SCIENCE AND TECHNOLOGY POLICIES, COMPETITIVENESS, AND ECONOMIC DEVELOPEMNT – A CASE STUDY OF TAIWAN

by

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ABSTRACT

The economic growth in Taiwan for the last few decades has been credited as stellar performance. However, what accounts for the growth? Institutions, political regime, geographical locations, or legal origins? This thesis attempts to explain the economic growth in terms of science and technology (S&T) based on the neoclassical and new growth theories, and comes at a finding that S&T development is significant along with the economic growth. In the process, the author also finds that the government is the major player in Taiwan's S&T development. Based on these findings, the author concludes that from Taiwan's lessons, the S&T is a direction and an area for those developing countries that strive to gain economic growth to make their endeavors on. And, for those latecomer countries, state-led S&T development will be a sufficient condition for economic development, for the government is the major role that is most likely to initiate the development through appropriate policy implementation and is most likely to provide a momentum to the stagnating economic deadlock.

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Finally, as I have dedicated my previous thesis to my grandfather, Nan-Peng Li (李南鵬), I would like to dedicate this thesis to my grandmother, Feng-Mei Chen (陳鳳妹), who gave me enormous courage to face every challenge.

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Chapter 1 Introduction

The economic growth in Taiwan for the last few decades has been credited as stellar performance. Back to five decades ago, the per capita national income was $137 in 1951 (Figure 1-1). Fifty years later, it was $11,637 in 2001, about 85 times of that in 1951, with the average annual growth rate of 9.1%[1]. In accordance with the World Bank's country classification[2], Taiwan was a low-income country before 1973, and was a lower-middle income country between 1973 and 1985. In 1986, it turned out to be an upper-middle income country and became a high income country in 1992. Within two decades, Taiwan metamorphosed from a developing country to a developed country.

What accounts for the growth? An abundant literature has indicated that Taiwan's economic growth is usually attributed to several factors: macroeconomic stability – low inflation rates and positive real interest rates, fiscal balance, and overvalued real (purchasing power parity) exchange rates; unprecedented export growth – high degree of outward orientation; free market mechanism – free markets for the commodities and labor, and so on. Different explanations seem to have their own grounds and provide evidences to support their logic. However, to comment on which growth account has the most significant explanation ability is not the primary goal in this thesis. Rather, this thesis tries to provide a different account from the conventional wisdom to explain the economic growth in relation to the science and technology (S&T, hereafter).

Based on the New Growth Theory, which stresses that economic growth results from the increasing returns associated with knowledge, and, consequently, knowledge is taken into account and juxtaposed with the traditional inputs, namely, labor and capital, accounting for the most important part of the production function, this thesis attempts to look at the knowledge-intensive part of the social activities, defined as S&T in this thesis, to examine how S&T have come into play in the developmental course and to what extent have S&T contributed to the economy.

