rise. When examining the sources of R&D investment, private business sector was the main contributor, constituting 62.9% of the total R&D expenditure. Meanwhile, R&D spending by universities and nonprofit research institutes showed obvious growth, about eight times from 1997 to 1999, while R&D spending by government decreased over the same period, as shown in Table 2.5.

TABLE 2.4. R&D EXPENDITURE IN TAIWAN

(Unit: NT\$ million, %)

Year	R&D Spending						R&D Spending/GDP		
	National		Business		Manufacturing		National	Business	Manu- facturing
	Amount	Growth	Amount	Growth	Amount	Growth	%	%	%
1988	43,839	18.10	20,948	-4.63	20,826	3.85	1.24	0.59	0.59
1989	54,789	20.99	30,695	41.86	30,510	41.83	1.39	0.78	0.77
1990	71,548	25.87	42,240	32.64	38,933	23.00	1.66	0.98	0.90
1991	81,765	10.04	43,836	-0.07	40,602	0.42	1.70	0.91	0.84
1992	94,828	12.32	49,825	10.08	46,512	10.94	1.78	0.93	0.87
1993	103,617	5.48	58,968	14.25	56,750	17.78	1.75	1.00	0.96
1994	114,682	8.55	65,921	9.64	63,552	9.83	1.77	1.02	0.98
1995	125,031	6.87	71,972	7.02	70,162	8.22	1.78	1.03	1.00
1996	137,955	7.00	79,806	7.54	77,706	7.41	1.80	1.04	1.01
1997	156,321	11.44	95,968	18.26	93,786	18.70	1.88	1.15	1.13
1998	176,455	10.35	111,422	13.12	108,331	12.54	1.98	1.25	1.21
1999	190,520	9.51	120,597	9.79	117,307	9.85	2.05	1.28	1.25

Source: NSC (2000), Indicators of S&T ROC.

In Table 2.6, it is observed that in 1999 the U.S. ranked the first in R&D spending, followed by Japan, Germany, France, U.K., South Korea, Italy, Canada, China, Netherlands, Sweden, Australia, Spain, and Taiwan. While Taiwan ranked 14th, the

gap between the U.S. and Taiwan has grown, and China had exceeded Taiwan in total R&D expenditure since 1996, ranking 9th in 1999. As for the ratio of R&D to GDP, Sweden ranked the first at 3.7% in 1997, followed by Finland's 3.09% (in 1999), Japan's 3.04% (in 1998), Swiss's 2.73% (in 1996), the U.S.'s 2.65%, and South Korea's 2.55% (in 1998), while Germany, France, and Taiwan were all just above 2%, and Denmark and Netherlands close to 2%. As for the sources of R&D investment, the average R&D spending by private business sector of OECD countries was also around 60%, with Japan's 72.6% ranking the first.

TABLE 2.5. COMPOSITION OF R&D EXPENDITURE IN TAIWAN

(Unit: NT\$ million, %)

Spending Sectors		Business		Research Institute		Universities	
Source Sectors		1998	1999	1998	1999	1998	1999
Total	Amount	111,422	120,597	44,341	47,720	21,291	22,204
	Nominal Growth Rate	16.10	8.23	5.51	7.62	16.17	4.29
	Real Growth Rate	13.12	9.78	2.80	9.16	13.18	5.78
	Proportion	100	100	100	100	100	100
Government	Amount	10,542	10,728	38,308	41,720	20,533	19,679
	Nominal Growth Rate	8.28	1.76	4.96	8.91	17.19	-4.16
	Real Growth Rate	5.50	3.22	2.26	10.46	14.18	-2.79
	Proportion	9.50	8.90	86.40	87.40	96.40	88.60
Private	Amount	100,880	109,869	6,033	5,999	758	2,525
	Nominal Growth Rate	7.90	8.91	9.16	-0.56	-6.07	233.11
	Real Growth Rate	5.13	10.47	6.35	0.86	-8.48	237.87
	Proportion	90.50	91.10	13.60	12.60	3.60	11.40

Source: TIER.

c. ICT Investment

According to a study entitled, "Digital Planet The Global Information Economy" by WITSA and IDC, ICT expenditure consists of three parts: (1) spending on IT hardware, (2) spending on IT service and software, and (3) spending on telecommunication. In their 2000 report, 55 countries were investigated for ICT expenditure, and as shown in Table 2.7, the first five countries in ranking order were the U.S., Japan, Germany, U.K., and France. In 1999, the ICT spending of the U.S. were US\$ 761.9 billion, about twice as large as that of Japan's US\$ 362 billion and more than the total of the other four countries' spending. The total ICT spending of the first five accounted for 68.9% of the world's ICT spending, while the share of the U.S. was 35.4% and Japan 16.8%.

The ICT spending in US\$ of countries in the Asia Pacific area in 1999 is as follows: Japan 362 billion, China 47.9 billion, Australia 36.8 billion, South Korea 22.4 billion, Taiwan 16 billion, India 15.5 billion, Hong Kong 12.8 billion, and Singapore 8 billion. Considering the ratio of ICT spending to GDP, the world average in 1999

was 6.6%, rising from 5.6% in 1992. The ratios of different countries ranged from 3% to 9%. Generally speaking, higher ratios are observed in the English-speaking and North European countries, with New Zealand's 10.5% ranking the first. In Asia, the ranking is as follows: Hong Kong 8.3%, Singapore 7.7%, Vietnam 7.4%, Japan 7.1%, China 4.9%, while Taiwan's 4.8% and South Korea's 4.4% seemed relatively small.

