Pergamon

Technology in Society 23 (2001) 227–240

Technology In Society

www.elsevier.com/locate/techsoc

# A cross-national comparative analysis of innovation policy in the integrated circuit industry

Joseph Z. Shyu *, Yi-Chia Chiu, Chao-Chen Yuo

*Institute of Management of Technology, National Chiao-Tung University, P.O. Box 7-17 Hsinchu, Taiwan, ROC*

**Abstract**

This research discusses innovation policies in the integrated circuit industries of the Republic of Korea, Taiwan, the United States, and the People's Republic of China. Using Rothwell and Zegveld's model of industrial innovation policy as a starting point, this research compares innovation policy across the four nations, specifically focusing on three topics: (1) national preferences for innovation policy; (2) the influence of innovation policy on industry innovation requirements; and (3) the competitive advantages realized as a result of industrial innovation requirements in the four countries. Our research indicates the policy tools used by each country, followed by results that indicate the effectiveness of industry innovation policies on requirements for industry innovation.

This work generates several suggestions for Taiwan's integrated circuit industry: the Taiwan government should emphasize specific policies to provide a better research and development environment; it should build a complete information system that encourages knowledge diffusion and accumulation; and it should adopt *Procurement* as a policy to extend domestic market demand. 

*Keywords:* Innovation policy; National innovation system; Industrial innovation; Integrated circuit industry

## 1. Introduction

Knowledge is a key strategic resource for economic development world-wide [1,2], and innovation is one of the primary means of obtaining this knowledge. Tech-

* Corresponding author.
*E-mail address:* joseph@cc.nctu.edu.tw (J. Z. Shyu).


PII: S0160-791X(01)00011-2

nological innovation has played a critical role in the integrated circuit (IC) industry and, over the past 50 years, strong relationships have been created between IC industry innovations and government innovation policies in many countries. In the 1950s, as the semiconductor industry was emerging, propelled in part by the Cold War between the USA and Russia, the IC industry began evolving as a result of concentrated governmental procurement and military support of various related research and development (R&D) activities.

For example, Korea decided on a policy for IC industry development which brought in several foreign companies and encouraged them to import advanced technologies. Korea concentrated its resources on cultivating three major conglomerates that could compete in the global market, successfully bringing DRAM to the global market. Similarly, the Taiwan IC industry introduced technology that had been produced by the RCA Company. Taiwan's Industrial Technology Research Institute (ITRI) was then responsible for transferring this technology to various companies.

Numerous studies based on the "national systems of innovation" approach found that national government policies can make a significant difference, as seen from the various performance levels of neighboring countries [3]. Clearly, research on national innovation policy is becoming much more important.

Few papers have offered a comprehensive analysis of cross-national innovation policy. This article reports on our comparative analysis of innovation policy covering a developed country (the USA); emerging industrial countries (Korea and Taiwan); and a fast developing country (mainland China).

## 2. Innovation and innovation policy

### *2.1. Emergence of the concept of innovation*

Schumpeter defines innovation as the activity of developing an invented element into a commercially useful element that becomes accepted in a social system [4]. Drucker wrote: "Business has only two basic functions: marketing and innovation. Marketing and innovation produce results. All the rest are costs" [5]. Innovation is also regarded as the use of new knowledge to offer a new product or service which customers want [6]. However, some scholars argue that this is actually the first application of invention.

The process of innovation cannot be separated from a firm's strategic and competitive context [7]. Therefore, innovation includes a series of activities such as science, technology, organization, finance, and commerce. Innovation is not a single function; rather, it is a network that interacts with all the value-chain activities. Innovation plays different roles for companies and for governments. Companies develop new products through innovation; a government uses innovative policies to enhance its industrial innovative capacity. The primary objective for companies engaged in innovation is higher profits; for governments, it is overall economic development.

Sundbo suggested that innovation theory has had three paradigms since the beginning of the twentieth century: (1) entrepreneurship paradigm; (2) technology–economic paradigm; and (3) strategic paradigm [8].

#### 2.1.1. *Entrepreneurship paradigm*

This paradigm emerged around 1900, evolving out of the economic wave of growth in the late nineteenth century, and early innovation theories were intended to explain this growth. This was the period of the "great founder", and the fundamental element in these theories was the entrepreneur — an individual who is driven by some need to create business activities. Thus, the behavior of these individuals helped explain economic growth.