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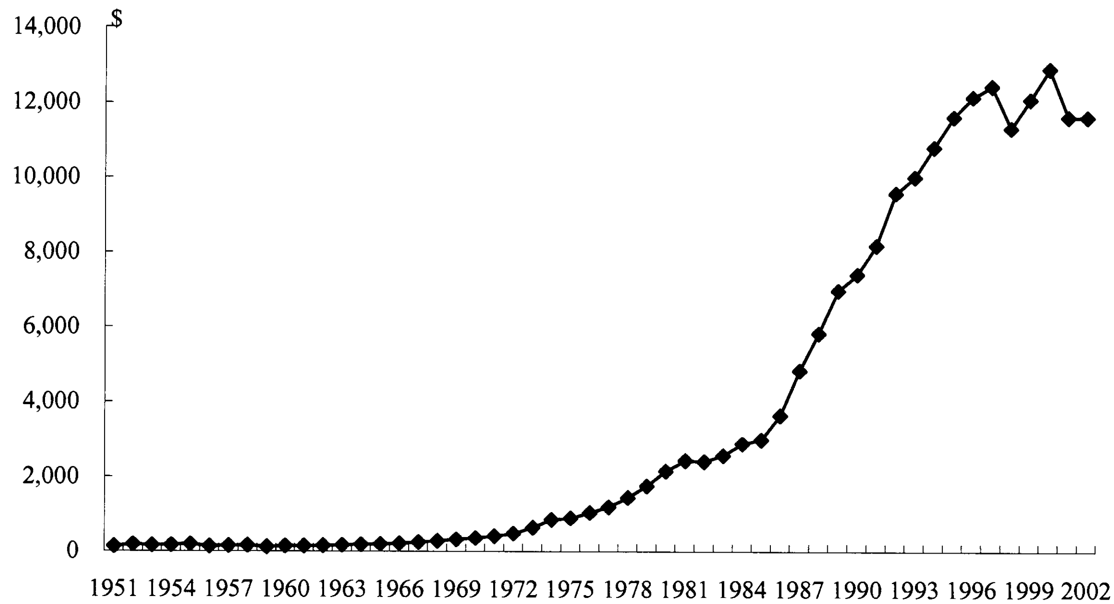
[1] Annual average growth rate is calculated according to the definition in World Bank: $r=\exp((\ln(p_n/p_1))/n)-1$.

[2] According to the classification of World Bank, economies are divided into: (1) low income, $745 or less; (2) lower middle income, $746 - $2,975; (3) upper middle income, $2,976 - $9,205; and (4) high income, $9,206 or more. Low-income and middle-income economies are sometimes referred to as developing economies. (http://www.worldbank.org/data/countryclass/countryclass.html)



Note: The data in 2002 is a predicted value.
Source: Directorate General of Budget Accounting and Statistics, Executive Yuan, ROC.

Figure 1-1 National Income per Capita, 1951-2002

For a developing country, like Taiwan in decades ago, what was the momentum to stimulate the economic growth and what was the impetus to leap out of the economic backwardness and long-term stagnation. Presumably, the state's efforts could be that momentum as well as the impetus to raise hope to the economic deadlock. As has been widely known that the government in Taiwan has played a vital role on each of its developmental stage, this thesis will examine whether or not the government's role still holds true in the S&T development.

Therefore, the intent of this thesis is to examine the S&T development in Taiwan, to seek for what results in its S&T development, and ultimately to provide a developmental instance for other developing countries that seek to find themselves a prospect that narrows down their gap with those advanced countries.

Several research questions will be posed in this thesis: (1) to what extent has Taiwan developed its science and technology? (2) does the S&T development contribute to the economic growth? (3) does the government play a vital role to initiate the S&T development in Taiwan? If so, how important is it, and what is the evidence?

(4) do the government's efforts on S&T via those S&T policies effective? (5) what are the unusual features in Taiwan's developmental course? (6) what are the lessons derived from Taiwan's experience for a model that can be learned by other developing countries?

This thesis starts with literature review of different aspects in Chapter 2 concerning diversified economic growth accounts and economic growth in specific countries, namely, the Asian new industrialized economies (NIEs), followed by the literature regarding competitiveness and productivity, and then the literature related to science and technology policies. After reviewing the literature, this thesis, then, presumes that the government plays an important role from the outset and during the developmental course. Therefore, Chapter 3 examines what S&T policies were enacted and implemented along the time frame and under different government agencies. Chapter 4 examines the effectiveness of some selected S&T policies and then brings up evidences that show the government is the main driver that foster the S&T development in Taiwan. Chapter 5 tries to quantify the S&T development by showing the productivity and technological competitiveness in terms of various indicators both at industrial and national level to explore to what degree the S&T development has reached. Chapter 6 is the conclusion.

