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Science and Technology Development Policy in Taiwan, ROC

I. Foreword

The industrial revolution was the basis to shape modern era. The uses of combustion power and machines to surpass the productive capability of agrarian eras were the major driving forces in early days of industrial revolution. How well scientific and technical knowledge were propagated and advanced in this period was key in determining whether a traditional society could enter the modern era. By the beginning of the 20th century, the applications of electric energy and electromagnetic wave led the human society to enter the era of electrical machinery and telecommunication. More influential in molding modern society's technology, however, was the invention of transistor and its subsequent development. Today, as we look ahead into the 21st century, the development of the Internet and biotechnology will have an even greater impact on the basic view of the coming age. At the turn of the millennium we will face a fervent wave of new challenges in science and technology. The governments and citizens of all countries invariably pay great attention to these potential impacts so that they will not get lost at the crucial moment of development due to the negligence and misjudgment of technology.

The scientific and technological development over the past two to three hundred years demonstrated that the economic and cultural development processes have been invariably reliant upon the implementation and advancement of basic scientific understanding. Examples are the mechanics and thermodynamics to the early phases of the industrial revolution; electromagnetism to the development of electrical machinery and telecommunications; the quantum mechanics to the computer age; optoelectronics to network communication; and molecular biology to the modern biotechnology. As the society evolves, the trend of development relying on basic science has become increasingly clear. The problems of capital, land, and labor allocation in traditional capitalism have now transform into the complex issues based on new forms of knowledge. The onset of knowledge-based economy has profoundly altered the perception of human value. Reliance only on tangible resources has no way of competing with the intangible entity of human intellectual property. Human intellect and the culture that it has created has already become the most important asset of all human activity. Based on this view, we need to re-examine Taiwan's previous scientific and technological achievements. Moreover, we need to recognize the crises and challenges we are facing today so that we can design our future policies and measures.

II. Current Achievements and Future Challenges in the Area of Science and Technology

The evolution of Taiwan's manufacturing sector has closely followed the path taken by the developed countries such as the United States and Japan. Development of the textile industry was followed by the rise of the petrochemical industry, which in turn was followed by the information and electronics industries. This evolutionary process has not only been driven by the hard work of the private manufacturing sector, the leadership and incentive provided by government science and technology policy have also played important roles. Currently, Taiwan's global position in the area of high-tech manufacturing is truly on the rise. The percentage of technically intensive manufacturing industry in overall manufacturing sector rose from 24% in 1986 to 46% in 1999. High-tech industry exports now total more than half of total exports. Globally, our information technology industry has leapt into third place, and our semiconductor industry holds fourth place. This is ample evidence that these two industries greatly influence the world-wide development of high-tech manufacturing. In terms of personal computers and semiconductor manufacturing, Taiwan is a very powerful competitor, and thereby holds an important position within the international economy. Thus, the development of high-tech manufacturing undoubtedly plays a key role in maintaining Taiwan's economic strength.

It must be noted, however, that in light of the achievements just mentioned, we have started to experience an emerging crisis. The development of global information networks directly exposes the entrepreneurs to the intense competition of the international marketplace. For the same token, the government policies also encounter similar challenges and competition from global financial developments and influence from other nations' policies. Facing today's impact due to the importance of new R&D-driven knowledge based economy, our capital-intensive and high-tech intensive manufacturing

systems obviously meet great difficulty. Due to costs and the changing business environment, many traditional manufacturers are forced to relocate overseas. The profit margins of most high-tech manufacturers become less competitive because of the difficulty to break through the obstacles posed by the lack of intellectual properties held in technically advanced countries. This of course is a direct consequence of our insufficient research and development capability in our private manufacturing sectors. A more careful and thorough review of our status, however, shows that our science and technology education, instead of encouraging creativity, has over-emphasized testing and standardized answers. Isn't it these wrong approaches drag our ability to raise our capabilities? Therefore, it is more important to change the R&D atmosphere within Taiwan's educational system, in addition to considering changes in the manufacturing environment, when we draft our future science and technology policy. Such that we need to liberate the productive capabilities of the universities within the knowledge based economy. We must use an all-rounded viewpoint to integratedly tackle these issues.

III. Basic Policies Promoting the Future Development of Science and Technology in Taiwan

Generally speaking, the establishment of manufacturing economy follows the process of basic research and development, manufacturing physical production, and then marketing and sales. It is clear that the making of all new products starts from research and development, then manufacture in mass quantity through proper adjustment of the production cost, and finally sale with strategic marketing and promotion to achieve profit. The operating principle of previous capitalism economic activities uses capital-control production equipment to manufacture various products. The lifecycle of most of these products was long, and generally it was difficult to quickly introduce new products into the marketplace. Consequently, basic research and development was less important than technical advancement and controlling market shares. This fact can be well exemplified by the history of the development of the textiles, petrochemicals, and aviation industries. Since the rise of the electronics industry, however, all advanced products have rather short lifecycles, and they have to be in market quick to be profitable. Now the manufacturing economy has entered to an era that follows the "Moore's Law". The basic R&D and new innovation have now become inevitable, and are far more important than the capital endeavors and simple technical advancement. In response to this challenge, major companies worldwide are all expanding their basic R&D functions on a scale unmatched by most university laboratories. Universities are also taking new approaches and directing their R&D resources into manufacturing activities. It is foreseeable that the organizations can still survive at the age of knowledge based economy are those with advanced R&D capabilities. With this mind, to liberate the university capability to be part of the technology R&D system will be one of the basic principles for deciding national science and technology policy. Certainly, this new direction would require the proper planning and implementation on the part of government agencies.