#### 2.1.2. *Technology–economic paradigm*

In the late 1930s, through the 1940s and into the 1950s, a new wave of world economic growth appeared. Enterprises had grown into large companies and were well-organized. The number of engineers and technicians increased greatly, and technological development became the key factor in new innovation.

#### 2.1.3. *Strategic innovation paradigm*

The basis of this paradigm is the market functions of a firm. In 1960, Levitt [9] wrote his seminal article rejecting Schumpeter's postulate that the entrepreneur is the active creator of economic growth through innovation. Levitt's theories emphasized the innovation function, but only from a pure pull or marketing view. He argued that innovation involved seeing new market possibilities and exploiting them by marketing new or old products in new ways or in new combinations.

### 2.2. *Policy perspectives on innovation*

According to studies by Edquist and Hommen [10], innovation policies can be classified as demand-side oriented or supply-side oriented. Similarly, theories of innovation process can be classified as linear or systems-oriented. Important parallels and logical connections can be drawn from these two classifications. For instance, a linear view of the innovation process supports a supply-side orientation in innovation polices. Conversely, a systems perspective on innovation yields a more fruitful perspective from the demand side in terms of both theoretical and policy relevance.

### 2.3. *Industry innovation requirements (IIRs)*

Most management scholars and economists regard innovation as a fundamental factor in economic growth, but few people have studied the impact of innovation on economic growth. Until the mid-1960s, most studies discussed how innovation would change the structure and competitiveness of industry. Rothwell and Zegveld [11] pointed out that industry innovation could increase overall economic development. Porter [7] determined that, in order to upgrade local competitive advantages to the national level, new competitive theories must also consider technological progress and innovation.

Rothwell and Zegveld summarized the factors required for industry innovation, including *technical knowledge*, *manpower*, *market information*, *management skill*, *financial resources*, *research and development*, *R&D environment*, *domestic market*, and *international market*. These are shown in Fig. 1.

## 2.4. Innovation policy

Science, technology, and innovation policy (in the narrow sense) are specific parts of what could be labeled more broadly as “innovation policy”. Science policy is the most supply-side-oriented and the least direct of these policies. Technology policy is the most difficult to define because technological research varies significantly in the continuum from relatively mono-disciplinary scientific research to multidisciplinary commercial innovation. However, innovation policy, oriented toward appropriate new product ideas, production processes, and marketing concepts, can produce, at minimum, temporary competitive advantages [12].

The search for appropriate policy tools is not easy. Macro measures are not effective; thus, proposals like a general R&D tax credit are pointless. Policies must be designed to influence particular economic sectors and activities. In this regard, the key policy problem is to augment or redesign institutions rather than to achieve particular resource allocations [13]. A list of possible innovation policies given by Rothwell and Zegveld is summarized in Table 1. These policies can be grouped under three main headings.

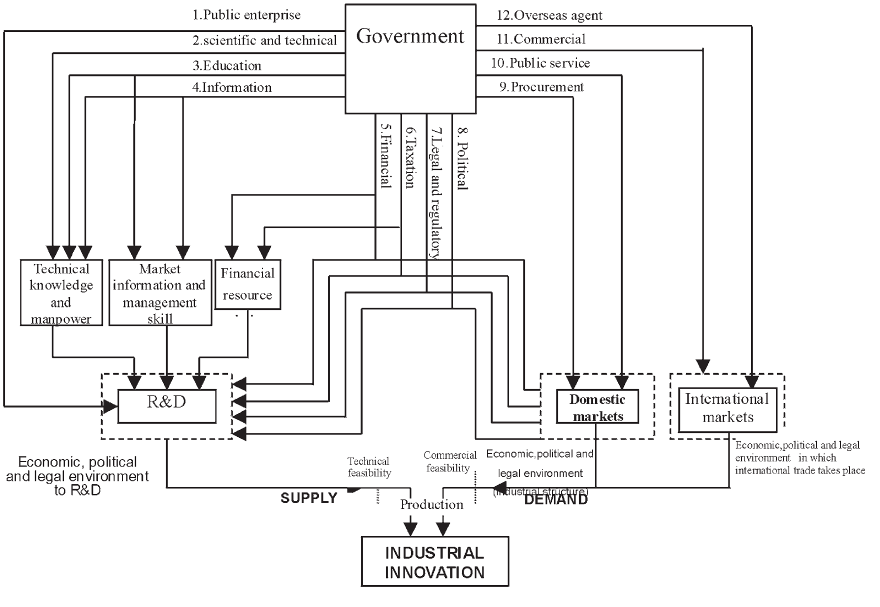


Fig. 1. Policy targets and tools for inducing innovation. Source [11, p59].