Some terminologies should be clearly defined from the outset. First of all, science refers to knowledge of all kinds, in general; technology is a set of techniques that are themselves defined as "a set of actions and decision rules guiding their sequential application that people have learned will generally lead to a predictable (and sometimes desirable) outcome under certain specified circumstances" (OECD, 1990); and science and technology development in this thesis mainly refer to a very broad definition that people make their efforts to enhance the existing knowledge and techniques in order to make money, to increase convenience, and to enhance the welfare of human kind. Technology transfer refers to the sharing of knowledge and facilities among different entities, either related to money transaction or knowledge spillover.

Chapter 2 Literature Review

This chapter reviews literature regarding science and technology policy, competitiveness and economic development, respectively, but in a bottom-up order. Literature on different determinants of economic development is first discussed, and then the scope will be narrowed down to the literature on Taiwan's economic development. Second, literature concerning productivity, primarily the growth theory, will be summarized, followed by literature review pertinent to S&T policies.

2.1 Literature Regarding Economic Growth

Economic growth can be explained by a number of determinants with different aspects. Contemporary literature on development economics has proposed many different perspectives on economic growth. Neoclassical economists contend that free market is the base of economic development. Sachs and Warner (1995) based on Baumal's study (1994) group 135 countries into qualifying and nonqualifying categories according to the political steadiness in each country and whether or not they have enforced market-based economic policies, namely, private property rights ownership and trade openness. Their findings suggest that there is strong evidence of unconditional convergence for qualifying countries, but no evidence of unconditional convergence for non-qualifying countries. Therefore, whether or not they have good policies, in other words, market-based policies matter for their growth. Przeworski and Limongi (1993) examine the literature on the relationship between political regimes and economic development, looking at the contending issues of whether democracy or dictatorship helps economic development[3]. After collecting and analyzing 18 studies, they conclude that political regimes do not seem to capture the relevant differences. North and Weingast (1989) explore the economic development in terms of institutions by employing the 17^{th} century England political institutions as an example to illustrate the successful evolution of institutional forms brought about the considerable economic growth as opposed to the stagnation in Spain and France in the long run and conclude that economic development should be accompanied by the appropriate political institutions that limit the sovereign's intervention and allow private rights and markets

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[3] The main arguments of these 2 schools: democracy hinders economic development because pressures for immediate consumption reduce investment; authoritarian rulers have no interest in maximizing total social welfare.

to prevail. De Soto (2000) views capital formation as a critical essential for development (capitalism) and discusses the mysteries that keep the rest of the world, in contrast to the West, from benefiting from the capitalism, finally concluding that no proper legal property system in those former communist and developing nations is the key. Fukuyama (1999) stresses differences in economic performance across countries arise from differences in their cultural propensities to create trusting relations beyond their nuclear families, in other words, social capital matters for economic development, because it reduces the transaction costs that contracts or rules cannot specify and promotes associational life that bridles the government and leads to democracy; Putnam (1993) in his book *Making Democracy Work: Civic Traditions in Modern Italy* also emphasizes the economic development is related to social capital by looking at Italy's case and concludes that differences in civic engagement and effective regional government between Italy's Center-North and the Italian South are resulted form their very different stocks of social capital. La Porta et al. (1997) set out from the legal origin and system to look at their relationship with economic development and conclude that countries with poor investor protections tend to have significantly smaller debt and equity markets and have poorer economic development. Rajan and Zingales (1998) as well as Levine (1998) also explore from the aspect of capital market, inferring that countries with better developed financial systems show superior growth in capital-intensive sectors that rely particularly heavily on external finance.

So far, literature on economic development is listed in different aspects: free market, political regimes, institutions, social capital, laws, capital market, and so on. An important aspect has not yet mentioned – the role of the state. Literature on the role of the state has contending views of the extent of state intervention. Shleifer and Vishny (1998) argue that politicians and dictators do not maximize social welfare, simply put, government failures are rife in the real world. Therefore, government should perform only basic functions needed to support a market economy, such as the provision of law, order, and national defense. Other than delivering these public goods, the less the government does, the better. They also provide reform suggestions concerning what governments should actually do and how governments should be limited lest they should distort the social welfare. They further categorize this view as the grabbing hand model. Stiglitz (1998), on the other hand, emphasizes the market failures and imperfect information. Therefore, governments play a role in correcting the failures. The rationales underlie this argument is that government has power that the private sector doesn't have. Facing the market school's accusation against government failures, Stiglitz argues that state still plays an important role if governments rectify those failures by ways of improving governance[4]. Amsden (2001) in her book, *The Rise of the Rest* also implied the importance of the role that the governments play in those late-industrializing economies in the form of their industrial policies, including development banking, local-content management, selective seclusion [5], import substitution, picking winners[6], national firm formation, and so forth.