TABLE 2.6. INTERNATIONAL COMPARISON OF R&D EXPENDITURE IN 1999

	National R&D Expenditure	National R&D Expenditure	Business R&D Expenditure	Business R&D Expenditure	Business R&D Expenditure
	US\$ million (current PPP)	Share in GDP &	US\$ million (current PPP)	Share in GDP &	Share in DPI &
U.S.	243,548	2.65	184,379	2.01	2.36
Japan ¹	92,663	3.04	65,974	2.17	2.44
Germany	46,218	2.38	31,721	1.63	2.10
France ¹	27,880	2.18	17,289	1.35	1.83
U.K. ¹	23,445	1.83	15,423	1.20	1.64
South Korea ¹	16,981	2.55	11,941	1.79	2.17
Italy	13,311	1.02	7,158	0.56	0.73
Canada	12,775	1.62	8,042	1.00	1.26
China ⁴	8,200	0.83	3,019	0.31	-
Netherlands ¹	7,392	1.95	4,004	1.06	1.36
Sweden ²	6,845	3.7	5,124	2.77	4.40
Australia ¹	6,759	1.49	3,049	0.67	0.73
Spain	6,444	0.9	3,320	0.47	0.62
Taiwan ⁴	5,904	2.05	3,673	1.30	1.40
Switzerland ³	4,868	2.73	3,440	1.93	2.32
Belgium ²	4,271	1.84	3,213	1.33	1.70
Finland	3,652	3.09	2,530	2.14	3.19
Denmark	2,770	1.99	1,756	1.26	2.04
Norway	2,146	1.73	1,111	0.94	1.34
Ireland ²	1,084	1.39	792	1.01	1.34
Portugal ²	946	0.62	213	0.14	0.20
New Zealand ²	752	1.13	212	0.32	0.39
OECD Total ¹	518,114	2.18	358,697	1.51	1.84
North America ¹	241,869	2.22	177,369	1.67	1.98
EU ¹	144,990	1.81	92,269	1.15	1.54

Note: 1) 1998 2) 1997 3) 1996 4) calculated by average annual exchange rate.

Source: OECD, Main Science and Technology Indicators 2000/2, 2001.

NSC (2000), Indicators of S&T ROC.

NBS & MST (2000), China Statistical Yearbook on S&T.

TABLE 2.7. INTERNATIONAL COMPARISON OF ICT INVESTMENT STATUS

Ranks	Country	1999			1992-1999	1992-1995	1996-1999
		Ratio of GDP %	Expenditure USD million	Global Market Share %	Compound Annual Growth Rate %	Compound Annual Growth Rate %	Compound Annual Growth Rate %
1	New Zealand	10.50	6549	0.30	8.80	11.41	7.74
2	U.K.	9.30	116847	5.43	6.43	4.21	8.50
3	Sweden	9.30	21842	1.01	2.13	-1.67	4.02
4	U.S.	8.90	761863	35.38	7.76	7.26	10.83
5	Australia	8.90	36755	1.71	8.02	8.76	6.05
6	Columbia	8.80	8694	0.40	21.97	11.28	28.15
7	Canada	8.50	55345	2.57	5.26	2.13	7.90
8	Czech	8.50	4284	0.20	13.44	20.42	8.54
9	Hong Kong	8.30	12772	0.59	14.70	20.47	7.21
10	Singapore	7.70	8025	0.37	13.13	19.24	6.59
11	Switzerland	7.50	23768	1.10	3.63	5.32	3.31
12	Israel	7.40	8322	0.39	11.21	9.59	16.25
13	Vietnam	7.40	1735	0.08	34.49	50.29	20.12
14	South Africa	7.20	10898	0.51	7.90	10.56	5.49
15	Japan	7.10	361964	16.81	8.07	10.00	6.55
16	Holland	7.10	32459	1.51	6.12	6.95	6.25
17	Denmark	6.90	13524	0.63	5.94	7.59	4.63
18	Norway	6.90	10268	0.48	5.55	5.10	5.22
19	Ireland	6.50	5556	0.26	9.80	9.35	9.69
20	Hungary	6.40	3984	0.19	16.27	7.71	27.26
31	Malaysia	5.20	5265	0.24	10.07	18.19	-1.06
32	China	4.90	47871	2.22	29.19	36.80	23.89
34	Taiwan	4.80	16017	0.74	10.86	5.67	16.45
38	South Korea	4.40	24433	1.14	7.30	15.78	-7.09

Source: WITSA & IDC "Digital Planet 2000: the global information economy."

The growth of the global ICT spending was obvious, at the average annual rate of 7.46%. In the period of 1996-1999, Taiwan's average annual growth rate of ICT spending was 16.45%. In the period of 1992-1999, China, Taiwan, and India were among the highest growth. The growth rate of Taiwan in ICT spending ranked 18th, rising from 22nd in 1992, while China ranked 10th in 1999, rising from 19th in 1992.

(2) Human Capital/Resources

Owing to the limitation of definitional difference and data availability in Taiwan, the following indicators, summarized in Table 2.8, are selected to make the international comparison possible:

TABLE 2.8. SUMMARY OF HUMAN CAPITAL INDICATORS

Type	Indicators	Source
Citizen Educational Level	• Educational level of population of age 25-64	1. OECD, Education at Glance 2. Taiwan-Fukien Demographic Fact Book, R.O.C.
Human Capital in Labor Force	• Education level of workers	1. OECD, Employment Outlook 2. OECD, MSTI database 3. Yearbook of Manpower Statistics Taiwan Area, R.O.C. 4. Employees Survey Report, R.O.C.
Human Capital in R&D Personnel	• Total R&D researchers • R&D researchers per 10 thousand workers • Educational level of R&D researchers	1. OECD, ANRSE database 2. OECD, MSTI database 3. OECD, STI scoreboard 1999 4. NSC Indicators of S&T, ROC

a. Citizen Educational Level

As shown in Figure 2.1, citizen of age between 24 and 64 with the degree of college and above accounted for 19.93% of the total population in Taiwan in 1999, rising from 12.09% in 1987.

FIGURE 2.1. EDUCATION ATTAINMENT OF THE POPULATION AGED 25-64

Source: Taiwan-Fukien Demographic Fact Book 2000, Taiwan R.O.C.