Table 1
Classification of government policy tools (source: Ref. [11, p. 59])

| | Policy tool | Example |
|---|---|---|
| Supply side | Public enterprise | Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, participation in private enterprise |
| | Scientific and technical development | Research laboratories, support for research associations, learned societies, professional associations, research grants |
| | Education | General education, universities, technical education, apprenticeship schemes, continuing and further education, retraining |
| | Information | Information networks and centers, libraries, advisory and consultancy services, databases, liaison services |
| Environmental side | Financial | Grant loans, subsidies, financial sharing arrangements, provision of equipment buildings or services, loan guarantees, export credits |
| | Taxation | Company, personal, indirect and payroll taxation, tax allowances |
| | Legal regulatory | Patents, environmental and health regulations, inspectorates, monopoly regulations |
| | Political | Planning, regional policies, honor or awards for innovation, encouragement of mergers of joint consortia, public consultation |
| Demand side | Procurement | Central or local government purchases and contracts, public corporations R&D contracts, prototype purchases |
| | Public services | Purchases, maintenance, supervision and innovation in health service, public building, construction, transport, telecommunications |
| | Commercial | Trade agreements, tariffs, currency regulations |
| | Overseas agent | Defense sales organizations |

1. *Supply*: provision of financial, manpower and technical assistance, including the establishment of scientific and technological infrastructure.
2. *Demand*: central and local government purchases and contracts, notably for innovative products, processes, and services.
3. *Environment*: taxation policies, patent policies and regulations, such as measures that establish the legal and fiscal framework in which an industry operates.

## 3. The cross-nation comparison

Innovation policies within the integrated circuit industries of four nations were investigated. Three issues are discussed which enabled us to produce a full cross-nation comparison: (1) the character and tendency of each nation's IC industry innovation policy; (2) the impact of innovation policy on IIRs; and (3) the competitiveness of each nation's IIRs.

The methodology used here includes both qualitative and quantitative methods. An empirical study and an expert survey questionnaire were used to determine the findings. First, we present the history and content of each nation's IC innovation policy. Then follows a comparison of each nation's IC innovation policy to highlight differences in each country. Second, we discuss the impact of policy tools on IIR. An expert questionnaire, completed by 34 experts, was designed to determine the competitiveness of every IIR in each nation. The analysis of variance (ANOVA) statistical method was used to calculate the data.

### *3.1. Cross-nation IC industry innovation policy tools*

Through secondary data collection, 72 innovation policy tools used by the US government, 96 from Korea, 159 from Taiwan, and 88 from mainland China were collected. Preliminary categorization results are shown in Table 2.

The main differences between the four national innovation policies are summarized in Table 3, which lists all factors with weights higher than 10%.

Tools that are common to all four countries are *scientific and technical*, and *legal regulatory*. In addition, each nation has unique tools. The US government used *procurement* as the main tool for guiding the development of its IC industry. Korea used *financial*, *taxation*, and *education* as innovation policy tools. Taiwan used *political*, *commercial*, *education*, and *financial* tools. Mainland China used the *commercial* tool to support its IC industry.

### *3.2. The impact of innovation policy tools on IIRs*

Using Fig. 1 as a basis, Shyu [14] defined the relationship between policy tools and IIRs, summarizing his findings in Fig. 2.