2.2 Literature Regarding the Economic Growth in Taiwan

Literature in relation to Taiwan's economic growth usually embeds in the literature on East Asian economic miracle, with very few exceptions only focusing on Taiwan. Four tigers/dragons, namely, Hong Kong, Singapore, South Korea, and Taiwan are always categorized as a group due to its similar features in terms of initial conditions of economic condition, the timing of economic takeoff, and the sources of economic success in some respects. Many analysts have sought to comprehend the fundamental sources of East Asia's hyper economic growth. There is consensus that several factors, aside from endowment-determined ones[7], are critical (Westphal, 2000):

1. Macroeconomic stability, reflected in relatively low inflation rates and positive real interest rates, fiscal balance, and overvalued real (purchasing power parity) exchange rates (World Bank, 1993);
2. Unprecedented export growth (World Bank, 1987);
3. Rapid accumulation of physical and human capital (World Bank, 1993; Krugman, 1994);
4. Successful agricultural development from the outset (Westphal, 2001);
5. Competent bureaucracies, effectively able to orchestrate the development

[4] The ways of improving governance include restricting government interventions in areas in which there is evidence of a systematic and significant influence of special interests; against government actions restricting competition and in favor of governments actions promote competition; in favor of openness in government and against secrecy; encouraging the private provision pf public goods through NGOs to create effective competition and mechanism of conveying voice; achieving a balance between expertise and democratic representativeness and accountability.

[5] Selective seclusion means opening some markets to foreign transactions and keeping others closed.

[6] Particular industries with potential growth are targeted by governments and are fostered through subsidies and tax exemption.

[7] Endowment-determined factors include geographical location, natural resources, and so on.

process (Akyuz et al., 1999 and Cheng, 1999).

Disagreement arises from the appropriateness of government's role, namely, the efficacy of government's intervention. Some literature contends that the government's intervention is appropriate and vital to the stellar performance (Wade, 1990; World Bank, 1993; Lall, 1996; Amsden, 2001, 2003), while other literature argues that if it were not for the government's significant intervention, the economy would have developed even better than it has been.

2.3 Literature Regarding Competitiveness and Productivity

A great number of research papers debating the East Asian newly industrialized economies (NIEs) due to the miraculous growth during the last 35 years, give rise to the upsurging discussion of the so-called Asian Miracle. The literature of this kind mainly can be divided into two strands: accumulation theory and assimilation theory in Nelson and Pack's (1997) taxonomy or fundamentalism and assimilationism according to Felipe's (1997) categorization.

The polemic was ignited by the fundamentalists (Young, 1992), who maintain that growth in the region is input-driven (simply increasing investments) and agile resources relocation, mainly capital relocation, and that productivity increases are negligible if not zero. The controversy was dilated by the article on "The Myth of Asia's Miracle" published by Krugman (1994) based on the total factor productivity (TFP) calculation results in Young's (1992) and Kim and Lau's (1994) papers. The background of Krugman's paper, later called "Krugman's thesis" is that in the late 1980s and early 1990s many people saw the East Asia's economic miracle and asserted that the economic success had demonstrated the fallacy of the US's traditional laissez-faire approach to economic policy and the growth of these economies showed the effectiveness of sophisticated industrial policies and selective protectionism. By comparing the Asian NIEs with the Soviet Union, Krugman's thesis contends that Asia's rapid growth is merely through an astonishing mobilization of resources, rather than efficiency enhancement. In this sense, Asia's miracle could be similar to the communist seeming growth. This theory had been pushed hard over the early 1990s by several economists.