In 1996, as shown in Figure 2.2, the overall educational level of Taiwan's population aged between 25 and 64 was lower than that of OECD countries as a whole. There were about 60% of the total population aged between 25 and 64 who received at least secondary education or higher in OECD countries. In contrast, there were

only 44% in Taiwan. Moreover, there were about 13% (20% in the U.S.) who received higher education in OECD countries, while only 7.15% did in Taiwan. The gap of overall educational level between Taiwan and the developed countries was significant.

FIGURE 2.2. INTERNATIONAL COMPARISON OF EDUCATION ATTAINMENT OF THE POPULATION AGED 25-64

Source: 1. OECD, *Education at Glance*, 2001.

2. See Figure 2.1.

b. Human Capital in R&D

The selected indicators include the total number of R&D researchers, R&D researchers full time equivalent (FTE) per 10 thousand in labor force, and the educational level of R&D researchers.

First of all, in 1999 the R&D researchers amounted to 88,708 (72,664 by FTE) in Taiwan, rising from 46,173 (32,857 by FTE) in 1991, at the growth rate of 8.64%, as shown in Figure 2.3. The periods of 1986-1990, 1991-1995, and 1996-1999 all showed about the growth of 1.5 times, revealing the trend of steady growth, as depicted in Figure 2.4. Also, in 1998 the R&D researchers in private business sector amounted to 58% of the total R&D researchers, followed by 21.6% in research institutes and 20% in universities. The distribution of R&D researchers in different sectors showed little change over the period of 1989-1999 (see Figure 2.5).

FIGURE 2.3. THE TREND OF R&D RESEARCHER IN TAIWAN

Source: NSC, Indicators of Science and Technology R.O.C., 1995, 2000.

FIGURE 2.4. THE AVERAGE NUMBERS OF R&D RESEARCHER IN THREE PERIODS

Source: See Figure 2.3.

FIGURE 2.5. THE STRUCTURE CHANGE OF R&D RESEARCHER IN TAIWAN

Source: see Figure 2.3.

In 1998, the total R&D researchers by FTE in Taiwan was 71,118, after the U.S., Japan, China, Germany, U.K., France, South Korea, Canada, and Italy, as shown in Table 2.9.

TABLE 2.9. INTERNATIONAL COMPARISON OF R&D PERSONNEL (FTE)

	National R&D Researchers			Business R&D Researchers		
	1997	1998	1999	1997	1998	1999
U.S. ¹	964800	-	-	918600	974600	-
Japan	625442	652845		404232	429195	-
China	588700	485500	531100	-	-	-
Germany	235793	237712	-	132687	133529	
France	155302	-	-	70698	-	-
U.K.	146546	158671	-	83600	92280	-
South Korea	102660	-	-	69871	-	-
Canada ²	84583	-	-	46130	-	-
Italy	76056	-	-	27612	-	-
Taiwan	64580	71118	72664	39221	43903	46192
Australia	-	62250	-	14400	14087	
Spain	53883	60269	-	12009	13902	-
Netherlands	38055	39081	-	17302	18164	-
Sweden	36878	-	-	20924	-	-
Belgium	23486	-	-	11805	-	-
Finland	21149	23745		8675	9689	-
Norway	17490	-	-	9348	-	-
Denmark	17443	-	-	7522	-	-
Portugal	13607	-	-	1193	-	-
New Zealand	8264	-	-	1692	-	-
Ireland	7825	-	-	5098	-	-

Note: 1. The latest data of national R&D researchers for the U.S is in 1993, Business R&D researchers in 1997.

2. The latest data of national R&D researchers for Canada is in 1995.

3. Business R&D researchers in China are calculated by FTE.

Source: See Table 2.6.

The number of R&D researchers by FTE per 10 thousand in the labor force in Taiwan in 1999 was 75, raised from 38.4 in 1991, as shown in Figure 2.6. Compared with OECD countries, in 1999 only four countries including Japan's 96, Finland's 94, Sweden's 84, Norway's 76 had better rankings than Taiwan. As for the average annual growth rate in the period of 1991-1998, Taiwan's 10.22% led all OECD countries (see Table 2.10).

(3) Knowledge Diffusion

The selected indicators and associated references are summarized in Table 2.11:

FIGURE 2.6. R&D RESEARCHERS PER 10 THOUSAND LABOUR FORCE IN TAIWAN

Source: See Figure 2.3.

TABLE 2.10. R&D RESEARCHERS (FTE) PER 10 THOUSAND LABOUR FORCE

	1981	1991	1998	Average Growth Rate
Japan	69	92	96	0.61
Finland	-	55	94	7.96
Sweden ¹	41	59	84	6.06
Norway ¹	38	63	76	3.18
Taiwan	25	38	75	10.22
U.S. ³	62	75	74	-0.67
Australia	35	55	67	2.86
Denmark ¹	25	41	61	6.85
Germany	44	61	60	-0.24
France ¹	36	52	60	2.41
Canada ¹	31	46	57	3.64
U.K.	47	45	55	2.91
Switzerland ²	-	45	55	4.10
Belgium ¹	31	43	54	3.87
Ireland ¹	17	39	51	4.57
Netherlands	34	40	50	3.24
South Korea ¹	14	40	47	2.72
New Zealand ¹	34	40	44	1.60
Spain	14	26	37	5.17
Italy ¹	23	31	32	0.53
Portugal ¹	7	12	27	14.47
China	-	20	21	0.70

Notes: 1: 1997; 2: 1996; 3: 1993.

Source: See Table 2.14.