Based on these relationships, the impact of innovation policy on IIRs could then be studied, and the analysis results are shown in Table 4. Our research suggests that

Table 2
Analysis of cross-nation innovation policy tools

| | | Cross-national innovation policy tools | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | USA | | Korea | | Taiwan | | China | |
| | | Item | Weight | Item | Weight | Item | Weight | Item | Weight |
| Supply side | Public enterprise | 0 | 0.00 | 1 | 1.04 | 5 | 3.14 | 8 | 9.09 |
| | Scientific and technical development | 15 | 20.83 | 19 | 19.79 | 23 | 14.47 | 27 | 30.68 |
| | Education | 3 | 4.17 | 12 | 12.50 | 18 | 11.32 | 5 | 5.68 |
| | Information | 6 | 8.33 | 4 | 4.17 | 6 | 3.77 | 6 | 6.82 |
| Environment side | Financial | 2 | 2.78 | 19 | 19.79 | 17 | 10.69 | 3 | 3.41 |
| | Taxation | 7 | 9.72 | 12 | 12.50 | 9 | 5.66 | 5 | 5.68 |
| | Legal regulatory | 11 | 15.28 | 10 | 10.42 | 17 | 10.69 | 11 | 12.50 |
| | Political | 2 | 2.78 | 6 | 6.25 | 26 | 16.35 | 7 | 7.95 |
| Demand side | Procurement | 14 | 19.44 | 4 | 4.17 | 2 | 1.26 | 1 | 1.14 |
| | Public services | 5 | 6.94 | 2 | 2.08 | 15 | 9.43 | 4 | 4.55 |
| | Commercial | 7 | 9.72 | 7 | 7.29 | 20 | 12.58 | 11 | 12.50 |
| | Overseas agent | 0 | 0.00 | 0 | 0.00 | 1 | 0.63 | 0 | 0.00 |
| | Total | 72 | 100 | 96 | 100 | 159 | 100 | 88 | 100 |

Table 3
Cross-national innovation policy comparison

| Inclination of every nation's innovation policy tools | USA | Korea | Taiwan | Mainland China |
|---|---|---|---|---|
| Unique policy tools | Procurement | Financial<br>Taxation<br>Education | Political<br>Commercial<br>Education<br>Financial | Commercial |
| Common policy tools | Scientific and technical, Legal regulatory | | | |

| | | Innovation policy tool | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | public enterprise | SciENTIfic and technical | education | information | Financial | taxation | legal Regulatory | political | procurement | public services | commerial | overseas agent |
| IIRs | R&D | ● | □ | □ | □ | □ | □ | | | | | | |
| | TECHNICAL KNOWLEDGE | | ● | ● | □ | | | | | | | | |
| | RESEARCH ENVIRONMENT | | □ | □ | □ | □ | □ | ● | ● | | | | |
| | MANAGEMENT SKILL | | | ● | ● | | | | | | | | |
| | MANPOWER | | ● | ● | □ | | | | | | | | |
| | FINANCIAL RESOURCE | | | | | ● | ● | | | | | | |
| | MARKET INFORMATION | | | ● | ● | | | | | | | | |
| | DOMESTIC MARKET | | | | | □ | □ | □ | □ | ● | ● | | |
| | INTERNATIONAL MARKET | | | | | | | | | | | ● | ● |

● directly related □ indirectly related

Fig. 2. Relationship between policy tools and IIRs.

US government innovation policy tools have the greatest influence on *domestic market*, which accounts for 20.85%, followed by *research and development* at 16.61%. The smallest impact is on *market information*, *international market*, *management skills*, and *financial resources*, which account for 3.91%, 4.56%, 5.86%, and 5.86%, respectively.

Korean government innovation policy tools have the greatest influence on *research and development*, which accounts for 19.19%. The smallest impact is on *inter-*

Table 4
The impact of innovation policy tools on IIRs

| Industry innovation requirements (IIRs) | Nation | | | |
|---|---|---|---|---|
| | USA | Korea | Taiwan | Mainland China |
| 1. R&D | 16.61[a] | 19.19[a] | 17.49[a] | 22.60[a] |
| 2. Technical knowledge | 13.68[a] | 12.79[a] | 12.41[a] | 16.83[a] |
| 3. R&D environment | 14.98[a] | 16.67[a] | 16.31[a] | 15.83[a] |
| 4. Management skill | 5.86 | 6.20 | 6.77 | 5.29 |
| 5. Manpower | 13.68[a] | 12.79[a] | 12.41[a] | 16.83[a] |
| 6. Financial resource | 5.86 | 12.02[a] | 7.33 | 3.85 |
| 7. Market information | 3.91 | 5.43 | 6.77 | 5.29 |
| 8. Domestic market | 20.85[a] | 12.21[a] | 14.53[a] | 8.65 |
| 9. International market | 4.56 | 2.71 | 5.92 | 5.29 |

[a] Influential extent exceeds 10%.