1. Liberating Universities' Productivity of Knowledge

It is well known that universities are the cradles of modern culture. In return, the development of universities needs to be modified accordingly as the society evolves. Nevertheless, to remain at the pinnacle during societal development is a role that universities must continue to play.

Taiwan's universities, whether public or private, have developed under the control of the government. Traditionally, their function has, more or less, been to train high quality personnel to serve the needs of the manufacturing sector. In the area of R&D support, because Taiwan manufacturers have grown accustomed to directly transfer technology overseas, most universities have had difficulty to bring into full play of their role in terms of R&D contribution. Thus, the academic development in the universities has not been successful at building a comprehensive model of cooperation with local industries. And most R&D support activities are handled by government-established non-profit organizations, such as the Industrial Technology Research Institute. When facing the new challenges today, however, Taiwan industry can no longer rely on these research institutes to achieve advancement in prominent new enterprises. It requires the contributions from those universities with the most advanced academic resources in order to enter into the mainstream of the knowledge-based economy.

To encourage universities in Taiwan in helping local industry create new innovative products, in short term, they must first learn the experiences established by well-known universities overseas. Through establishing a new relationship with the business society, faculties and students in the universities will be able to play their roles in the industrial marketplace, and to extend their creative potential to entrepreneurship. Furthermore, university executives must be aware of the fact that they can no longer passively act as administrators. Rather, they must play the role of managers in the new knowledge-based economy. They must not only be able to take hold of all the knowledge resources that exist among the students and teachers on campus, they must also be able to effectively utilize the venture capital they accumulate based on their schools' public trust. I strongly believe that with the benefits generated from the above mentioned resources will feedback to the university R&D system, and allow the universities to establish top-notch advanced laboratories.

Over the long term, our challenge is how to develop the right education contents in today's universities. To

build up high-level R&D capabilities necessary for high-tech society, it is necessary to discard traditional cookie-cutter courses, and replace them with more stimulating and enlightening classes. More importantly, we must consider not only renewing the research topics in the existing traditional academic units, but also relaxing the limitation on departmental reprogramming. These changes will then allow the subjects dealing with innovative technological development in our universities to thrive. And consequently to allow the university to match the dynamical need in the new knowledge-based economy. Of course, we cannot randomly invest our resources to those minor, invaluable subjects. We need to focus our effort on those new and outstanding subjects. Then we can surely upgrade the capabilities to accumulate science and technology resources in Taiwan's universities.

2. Building an Innovative Manufacturing R&D System

Traditionally, we have classified the manufacturing enterprise into two different natures — traditional manufacturers and high-tech manufacturers. Regardless of the nature, however, the main goal of an enterprise is to make sufficient profit in its operation. On the other hand, neither traditional manufacturers nor high-tech manufacturers can neglect the problems, such as environmental pollution or complicated labor disputes, created during the production processes. Thus, it is our ultimate goal to create a new knowledge-based economy through effectively making use of the basic research and development capabilities. That is, we need to fully utilize the intellectual properties created by R&D to protect our technical advancement and to generate wealth in the new era. Meanwhile we shall re-orient our direction by enhancing high-level manufacturing and marketing, and allow the outflow of the traditional low-level manufacturing.

To implement the entrepreneurship development policy based on innovative R&D, we need to help the existing medium and small size enterprises identify their current capability and their scale. And then help them plan the resources and facilities needed to establish a productive R&D team so that they'll be capable to handle their own R&D. Furthermore, we also need to help these enterprises strategically move their manufacturing and production sectors abroad, while leave their R&D sector in Taiwan. Consequently, these enterprises can better respond to the challenges posed by the opening up of trade and investment across the Taiwan Strait and take better strategy for the "Eye-on-China" entrepreneurship.

Generally, Taiwan manufacturers lack basic R&D experience. On the other hand, most universities do not pay much attention to product-oriented R&D. Thus, it will be an effective approach to tackle the new challenges by creating research laboratory jointly operated by the manufacturer and university, and optimally invigorating their respective strength. However, in terms of academic resources or company size, Taiwan is far behind advanced countries like the US and Japan. It is therefore necessary to adopt a more realistic and effective method than that of the advanced countries in creating cooperation between manufacturers and universities. For example, we should consider liberating our leading public research laboratories to become semi-privatized so that they are allowed to receive both the government and private-sector support. These labs can then act as important links in the knowledge-based economy that attract investment capital, state-of-the-art equipment, and first-rate research personnel. These facilities will also serve to shoulder the responsibility of making innovative R&D a profitable activity. Of course, we also need to allow small and medium size enterprises to participate in basic R&D by joining major research labs, or becoming partners. On the other hand, the advanced research lab can promptly recognize the pressure of open market through cooperation with private sectors. This mutual education mechanism certainly requires the government's proper assistance and guidance.