TABLE 2.11. SUMMARY OF KNOWLEDGE DIFFUSION INDICATORS

Types	Indicators	Source
ICT Infrastructure and Use	<ul style="list-style-type: none"> • PC in use • PC per 1000 people • Million of instructions per second (MIPS) • MIPS per 1000 people • Internet users per 1000 people • Phone lines per 100 inhabitants • Cellular phone subscribers per 1000 inhabitants • International phone costs • Availability of IT skills • New IT meets business requirement • E-commerce enhancing business opportunities 	IMD Computer Industry Almanac database (2001)
Social Innovation Capital	<ul style="list-style-type: none"> • Technological cooperation between firms • Technological transfer between firms and the academia • Values of society (hard work, innovation) support competitiveness 	IMD Global Competitiveness Report 2000-2001

a. ICT Infrastructure and Use

Under the consideration of data availability and comparability, in this paper some indicators used by IMD in its Global Competitiveness Report are chosen as follows:

- **PC in use (% of world total).** Among the 49 countries reported by IMD's Computer Industry Almanac, in 2001 Taiwan's 1.38% ranked 14th, rising from the 16th in 2000. In Asia, only Japan, China, and South Korea ranked better in 2001. The first 5 countries were the U.S., Japan, Germany, U.K., and France in the ranking order.
- **PC per 1000 people.** In 2001 Taiwan's 336 ranked 22nd, rising from 226 in 2000. In Asia, only Singapore's 440 and Japan's 414 ranked better in 2001. Apart from the Asian countries, the U.S., Sweden, Finland, Norway, and Denmark were among the top.
- **Million of instructions per second (MIPS).** In 2001 Taiwan ranked 17th, following after Japan, China, and South Korea among the Asian countries. On the whole, the U.S., Japan, Germany, U.K., and France were among the top five, and the U.S. alone amounted to 35.63% of the world total.
- **MIPS per 1000 people.** In 2001 Taiwan ranked 23rd, ranking after Singapore (the 11th) and Japan (the 19th) among the Asian countries. On the whole, the U.S. ranked still the first.

- **Internet users per 1000 people.** In 2001 Taiwan's 314 ranked 15th, ranking after South Korea's 402 (ranking 7th) and Hong Kong's 324 (ranking 14th) among the Asian countries. On the whole, Canada's 501, Sweden's 496, Norway's 490, the U.S.'s 488, Denmark's 487, Finland's 462, and South Korea were among the top.
- **Phone lines per 1000 inhabitants.** In 2001 Taiwan's 598 ranked 12th, ranking the first among the Asian countries. On the whole, Norway, the U.S., Swiss, Denmark, and Sweden were among the top five.
- **Cellular phone subscribers per 1000 inhabitants.** In 2001 Taiwan's 750 ranked 2nd, shared with Austria, followed by Hong Kong's 749.4. Finland ranked the first.
- **International phone costs.** The higher the international phone costs, the more people could not afford to use the related facilities. Hence, in IMD's reports, higher international costs lead to the lower ranks. In 2001, Taiwan ranked 35th, falling from the 29th in 2000. On the whole, Swiss, Netherlands, Germany, Norway, and the U.S. ranked the top five.
- **Availability of IT skills.** In 2001, Taiwan ranked 12th, falling from the 8th in 2000, ranking after Singapore among the Asian countries. On the whole, North European countries and the U.S. led all the other countries.
- **New IT meets business requirement.** In 2001, Taiwan ranked 20th, falling from the 16th in 2000, ranking after Singapore among the Asian countries. On the whole, Finland, Sweden, Singapore, the U.S., and Canada ranked the top five.
- **E-commerce enhancing business opportunities.** In 2001, Taiwan ranked 18th, falling from the 12th in 2000, ranking after Singapore and Hong Kong among the Asian countries. On the whole, Finland, the U.S., Sweden, Singapore, and Australia ranked the top five.

b. Social Innovation Capital

Indicators of this category are still at their early stage. In this paper, "technological cooperation between firms," "technological transfer between firms and the academia," and "values of society (hard work, innovation) support competitiveness" used by IMD in its Global Competitiveness Report are chosen for measuring the degree of knowledge diffusion.

As shown in Table 2.12, in 2001 Taiwan ranked 10th for technological cooperation between firms, rising from the 12th in 2000, ranking after Japan (the 8th) and Singapore (the 9th) among the Asian countries. On the whole, Finland, Sweden, Israel, the

U.S., and Iceland ranked the top five. For technological transfer between firms and the academia, in 2001 Taiwan ranked 12th, falling from the 11th in 2000, nevertheless in Asia ranking the first. On the whole, Finland, Israel, the U.S., Singapore, and Ireland ranked the top five. Finally, for the social values, in 2001 Taiwan ranked 9th, rising from the 10th in 2000, ranking the first among the Asian countries. On the whole, Singapore, the U.S., Iceland, Finland, and Hong Kong ranked the top five as in the previous year.