*national market*, *market information*, and *management skill*, which account for 2.73%, 5.43%, and 6.20%, respectively.

Taiwan government innovation policy tools have the greatest influence on *research and development*, which accounts for 17.49%, followed by *R&D environment* which accounts for 16.31%. The smallest impact is on *international market*, *market information*, and *management skill*, accounting for 5.92%, 6.77%, and 6.77%, respectively.

Mainland China government innovation policy tools have the greatest influence on *research and development*, which accounts for 22.60%, followed by *technical knowledge* and *manpower*, each accounting for 16.83%. The smallest impact is on *financial resource*, *international market*, *market information*, and *management skill*, accounting for 3.85%, 5.29%, 5.29%, and 5.29%, respectively.

The impact of cross-nation IC industry policy tools on IIRs was found primarily on *research and development*, *R&D environment*, *technical knowledge*, and *manpower*. Other IIRs, such as *management skill*, *market information*, and *international market* received a much lower impact. Table 5 shows a clear comparison of every nation's policy tools on IIR.

### *3.3. The relative competitiveness of each nation's IIRs*

Our research adopted Rothwell and Zegveld's concepts of IIRs as the major variables in questionnaires sent to experts. To test the reliability of the questionnaires, the Cronbach Alpha method was used. The results are shown in Table 6.

If we regard 0.75 as the standard, the four nation's Cronbach Alpha values are above this standard. The reliability of the questionnaire is *critical high*. ANOVA and Tukey statistical methods were used to evaluate the competitiveness of each nation's IIRs. The results are shown in Table 7, which indicates the competitive conditions for every nation with respect to innovation.

Table 5
A comparison of each nation's policy tools in IIR (note: items in italics denote common characteristics)

| | USA | Korea | Taiwan | Mainland China |
|---|---|---|---|---|
| Exceeds 10% | 1. Domestic market | *1. R&D* | *1. R&D* | *1. R&D* |
| | *2. R&D* | *2. R&D environment* | *2. R&D environment* | *2. Technical knowledge* |
| | *3. R&D environment* | *3. Technical knowledge* | 3. Domestic market | *3. Manpower* |
| | *4. Technical knowledge* | *4. Manpower* | *4. Technical knowledge* | *4. R&D environment* |
| | *5. Manpower* | 5. Domestic market | *5. Manpower* | |
| | | 6. Financial resource | | |
| Below 10% | *6. Management skill* | *7. Management skill* | 6. Financial resource | 5. Domestic market |
| | 7. Financial resource | *8. Market information* | *7. Management skill* | *6. Management skill* |
| | *8. International market* | *9. International market* | *8. Market information* | *7. Market information* |
| | *9. Market information* | | *9. International market* | *8. International market* |
| | | | | 9. Financial resource |

Table 6
Cronbach's Alpha values

| | Nation | | | |
|---|---|---|---|---|
| | US | Korea | Taiwan | Mainland China |
| Value | 0.7965 | 0.7632 | 0.7572 | 0.7569 |

The table shows that the US has a competitive advantage in almost every factor. Mainland China is at a relative competitive disadvantage. Its only competitive advantage is in *domestic market* over Taiwan and Korea. Korea is at a competitive advantage compared with mainland China, while Korea is inferior to Taiwan in terms of *management skill*, *manpower*, and *financial resource*. Taiwan has several competitive advantages compared with mainland China, and is superior to Korea in terms of *management skill*, *manpower*, and *financial resource*. However, relative to the US, Taiwan is at a competitive disadvantage in *R&D*, *R&D environment*, *market information*, and *domestic market*. Table 8 shows the relative IIR competitiveness of each nation.

## 4. Conclusions

This research investigated the IC industry innovation policies of four countries: the United States, Korea, Taiwan, and mainland China. A theoretical framework was used to analyze the subjects, and the following conclusions were reached.