Accumulation theory/fundamentalism was harshly criticized by many other studies.

Among them, focusing on the methodological problems of the fundamentalists are Felipe and McCombie (1997) and Felipe (1997). The authors argue that the conventional measures of the TFP cannot be unambiguously interpreted as an estimate of the rate of technical change because of the following reasons: (1) the view of taking technological progress as exogenous, disembodied, and Hicks-neutral cannot be taken as the departing point in the analysis of productivity growth; (2) it is problematic to decompose overall growth (the attribution problem) because the factors exhibit complementarity. Likewise, if imperfect competition prevails, factor shares and elasticities will diverge; (3) this approach does not allow to make an overall evaluation of the industrial policy and government intervention in any country.

Another controversy comes from the assimilationists or assimilation theorists, whose argument is that what made the East Asian countries' performance special is how spectacularly well they master foreign technology. In order to master the "borrowed" technology, a long process of learning should be involved because the knowledge embedded in the technology is usually tacit and uncodifiable (Amsden, 1989 and 2001). By so doing, they require new sets of skills, new ways of organizing economic activities, and becoming competent in new markets (Nelson and Pack, 1997). Romer (1993) also stresses that what distinguishes those countries and explains their different growth rates is their capacity to generate and put ideas into practice. This school is also related to the so-called new growth theory or endogenous growth theory, emphasizing that economic growth results from the increasing returns with knowledge, and with this feature, the gap between the advanced countries and developing countries will eventually diverge as opposed to the neoclassical growth theory, in which diminishing return to scale of inputs, such as labor and capital is assumed, and, thereof, the economic development levels of both groups will eventually converge.

The new growth theory, consequently, underscores the importance of investing in new knowledge formation so as to sustain economic growth (Cortright, 2001). Given that knowledge is the key driver of economic growth, this argument has implied that countries can make efforts via making policies and creating institutions to accelerate knowledge formation and to facilitate knowledge dissemination so as to manipulate their growth Even though it seems to be implausible for countries suffering from economic backwardness to reach the convergence to the advanced countries via policy and institutional reforms, the new growth theory still shed light on the direction and the ways for countries endeavoring to grow.

2.4 Literature Regarding Science and Technology Policies

New growth theory has implied that sustained growth can be achieved by policies that facilitate knowledge creation and dissemination. Therefore, science and technology policies are the policies that a country striving to make differences should make efforts on. Literature on S&T policies can be divided into two contending views: pro-market view and state-promotion view. The former argues that profit-maximizing firms driven by competitive pressure will choose and develop technologies that are not only the most profitable but also beneficial for the society, while the latter argues that due to market imperfections, especially prevalent in developing countries, the state should intervene in order to create incentives for productivity growth and innovation. (Chang and Cheema, 2001).

Pro-market views on S&T policies basically contend that invigorating competition increases technical efficiency and decreases x-inefficiency. The term "x-inefficiency" was created by Leibenstein (1966), who argues that the state-created rents increase x-inefficiency by distorting the effort-leisure trade-off of firm managers (see Corden, 1974; Bergsman, 1974; White, 1976, and Martin and Page, 1983). Still, other scholars such as Krueger (1974), Posner (1975) stress that governments' policies will distract managers' attention toward rent-seeking activities. Therefore, instead of devoting their time and effort to managing production efficiently, managers will tend to fritter away their efforts in lobbying government officials to maintain or to attain policy created rents. If cumulated to a macro level, the rent-seeking behavior will affect the rate of economic growth. In this regard, government's heavy intervention will only create inefficiencies and the most efficient S&T policies are to let the market mechanism work properly so that the market-based competition will lead to an optimal rate not only of technological utilization but also of technology creation and diffusion.