TABLE 2.12. INTERNATIONAL COMPARISON OF SOCIAL INNOVATION CAPITAL

IMD	Score	Inter-firm Tech-coop		Tech-Industry- Academia Tech-coop		Social Values		Composite Index	
		2000	2001	2000	2001	2000	2001	2000	2001
1	Finland	7.0120	7.7040	6.9140	7.6800	8.2220	8.2720	7.3827	7.8853
2	U.S.	6.3330	6.6780	6.5400	6.6500	8.1920	8.3800	7.0217	7.2360
3	Israel	6.8460	6.7270	5.8850	7.3500	7.2160	6.9700	6.6490	7.0157
4	Singapore	6.1640	6.0000	6.0330	6.1500	8.7210	8.5070	6.9727	6.8857
5	Iceland	6.4000	6.3330	5.3600	5.3300	8.2400	8.3330	6.6667	6.6653
6	Sweden	6.1580	6.8480	5.6580	5.5800	6.2370	6.8790	6.0177	6.4557
7	Canada	6.0320	6.0750	5.1290	5.5900	7.1940	7.5610	6.1183	6.4087
8	Netherlands	6.4940	6.1450	5.9750	5.5600	7.5370	7.3890	6.6687	6.3647
9	Australia	5.1340	5.8140	5.0310	5.3200	7.0000	7.8140	5.7217	6.3160
10	Ireland	5.6000	5.6070	5.4000	5.8900	7.6670	7.4290	6.2223	6.3087
11	Switzerland	6.2240	5.6360	5.7960	5.7300	7.7960	7.3860	6.6053	6.2507
12	Taiwan	5.9000	6.0000	5.2670	5.1800	7.3330	7.4430	6.1667	6.2077
13	Austria	5.1000	5.5600	4.8000	5.1000	6.7670	7.5200	5.5557	6.0600
14	Germany	6.2350	5.8700	5.3410	5.1400	6.8240	6.8050	6.1333	5.9383
15	Hong Kong	4.4680	5.0950	3.8300	4.4400	8.4580	8.1950	5.5853	5.9100
16	Denmark	5.7010	5.4080	4.8510	5.0700	6.4600	6.3940	5.6707	5.6240
17	Belgium	5.6000	5.3130	5.0250	4.8200	6.9000	6.4240	5.8417	5.5190
18	South Korea	3.9430	4.1690	4.1140	4.5600	8.1140	7.3240	5.3903	5.3510
20	U.K.	4.9600	5.1080	4.4000	4.2200	6.5800	6.3810	5.3733	5.2363
22	Japan	6.0810	6.0190	3.9390	3.6000	7.0910	5.6150	5.7037	5.0780
23	Norway	5.2330	4.8480	4.5670	4.1100	6.1000	6.2370	5.3000	5.0650
24	New Zealand	5.2630	5.1540	4.3860	4.0400	6.5000	5.8870	5.3830	5.0270
28	Spain	4.3140	4.3480	3.2290	3.2500	5.5070	7.0720	4.3500	4.8900
29	Malaysia	4.2570	4.1750	3.5940	3.8300	7.2570	6.2250	5.0360	4.7433
30	France	5.3850	4.9460	4.3520	3.8700	5.3190	5.3550	5.0187	4.7237
34	China	3.9330	3.1870	3.5780	2.9200	7.0670	7.4070	4.8593	4.5047
42	Portugal	3.6670	3.3960	2.9630	2.9100	5.7040	5.7780	4.1113	4.0280
43	Italy	4.1410	3.7690	2.8940	2.7700	5.8590	5.4100	4.2980	3.9830

Note: Composite index is the average of the above three scores.

Source: IMD: "The World Competitiveness Yearbook," 2000-2001.

Overall ranking can be obtained by the average of the above three rankings. In 2001, Taiwan ranked 12th, falling from the 9th in 2000. On the whole, Finland, the U.S., Israel, Singapore, Iceland, Sweden, Canada, Netherlands, Australia, Swiss, and Ireland ranked higher than Taiwan.

(4) Institutional Settings for Knowledge Diffusion

Also based on IMD report, the selected indicators include the degree of intellectual property protection, legal settings for technological development and application, financial settings for technological R&D, and availability of venture capital. The measurement is summarized in Table 2.13.

TABLE 2.13. INTERNATIONAL COMPARISON OF INNOVATION SETTINGS

Score		IP Protection Legal Settings				Financial Settings		Venture Capital Availability		Composite Index	
Rank	Countries	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
1	Finland	8.750	8.642	8.074	8.325	7.605	7.375	7.605	7.392	8.009	7.934
2	U.S.	8.762	9.091	7.228	7.567	7.127	6.756	8.619	8.117	7.934	7.883
3	Sweden	8.026	8.182	7.079	7.631	6.632	6.758	7.263	7.333	7.250	7.476
4	Netherlands	8.840	8.514	7.316	7.159	6.840	6.441	7.951	7.583	7.737	7.424
5	Israel	7.077	7.333	7.269	7.758	6.346	6.606	7.769	7.765	7.115	7.366
6	Ireland	8.400	8.145	7.333	7.429	6.467	6.321	6.847	6.893	7.262	7.197
7	Singapore	8.131	8.060	8.164	7.758	6.984	6.328	7.049	6.358	7.582	7.126
8	Germany	9.153	8.494	6.612	6.857	6.847	6.571	6.118	6.545	7.183	7.117
9	Denmark	8.575	8.338	6.989	6.535	6.506	6.200	6.138	6.732	7.052	6.951
10	Canada	8.548	8.658	6.742	7.358	5.129	5.185	6.516	6.488	6.734	6.922
11	Switzerland	8.980	8.759	7.143	7.310	5.531	6.409	4.857	5.114	6.878	6.898
12	Australia	8.887	8.628	6.887	7.318	5.175	4.907	5.583	5.835	6.633	6.672
13	Austria	8.933	8.520	6.633	6.680	5.233	5.400	4.167	5.520	6.242	6.530
14	Belgium	7.975	7.254	6.100	6.388	5.500	5.091	5.650	6.492	6.306	6.306
15	Iceland	7.920	7.333	6.800	6.500	5.760	5.333	5.920	6.000	6.600	6.292
16	Luxembourg	8.074	7.789	6.889	6.526	6.000	5.263	5.333	5.474	6.574	6.263
17	U.K.	8.720	8.238	6.440	6.071	4.520	4.238	6.970	6.415	6.663	6.241
18	Taiwan	6.867	7.038	6.687	6.380	5.233	5.063	7.133	6.354	6.480	6.209
19	France	8.267	7.892	6.418	5.785	5.582	5.312	5.685	5.739	6.488	6.182
20	Hong Kong	5.833	6.143	6.875	6.667	5.833	4.550	6.792	6.829	6.333	6.047
21	New Zealand	8.175	8.692	6.737	6.154	4.211	4.077	4.035	4.755	5.790	5.920
22	Norway	8.567	7.652	6.800	5.670	6.506	4.440	6.400	5.870	7.068	5.908
23	Japan	7.394	7.500	6.184	6.192	5.143	5.301	3.320	3.569	5.510	5.641
24	South Africa	7.000	6.753	6.100	6.494	3.567	3.684	5.051	4.442	5.430	5.343
25	Spain	6.943	6.058	5.686	5.652	4.257	4.029	4.600	4.824	5.372	5.141

Source: See Table 2.12.