Table 7
The ANOVA and Tukey table of every nation's IIRs

| | | Sum of squares | Degrees of freedom | Mean square | *F* | Significance | Tukey |
|---|---|---|---|---|---|---|---|
| R&D | Between groups | 58.188 | 3 | 19.3969 | 37.690 | 0.000 | 1>2.3.4, 2>4, 3>4 |
| | Within groups | 63.813 | 124 | 0.515 | | | |
| | Total | 122.000 | 127 | | | | |
| Technical knowledge | Between groups | 56.813 | 3 | 18.938 | 39.097 | 0.000 | 1>2.3.4, 2>4, 3>4 |
| | Within groups | 60.063 | 124 | 0.484 | | | |
| | Total | 116.875 | 127 | | | | |
| R&D environment | Between groups | 77.063 | 3 | 25.688 | 56.439 | 0.000 | 1>2.3.4, 2>4, 3>4 |
| | Within groups | 56.438 | 124 | 0.4558 | | | |
| | Total | 133.500 | 127 | | | | |
| Management skill | Between groups | 60.688 | 3 | 20.229 | 44.153 | 0.000 | 1>2.4, 2>4, 3>2.4 |
| | Within groups | 56.813 | 124 | 0.458 | | | |
| | Total | 117.500 | 127 | | | | |
| Manpower | Between groups | 18.086 | 3 | 6.029 | 11.142 | 0.000 | 1>2.4, 2>4, 3>2.4 |
| | Within groups | 67.094 | 124 | 0.541 | | | |
| | Total | 85.180 | 127 | | | | |
| Financial resource | Between groups | 58.836 | 3 | 19.612 | 43.646 | 0.000 | 1>2.4, 3>2.4 |
| | Within groups | 55.719 | 124 | 0.449 | | | |
| | Total | 114.555 | 127 | | | | |
| Market information | Between groups | 86.688 | 3 | 28.896 | 82.966 | 0.000 | 1>2.3.4, 2>4, 3>4 |
| | Within groups | 43.188 | 124 | 0.348 | | | |
| | Total | 129.875 | 127 | | | | |
| Domestic market | Between groups | 68.594 | 3 | 22.865 | 31.285 | 0.000 | 1>2.3.4, 4>2.3 |
| | Within groups | 90.625 | 124 | 0.731 | | | |
| | Total | 159.219 | 127 | | | | |
| International market | Between groups | 68.461 | 3 | 22.820 | 44.064 | 0.000 | 1>2.4, 2>4, 3>4 |
| | Within groups | 64.219 | 124 | 0.518 | | | |
| | Total | 132.680 | 127 | | | | |

Table 8
Relative IIR competitiveness of each nation

| | | Relative advantage items | | | |
|---|---|---|---|---|---|
| | | USA | Korea | Taiwan | Mainland China |
| Relative disadvantage items | USA | | | | |
| | Korea | • R&D<br>• Technical knowledge<br>• R&D environment<br>• Management skill<br>• Manpower<br>• Financial resource<br>• Market information<br>• Domestic market demand<br>• Explore international market | | • Management skill<br>• Manpower<br>• Financial resource | • Domestic market demand |
| | Taiwan | • R&D<br>• Technical knowledge<br>• R&D environment<br>• Market information<br>• Domestic market demand | | | • Domestic market demand |
| | Mainland China | • R&D<br>• Technical knowledge<br>• R&D environment<br>• Management skill<br>• Manpower<br>• Financial resource<br>• Market information<br>• Domestic market demand<br>• Explore international market | • R&D<br>• Technical knowledge<br>• R&D environment<br>• Management skill<br>• Manpower<br>• Market information<br>• Explore international market | • R&D<br>• Technical knowledge<br>• R&D environment<br>• Management skill<br>• Manpower<br>• Financial resource<br>• Market information<br>• Explore international market | |

### 4.1. "Scientific and technical" and "legal regulatory" are the primary policy tools used in all four nations

This research found all four countries in this study used *scientific and technical* and *legal regulatory* as their primary policy tools for developing innovation. In addition, in the early stages, to support the semiconductor industry, the US government also used *procurement* as another primary tool.

In contrast, during the 1970s and 1980s, in order to cultivate its conglomerates, Korea's primary policy tools were *financial* and *taxation*. The development of the Taiwan IC industry was initiated by ITRI, and the use of *political* tools. To attract foreign capital and enhance competitiveness, mainland China introduced *commercial* tools as their main policy tool.