State-promotion views on S&T policies argue that the technical change is not exogenous and the effective use of technology requires not only adapting it to local conditions but also a significant amount of investment in organizational and institutional adaptation (Fransman, 1984 and Khan, 2000). Market imperfection affecting technological change includes: (1) externalities – knowledge creation and technological change have attributes of public goods, and the process of discovering and learning new technologies requires a lot of effort and investment; (2) increasing returns to scale – as mentioned in the previous section, knowledge in close relation to technology possesses the feature of increasing return to scale. In this sense, it may be extremely costly for a follower to enter these markets, even in the long-run (Ray, 1998). Therefore, state-promoted S&T policies are especially important to the developing countries and are the only approach to catch up those advanced countries.

In this chapter, literature regarding economic growth, economic growth, specifically, in Taiwan, competitiveness as well as productivity, and S&T policies have been reviewed. Form these studies, it is obvious that Taiwan's economic growth has been observed and studied as a group with the other three tigers/dragons, namely, Hong Kong, Singapore, and South Korea. Furthermore, the importance of science and technology that contribute to the economic growth has been explored by Rosenberg (1982), for the pioneering work, Nelson and Winter (1982), and so on (Chang and Cheema, 2001). However, none of the literature touches upon the role that science and technology play in specifically Taiwan's economic growth. Therefore, the following chapters will explore the relationship between S&T and economic growth in relation to the government's role in Taiwan's economic developmental course.

Chapter 3 Overview of Taiwan's Science and Technology Policies

Science and Technology (S&T) policies sometimes are embedded in industrial policies, which oftentimes provide guiding principals of technological development for industries through incentive mechanism, sometimes are presented in the form of regulations or laws, which specify measures to enforce the incentive mechanism. In this thesis, S&T policies are singled out from the industrial policies as well as laws and regulations and are examined individually. Thus, to provide a more clear-cut general idea of what S&T policies were promulgated and enforced in Taiwan circa the last half century, those policies are put in chronologicalorder in Table 3-1 and Figure 3-1, respectively.

In the course of discussion, this thesis intends to provide an overview of the S&T policies along the timeframe – 1950s until now and then, for a closer look, differentiates policies in the recent decade from different institutional settings as well as varied organizations, namely, public, quasi-public, or private, since these are all interrelated in the aspect of policy formulation and enforcement. Figure 3-2 shows the agencies that mainly conduct the S&T policies.

3.1 Science and Technology Policies along the Timeframe

3.1.1 Science and Technology Policies in the 1950s

After the World War II, the global economy was in its vivid recovery, while Taiwan was busy dedicating itself to rebuilding its infrastructure and industries after the Kuo Min Tang (KMT) government retreated from the mainland China and settled down on this Island. In the early 1950s, the per capita GNP was around $145. People were poor and devoted themselves to satiating their own physical life. Little scientific research was being conducted except some agriculture experimental and improvement agencies inherited from the Japanese colonialist did some research on agribusiness, not mention to the progress in S&T development. Besides, only a few universities had academic research units. The only research institute, Academia Sinica, had just relocated its headquarters to Taiwan[8] and was busy engaging in setting up new

[8] Academia Sinica moved to Taiwan with the KMT government in 1949, but only two institutes – the

departments. During this period, both academic and scientific research was just at their start.

In the early 1950s, the former presidents of Academia Sinica, Wu, Ta-you and Hu, Shih, observed the poor S&T environment and shortage of human resources, and then proposed that the government should formulate policies to address these issues. In 1959, the Executive Yuan[9] approved the "Guidelines on Long-term National Science Development Programs". The budget for this Guideline was mainly form the profit surplus of state owned enterprises and the U.S. aid. In the same year, the "Long-term National Science Development Council" was established, whose responsibility was to oversee the nation's scientific development. During this period, the government developed basic scientific research and set up a special fund for national scientific development. It also drew up long-term projects, organized special agencies, expanded academic research facilities, and recruited visiting professors.