For the degree of intellectual property protection, in 2001 Taiwan ranked 23rd, rising from the 28th in 2000. On the whole, leading countries included the U.S., Swiss, New Zealand, Canada, and Finland.

For the legal settings for technological development and application, in 2001 Taiwan ranked 20th, falling from the 17th in 2000. On the whole, leading countries included Finland, Israel, Singapore, Sweden, and the U.S.

For the financial settings for technological R&D, in 2001 Taiwan ranked 18th, ranking after Singapore and Japan among the Asian countries. On the whole, leading countries included Finland, Sweden, the U.S., Israel, and Germany.

Finally, for the availability of venture capital, in 2001 Taiwan ranked 14th, falling from the 6th in 2000, ranking after Hong Kong and Singapore among the Asian countries. On the whole, leading countries included the U.S., Israel, Netherlands, Finland, and Sweden.

Likewise, overall ranking can be obtained by the average of the above scores. In 2001, Taiwan ranked 18th, the same as in 2000. On the whole, Finland, the U.S., Sweden, Netherlands, Israel, Ireland, Singapore, and Germany were among the leading countries.

(5) Direct Knowledge Output and Knowledge Application

The selected indicators for direct knowledge output and knowledge application are summarized in Table 2.14.

TABLE 2.14. SUMMARY OF KNOWLEDGE OUTPUT INDICATORS

Type	Indicators	Source
Direct Knowledge Output	1. SCI Publications	1. US ISI Co., National Science Indicators on Diskette
	2. EI Publications	2. US E.I. Inc., COMPENDEX
	3. Patents Granted in the U.S.	3. USPTO
Knowledge Application	1. Export Composition	1. OECD, STAN Database 2. Import and Export Magnetic Tape, R.O.C.
	2. Industrial Composition	1. OECD, STAN Database 2. National Income Annual Report, R.O.C. 3. MOEA Industrial Production Report (1986-1999)
	3. Employment of Knowledge Workers	1. Yearbook of Manpower Statistics Taiwan Area, R.O.C. 2. APEC, Towards Knowledge-Based Economies In APEC (2000, 9) 3. OECD, STAN Database

a. The Number of Publications on SCI

In 1999, Taiwan's number of publications on SCI amounted to 8,931, ranking

19th, the same ranking as in 1998, but increased in quantity from 8,601, as shown in Table 2.15. The first 10 countries in the ranking order were the U.S., Japan, U.K., Germany, France, Canada, Italy, Russia, Australia, and Spain. China ranked 11th in 1999, rising from the 12th in 1998.

As shown in Table 2.15, for the number of publications on SCI per capita, in 1999 Taiwan's 405 ranked 15th. On the whole, the leading countries were Swiss (1,904), followed by Sweden, Israel, U.K., Netherlands, Australia, Canada, Belgium, the U.S., and France.

TABLE 2.15. INTERNATIONAL COMPARISON OF SCI AND EI PUBLICATIONS

Nation	SCI				Nation	EI			
	1999		1998			1999		1998	
	Amount	Rank	Amount	Rank		Amount	Rank	Amount	Rank
U.S.	245,284	1	244,654	1	U.S.	53,099	1	52,369	1
Japan	68,684	2	66,832	2	Japan	21,451	2	19,128	2
U.K.	67,069	3	65,494	3	China	11,347	3	12,584	3
Germany	63,257	4	62,787	4	U.K.	11,001	4	11,280	4
France	46,337	5	45,434	5	Germany	10,775	5	9,856	5
Canada	32,657	6	31,666	6	France	7,860	6	7,366	6
Italy	29,314	7	28,793	7	Canada	6,081	7	6,237	7
Russia	24,492	8	24,765	8	Italy	5,304	8	5,084	8
Australia	20,682	9	20,066	9	Russia	4,991	9	4,015	10
Spain	20,650	10	19,424	10	South Korea	4,777	10	3,645	11
China	19,849	11	16,612	12	Taiwan	4,376	11	4,026	9
Netherlands	18,042	12	18,116	11	India	4,333	12	3,613	12
India	16,046	13	14,923	13	Australia	3,328	13	3,176	13
Sweden	14,675	14	14,356	14	Spain	3,266	14	2,928	14
Switzerland	13,576	15	13,001	15	Netherlands	2,666	15	2,582	15
South Korea	10,992	19	9,503	16	Sweden	2,615	16	2,533	16
Belgium	9,651	17	9,321	17	Brazil	2,022	17	1,628	18
Brazil	8,941	18	7,918	20	Poland	1,993	18	1,558	19
Taiwan	8,931	19	8,601	19	Singapore	1,854	19	1,213	23
Israel	8,686	20	8,806	18	Switzerland	1,809	20	1,680	17

Source: NSC (2000), Indicators of S&T.

b. The Number of Publications on EI

In 1999, Taiwan's number of publications on EI amounted to 4,376, ranking 11th, falling from 9th in 1998, but increased in quantity from 4,026, as shown in Table 2.15. The first 10 countries in the ranking order were the U.S., Japan, China, U.K., Germany, France, Canada, Italy, Russia, and South Korea. As for the number of publications on EI per capita, as shown in Table 2.15, in 1999 Taiwan's 199 ranked 5th, following after Singapore, Sweden, Swiss, and Canada. The relative strength of

Taiwan in engineering research is significant.

c. The Number of Patents Granted in the U.S.

In 1999, Taiwan's number of patents granted in the U.S. amounted to 5,806, rising from 4,667 in 1998 and ranked 4th, the same ranking as in 1998, ranking after the U.S., Japan, and Germany, as shown in Table 2.16. As for the number of patents granted in the U.S. per capita, in 1999 Taiwan's 261 ranked the second, after the U.S. The relative strength of Taiwan in the U.S.-granting patents, at least in quantity, is even more significant.

TABLE 2.16. INTERNATIONAL COMPARISON OF PATENTS GRANTED IN THE U.S.