3. Revamping Government's System of High-tech Management

Over the years, many government agencies have been involved in the promotion of science and technology. However, this cross-ministerial approach has been characterized by a lack of coordinated effort. And for the most part, the government's primary means of control has been through the investment of funds and other resources. Generally speaking, there is a lack of performance indicators that can be used to assess the effectiveness of government policies. This, of course, must be remedied in future science and technology planning and management processes. This will be especially important in setting the strategy for the rise of new innovative technologies. The future enterprise development will be a single-mold process in terms of moving from basic R&D to marketplace. Thus, it will be even more important to effectively coordinate the resources provided by all ministries in the government. In response, the government should use a vertically integrated approach to planning large scale, strategic R&D policies so that basic research, applied development and market strategy operated in series.

It was a nontrivial effort for Taiwan to quickly develop into an innovative industrial nation after World War II. Unfortunately, we have not kept the same path of development in humanistic concern and environment protection as that in economic growth. This had led to severe ecological damage and a loss of social values. When taking a long-term view of cultural and environmental concern, we certainly will face these challenges and difficulties as we live in a society centered in science and technology. Therefore, it is inexorable that in the future we must include cultural and environmental experts and academics

in policymaking to ensure the implementation of appropriate policies. We can then avoid the damage brought about by the development of science and technology while more effectively raising humanistic and cultural values. Through promoting a spirit of "local globalization" in our R&D efforts, we can make our development that incorporates an ideal path with realism and critical awareness in the future.

IV. Conclusion: Imagining a Green Silicon Island

Since the 1990's, the world has gradually moved into the era of incorporating knowledge into the foundation of the global economy. The most notable example is the rapid increase of intellectual property rights. In the international arena of high-tech manufacturing, investments in high-tech patents and technology transfer easily require hundreds of millions of US dollars. And the success of an advanced technical research may influence the direction of development of related industries. Consequently, both the enterprises and countries are increasingly more reliant on the enhanced competitiveness provided by R&D and product innovation. The recent lost-last economic boom in the US has resulted in the longest economic prosperity in its history. One can attribute this high growth rates, low inflation, and low unemployment to the continuing progress in science and technology in the US. Developments such as biogenetic engineering, information industries and the widespread use of networks greatly enhance the production power and reduce the operation cost. As a result, this makes the US significantly in the lead in the global competitiveness, meanwhile shakes off the traditional prosperity-cycle and continues its economic growth. This type of knowledge-based economy, originating from the persisting technology innovation that leads to continuing economic growth, has become the role model of the global economy in the coming century. Europe and Japan have also been vigorously reshaping the characteristics of their societies and economies in hopes that they can catch this new wave. These developments certainly have great inspiration to us.

Taiwan has already become one of the world's most important high-tech product producers. This makes Taiwan not only an important strategic place for military consideration, but also strategically important in terms of economy. The high-tech industries, therefore, become important mechanism for the protection of our national security. Nevertheless, we are still facing great challenges. One of the most serious problems is the transformation of large number of small and medium size enterprises. Firstly, high-tech manufacturers' highly attraction in collecting capitals and labors results in traditional industries' hard time to find capital and qualified personnel. Secondly, most of the manufacture-oriented enterprises have yet accustomed to the new economic trend based on research and development. This impediment due to the off-balance of our industry system definitely requires significant governmental effort and assistance to re-shape and overcome.

In the past, capital controls were commonly used to regulate the outflow of manufacturers. In the new economy, however, the key to compete globally is to create a good infrastructure for industrial development and an excellent living environment to attract the best personnel worldwide. The new innovative enterprises, created by the gathering of first-rate personnel, will lead to an influx of both domestic and foreign capital, and establish highly profitable new industries. Therefore, the major strategy of our future science and technology policy will be to create a high-quality R&D environment. On the one hand, we must plan and organize a first-class environment to encourage high-quality personnel to stay in Taiwan. On the other hand, we must liberate the knowledge-based production power exists in universities and academic institutes, such that they can jointly work together with private sectors to create new innovative enterprises. Of course, we must also simultaneously maintain a balance development in both cultural values and the natural environment. Only through these efforts, the foresight to construct Taiwan as a "Green Silicon Island", can then generate new cultural values in the new era within the expansion of the new knowledge-based economy.

(National Science Council/Chairman Cheng-I Weng)

Notice

I. The Proceedings of the National Science Council, Part A: Physical Science and Engineering (ISSN 0255-6588); Part B: Life Sciences (ISSN 0255-6596); and Part C: Humanities and Social Sciences (ISSN 1018-4473) will cease publishing in the middle or at the end of 2001.

II. The acceptance of manuscripts for publication in the above periodicals will cease on October 31 of 2000, as determined by the postmark.

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