During the 1950s, Taiwan had already set up a series of institutions and agencies to deal with the S&T related issues, but, generally speaking, the agricultural research received a high priority in order to meet people's daily needs in this stage.

3.1.2 Science and Technology Policies in the 1960s

In the 60s, the focus of government's industrial policies had shifted from agriculture to light manufacture and labor-intensive manufacture. Textile and cement industries were steadily expanding during this period of time. At the same time, the government promoted export-oriented manufacturing owing to the small domestic market demands. On January 30, 1965, the government promulgated the "Statutes on the Establishment and Regulation of Export-processing Zones." The government's purposes for establishing these zones were to attract investments, to enhance exports, to increase employment opportunities and foreign exchange reserves, and, most important of all, to acquire foreign technologies. In December, 1966, the first export-processing zone was established on the reclaimed land of Chungtao in Kaohsiung City. Investment rushed in the zone and the production as well as sales of those firms located within the zone increased dramatically. In three years, the export-processing zone had reached its

Institute of History and Philology and the Institute of Mathematics – moved in the interim. During this unsettled period, books, periodicals, and archaeological objects were stored in Yangmei Railway Station's warehouse. In 1954, Academia Sinica moved to its present site at Nankang, Taipei.

[9] The Executive Yuan is the highest administrative organ of the State.

capacity in use and operation. In January and August 1969, the government established the Nantze and Taichung export-processing zones, respectively, solving land and investment problems for the manufacturing industry.

In 1967, the "Science Development Steering Committee" was established as a policy research and advisory agency under the National Security Council, in charge of S&T policy making. "The Long-term National Science Development Council" was reorganized and renamed as the "National Science Council" under the Executive Yuan, in charge of the planning, promotion, coordination, and execution of national scientific and technological development policies.

Furthermore, influenced in part by the American and Soviet policies that emphasized securing national security through consolidated scientific development and in part by the resolution to fight back the Communist Party in Mainland China, the government actively established an environment conducive to technological development. In the same year (1967), the "Chungshan Institute of Science and Technology" was established under the Ministry of National Defense to research military technology and to develop autonomous national defense system, in an attempt to be independent upon imported technology.

During the interim, some state-owned enterprises (SOEs) set out to set up their own research units. For example, the Telecommunications Laboratories was founded by the Directorate General of Telecommunications. In addition, many universities began to institute graduate schools in science and engineering. In 1968, the Science Development Steering Committee and the National Science Council jointly formulated a series of "Four-year National Scientific Development Programs" to be implemented in three phases, respectively, over a period of 12 years. These programs expanded the scope from the emphasis on basic scientific research to technological development in order to meet the needs of national infrastructure building. In addition, the "National Science and Technology Development Fund" was also raised in a larger scale. All of the above had built up a firm foundation for the R&Ds in the 1970s.

In the aspect of industrial technology, in 1965, the government promulgated "Statutes on Technological Cooperation", reviewed regulations on outward investment, and set up rules on the use of foreign patent rights and specialized technologies to clarify the capital investment principals of technological cooperation. Moreover, The

U.S. National Academy of Sciences and the Academia Sinica organized "The Sino-American Science Cooperation Committee" in 1964. Two years later, the Academia Sinica invited American Council of Learned Societies, and the Social Sciences Research Council organized "The Sino-American Cooperation Committee in Humanities and Social Sciences", framing the prototype of bilateral cooperation with the U.S. Later, this cooperation focused on industrial technology. In 1969 The National Science Council and American Science Foundation signed a contract, "The Sino-American Bilateral Agreement on Science and Scholarly Cooperation", aiming at promoting the technological cooperation between Taiwan and the U.S. and enhancing the S&T levels within both countries. These actions stimulated industrial involvement in many technological cooperation ventures and the inward transfer of foreign technology. Productivity continued to grow, foreign marketing channels were established, and exports increased. The economy gradually shifted from an agricultural base to a balanced agricultural and industrial base.