Nation	Patents Granted in the U.S. (all types)				Nation	Patents Granted in the U.S. (Inventions)			
	2000		1999			2000		1999	
	Number	Rank	Number	Rank		Number	Rank	Number	Rank
World	176,087	-	169,146	-	World	157,497	-	153,485	-
U.S.	97,016	1	94,090	1	U.S.	85,072	1	83,905	1
Japan	32,924	2	32,514	2	Japan	31,296	2	31,104	2
Germany	10,822	3	9,895	3	Germany	10,234	3	9,337	3
Taiwan	5,806	4	4,526	4	Taiwan	4,667	4	3,693	5
France	4,173	5	4,097	5	France	3,819	5	3,820	4
U.K.	4,090	6	3,900	6	U.K.	3,667	6	3,572	6
Canada	3,925	7	3,678	8	Canada	3,419	7	3,226	8
South Korea	3,472	8	3,679	7	South Korea	3,314	8	3,562	7
Italy	1,967	9	1,686	9	Italy	1,714	9	1,492	9
Sweden	1,738	10	1,542	10	Sweden	1,577	10	1,401	10
Switzerland	1,458	11	1,390	12	Switzerland	1,322	11	1,279	11
Netherlands	1,410	12	1,396	11	Netherlands	1,241	12	1,247	12
Australia	859	13	832	13	Israel	783	13	743	13
Israel	836	14	792	14	Australia	704	14	707	14
Belgium	756	15	718	13	Belgium	694	15	648	16
Finland	649	19	695	15	Finland	618	16	649	15
Hong Kong	548	17	413	19	Austria	505	17	479	17
Austria	537	18	505	18	Denmark	436	18	487	18
Denmark	509	19	588	17	Spain	270	19	222	20
Spain	318	20	265	20	Norway	248	20	224	19

Source: USPTO.

d. The Composition of Exported Products

Based on the definition by OECD (1999) of knowledge-intensive industries, as shown in Table 2.17, the export of the associated products in 2000 amounted to

69.02% of the total export, rising from 45.72% in 1989. The knowledge-intensive products have become the major component of the export in Taiwan.

TABLE 2.17. THE STRUCTURE OF MANUFACTURING'S EXPORTS IN TAIWAN

(unit: %)

Year	High-tech	Med-high-tech	Med-low-tech	Low-tech	K-I	Non-KI	Total
1989	21.55	24.17	25.73	28.55	45.72	54.28	100.00
1990	22.86	25.43	24.49	27.22	48.29	51.71	100.00
1991	22.82	26.17	23.85	27.16	48.99	51.01	100.00
1992	23.70	27.29	24.04	24.97	50.99	49.01	100.00
1993	25.43	28.49	23.13	22.94	53.93	46.07	100.00
1994	27.26	28.39	22.01	22.34	55.65	44.35	100.00
1995	30.59	29.05	20.41	19.96	59.64	40.36	100.00
1996	32.22	28.41	20.16	19.21	60.63	39.37	100.00
1997	34.37	27.54	20.51	17.58	61.91	38.09	100.00
1998	36.78	26.33	20.29	16.60	63.11	36.89	100.00
1999	39.42	26.57	19.21	14.79	66.00	34.00	100.00
2000	42.69	26.34	18.21	12.77	69.02	30.98	100.00

Source: OECD, STAN databased 2001.

R.O.C. Custom Import-Export Data, calculated by T.J.E.R.

As for the international comparison, in 2000 the proportion of exported knowledge-intensive products in the total exported in Taiwan was the highest in the world, followed by the U.S.'s 32.21%, U.K.'s 29.60%, South Korea's 31.49%, Japan's 25.72%, and Netherlands' 25.44%, as shown in Table 2.18 and Figure 2.7.

TABLE 2.18. INTERNATIONAL COMPARISON OF KI MANUFACTURING EXPORTS IN 1999

Country	High-tech	Med-high-tech	Med-low-tech	Low-tech	K-I Manf.
Denmark	14.53	32.59	19.17	33.71	47.12
Finland	21.57	27.04	18.08	33.31	48.61
Italy	8.45	42.30	24.63	24.50	50.75
Netherlands	25.44	33.28	17.17	24.12	57.71
Canada	11.54	47.69	18.03	22.74	59.23
South Korea	31.49	29.15	23.79	15.56	60.64
France	21.17	43.22	16.05	19.06	64.38
Taiwan	39.42	26.57	19.21	14.79	66.00
U.K.	29.60	41.15	14.97	13.62	70.74
Germany	14.65	57.00	16.07	12.28	71.65
U.S.	32.21	43.18	12.65	11.96	75.39
Japan	25.72	56.95	14.45	2.89	82.66

Source: See Table 2.17.

FIGURE 2.7. THE RATIO OF HIGH-TECH AND K-I EXPORTS TO MANUFACTURING EXPORTS AMONG MAJOR COUNTRIES

Source: See Table 2.17.

e. The Ratio of Knowledge-intensive Industrial Value-added to GDP

When dividing knowledge-intensive industries into two groups, knowledge-intensive manufacturing industries and knowledge-intensive service industries, such developed countries as Germany, France, the U.S., U.K., Japan, Finland, Denmark, and the like, have their knowledge-intensive service sector amounted to approximately 45%-55% of the entire industry sector. In sharp contrast, Taiwan or South Korea showed the opposite, revealing the large room for upgrading the knowledge-intensive service sector (See Table 2.19).

TABLE 2.19. INTERNATIONAL COMPARISON OF KI INDUSTRIES AS % OF DPI

(unit: %)

Country	Year	KI Manufacturing	KI Service	KI Industries
Denmark	1999	8.14	49.30	57.44
Finland	1999	10.18	45.26	55.44
Italy	1999	7.35	46.93	54.28
Canada	1997	7.04	47.06	54.10
South Korea	1999	13.33	36.71	50.04
France	1998	7.40	54.85	62.25
Taiwan	1999	13.50	34.11	47.60
U.K.	1999	7.80	51.56	59.36
Germany	1998	11.69	53.01	64.70
U.S.	1999	8.06	52.35	60.41
Japan	1998	10.81	48.10	58.91

Note: DPI Stands for Domestic Product of Industry.