### 4.2. Most tools impact technology development

The impact of the IIR innovation policy tool on *R&D*, *R&D environment*, *technical knowledge*, and *manpower* was greatest, and *management skill*, *market information*, and *international market* were impacted to a lesser degree. This finding shows that most policies are highly effective for developing technology but are less effective for increasing market opportunities. However, recent research strongly suggests that marketing factors are critical to innovation and technology development. For enhancing national innovation capacity, governments can provide marketing mechanisms.

### 4.3. The relative competitiveness of each nation's IIRs

After overall evaluation of the IIR competitiveness of each nation, this research found that the US currently has competitive advantages in every aspect. Mainland China has an overall competitive disadvantage, except for the *domestic market*, which has a higher competitive advantage than Taiwan and Korea. Korea has a competitive advantage compared with mainland China. Taiwan has several relative competitive advantages compared with mainland China and is superior to Korea in terms of *management skill*, *manpower*, and *financial resource*. Compared with the US, Taiwan is at a competitive disadvantage in *R&D*, *R&D environment*, *market information*, and *domestic market*. Overall, in the past two decades, under the leadership of ITRI and government-related policy tools, a comprehensive industry structure for the Taiwan IC industry has been well-established.

## 5. Recommendations for the Taiwan government

This research makes two recommendations for the Taiwan government.

1. The government should reconsider the *science and technical* and *taxation* policy tools. The industry infrastructure does not seem suitable for high-technology

enterprises. These tools can be designed to develop the proper R&D environment and further upgrade R&D and technical knowledge.

2. The *market information* innovation policy tool is obviously insufficient. An effective information service system should be established that will enhance the competitiveness of the IC industry. This information system will help businesses gain market opportunities which are critical to the innovation process.

## References

[1] World development report 1998: knowledge for development. New York: World Bank, 1997.
[2] Employment and growth in the knowledge-based economy. France: OECD, 1996.
[3] Freeman C, Soete L. The economics of industrial innovation. 3rd ed. London: Francis Printer, 1977.
[4] Schumpeter J. The theory of economic development. Cambridge (MA): Harvard University Press, 1934.
[5] Drucker PF. Innovation and entrepreneurship. New York: Harper & Row, 1985.
[6] Allan A. Innovation management: strategies, implementation, and profits. New York: Oxford University Press, 1998.
[7] Porter ME. The competitive advantage of nations. New York: Free Press, 1990.
[8] Sundbo J. Innovation theory Sci Public Policy 1995;22:399–410.
[9] Levitt T. Marketing myopia. Harvard Business Rev 1960;38:45–56.
[10] Edquist C, Hommen L. Systems of innovation: theory and policy for the demand side. Technol Soc 1999;21:63–79.
[11] Rothwell R, Zegveld W. Industrial innovation and public policy: preparing for the 1980s and the 1990s. London: Frances Printer, 1981.
[12] Jacobs D. Innovation policies within the framework of internationalization. Res Policy 1998;27:711–24.
[13] Nelson R, Winter S. In search of a useful theory of innovation. Res Policy 1977;6:36–76.
[14] Shyu JZ. Technology policy and national innovation system. Taiwan: Hwa-Tai Publication, 1999.

**Joseph Z. Shyu** received his B.S. degree in Chemistry from Fu-Jen Catholic University in 1976, an M.S. in Applied Chemistry from National Tsing-Hua University, Taiwan, in 1978, and his Ph.D. in Analytical Chemistry from the University of Pittsburgh, Pennsylvania, in 1982. He also received an MBA degree from the Illinois Institute of Technology in 1992. After working in industry in the USA for over 10 years, he returned to Taiwan in 1993, holding a position of associate professor in the Graduate Institute of Technology of Management in National Chiao-Tung University. His recent research interests include national innovation systems, high-technology business strategy, and global marketing strategy.

**Yi-Chia Chiu** received his Bachelor degree in Business Administration from Chung Yung Christian University in 1995 and an MBA in the Management of Technology from National Chiao-Tung University, Taiwan, in 1997. He is now a Ph.D. candidate at the Institute of Management of Technology, National Chiao-Tung University. For several years, he has associated with Dr Shyu in innovation policy research and strategy formulation analysis.

**Chao-Chen Yuo** received his B.A. in Economics from National Cheng-Chi University in 1998 and an MBA degree in Management of Technology at National Chiao-Tung University, Taiwan. His recent study interests are in national innovation systems and industrial economics of high technology industry.