Source: OECD, STAN database 2001, TIER.

f. The Ratio of Knowledge Workers to the Labor Force

Based on the definition of APEC (2000), this paper classifies legislators, business managers, and other professional personnel as the knowledge workers. As shown in Table 2.20, in 2000 the ratio of knowledge workers to the labor force in Taiwan was 26.71%, rising from 17.16% in 1987, showing some upgrading in the knowledge intensity of the labor force.

TABLE 2.20. KNOWLEDGE WORKERS IN THE LABOR FORCE IN TAIWAN

Year	(unit: thousands, %)								Ratio of Knowledge Workers to Employments	Ratio of Knowledge Workers to Labor
	Legislators, Business Managers	Professionals	Technologists	Admin Personals	Service Personals	Worker in Privacy	Workers	Knowledge Workers		
	a	b	c	d	e	f	g	a+b+c		
1987	315	357	732	591	1286	1212	3259	1404	17.50	17.16
1988	347	372	797	623	1359	1099	3510	1516	18.70	18.38
1989	371	395	863	650	1397	1053	3530	1629	19.72	19.42
1990	391	427	963	661	1383	1054	3405	1781	21.50	21.14
1991	408	434	1019	698	1410	1082	3387	1861	22.05	21.72
1992	432	462	1088	732	1440	1055	3424	1982	22.96	22.61
1993	441	485	1231	806	1405	995	3382	2157	24.67	24.31
1994	436	479	1296	839	1438	965	3486	2211	24.73	24.35
1995	436	500	1338	877	1479	942	3473	2274	25.14	24.69
1996	429	542	1376	922	1530	906	3362	2347	25.89	25.21
1997	420	560	1426	938	1550	865	3416	2406	26.22	25.51
1998	425	578	1498	955	1597	810	3426	2501	26.92	26.20
1999	414	601	1571	995	1667	764	3373	2586	27.55	26.75
2000	412	610	1591	1027	1712	726	3413	2613	27.53	26.71

Source: TIER.

Given the limited international data, comparison can only be made between some countries. As illustrated in Figure 2.8, Singapore's knowledge workers amounted in 1997 to 39.1% of the labor force, followed by Australia's 35.5%, Canada's 33.3%, the average of OECD countries 28%, all higher than Taiwan (see Figure 2.8).

As for the employment opportunities provided by the knowledge-intensive service sector, in 1999 Taiwan's knowledge-intensive service sector amounted only to 28.43% of the total employment, much lower than the U.S.'s 53.77%, Finland's 51.09% (in 1995), Canada's 49.14% (in 1996), and Japan's 47.16%. Considering the fact that more than 30% of GDP is attributable to the knowledge-intensive service sector in Taiwan, its employment contribution seemed relatively small (see Figure 2.9).

The above measurement indicates the followings: (1) while Taiwan performed relatively well in the investment in education and R&D, right next to that of the developed countries in general, the ICT investment on the other hand showed relative

shortage; (2) similar to the above flow indicators, the selected stock indicators revealed mixed messages: while human resources in R&D showed relatively well-organized performance, the national education level had obvious disadvantages compared with the developed countries; (3) in the aspect of knowledge diffusion, our measurement indicated that ICT infrastructure and its use illustrated for the most part some distance behind the developed countries, while the composite indicator of technological cooperation between the firms, technology transfer between the firms and universities, and social value indicators in IMD 2001 report ranked Taiwan the 12th, among the leading group; (4) in the institutional set of indicators for knowledge diffusion, Taiwan seemed to be in the relatively weak position; (5) regarding the direct knowledge output, Taiwan showed quantitatively exceptional performance both in professional publication and patents, consistent with the relative strong performance in R&D human resources; (6) indicators for the knowledge application and economic impact showed that Taiwan's knowledge intensive service sector was much weaker than manufacturing sector. Such feature suggests some development lag behind the developed countries.

To sum up, our measurement reflects the potential of Taiwan's KBE development, which nevertheless indicates considerable room for improvement. Except for ICT investment, the rest of knowledge investment indicators supported the perspective of Taiwan's KBE development. However, the knowledge diffusion perhaps is the weakest part for Taiwan's KBE development; Taiwan needs much improvement in order to stay close to the developed countries. Finally, as for the knowledge output and application, Taiwan's outstanding performance in research publication and patents is consistent with that in R&D human resources, but the obviously weak performance of knowledge-intensive service sector might have resulted from Taiwan's relative disadvantages indicated by the measurement of the knowledge diffusion.

FIGURE 2.8. INTERNATIONAL COMPARISON OF KNOWLEDGE WORKERS AS % OF THE LABOUR FORCE IN 1997

Source: APEC (2000), Yearbook of Manpower Statistics Taiwan Area 2000, Taiwan R.O.C.

FIGURE 2.9. INTERNATIONAL COMPARISON OF KI INDUSTRY'S EMPLOYEE SHARES

Source: OECD, STAN Database; see Figure 2.8.

CONCLUSION

One weakness in our research would be the failure in addressing the crucial issues such as institutional settings for promoting industrial innovation, academia-industry interaction, financial market development, human resource development, innovation networks or clusters, as well as the changing international economic environment resulting from the development of globalization. It is our conviction that more research efforts should be devoted into the above areas in a more thorough and comprehensive manner.

Another shortcoming in our indicator system would be the failure of including the negative impacts resulting from the development of KBE. As widely perceived, the speedy progress of knowledge might enlarge the wealth gap between those who make a good use of knowledge and those who do not. Moreover, higher degree of industrial specialization but shorter life cycles of products for every country in the world may lead to more frequent excessive fluctuations owing to some unexpected changes especially in small open economies such as Taiwan. It has become more and more important to seek safeguard against the above problems as we proceed toward the KBE. Hence, our research in this paper shall be regarded as a preliminary step toward further researches in the near future.

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