All in all, during the 1960s, the government strengthened basic research capabilities, raised educational levels for science at colleges and universities, consolidated domestic research in basic and applied sciences; and promoted technological research in the fields of industry, agriculture, transportation, medicine, and hygiene. Public and private enterprises and corporate entities were encouraged to actively engage in R&D.

3.1.3 Science and Technology Policies in the 1970s

In the 1970s, in order to reinforce insufficient infrastructure and increase employment, the government began undertaking "Ten Major Construction Projects", including building Chungshan Highway, electrifying the railway system, constructing Beihui railroad, international airport, and two sea ports, starting up steel and ship-building SOEs, developing petrochemical industries, and setting up a nuclear power plant.

In the early 1970s, the National Science Council founded the Precision Instruments Development Center and the Science and Technology Information Center to improve the research environment and strengthen information and precision instrument services. In 1973, the Industrial Technology Research Institute (ITRI) was established. ITRI was started with three institutes: the United Industrial Research Institute, the Mining Research Institute, and the Metal Industries Institute, previously affiliated with the Ministry of Economic Affairs (MOEA) and later spunoff to form this institute. Its mission is: (1) to engage in applied research and technical services to accelerate the industrial development of Taiwan; (2) to develop key, compatible, forward-looking technologies to meet industrial needs and strengthen industrial competitiveness; (3) to disseminate research results to the industrial sector in a timely and appropriate manner, in accordance with the principles of fairness and openness; (4) to foster the technology development of small and medium-sized businesses, and cultivate industrial technology human resources for the benefit of the nation. ITRI later played an important role by providing immense assistance to industry upgrading and high-technology development.

In 1978, the First National Science and Technology Conference was convened and the attendees included experts, scholars, business leaders, and the heads of government agencies. The objectives of this conference were to update the national S&T policies, to enhance the technological capabilities, and, further, to motivate industry upgrading. The "Science and Technology Development Program" was drawn up in accordance with the resolution in this conference and was promulgated in 1979. Three broad objectives were specified in this program: (1) to strengthen the national defense industry, develop updated armament, and construct an independent national defense system; (2) to support infrastructure necessary for economic development, develop capital-intensive industries, modernize agriculture, and to economize energy; (3) to increase people's welfare, reinforce medical research, and to improve citizens' nutrition. In addition, "energy", "materials", "information", and "automation" were designated as key technological areas.

In 1979, the Hisnchu Science-based Industrial Park was inaugurated after the 3-year planning of National Science Foundation in order to promote the development of high-technology manufacturing in Taiwan. This Park was deliberately built around ITRI and two national engineering universities – National Tsing Hua University and National Chiao Tung University to provide future high-technology manufacturing firms with a high-quality environment in terms of infrastructure, facilities and human capital. The government offered attractive terms for setting up a business as well as a range of taxation benefits and allowances, including low-interest loans, R&D matching funds, tax benefits, and special exemption from the tariffs, commodity, and business taxes. To attract and to keep the elites, the government built a high-quality enclave within the park, containing industrial, residential, educational, and recreation areas. To provide the Park's companies with integrated services, the government also introduced branch offices from organizations such as the Taipei Customs Bureau of the Ministry of Finance, Taiwan Power, Chunghwa Telecom, General Post Office, Taiwan Water Supply, and China Petroleum. Commercial services such as banks, expressage, law firms and accounting firms were also included.

In 1980, the Executive Yuan recruited senior scholars and experts from abroad to serve as science and technology advisors. Each year, a science and technology advisory conference and a mid-year consultation conference were held. Agencies were set up under various ministries to meet the increasing needs for dealing with the S&T issues: the National Science Council established a research and evaluation department, and the Ministries of Economic Affairs, Transportation and Communications, Education, and National Defense all set up science and technology advisory offices. These aforementioned practices quickly led Taiwan into an era where entrepreneurship and specialized management began to play key roles in scientific and technological development.

3.1.4 Science and Technology Policies in the 1980s

In the 1980s, Taiwan experienced an extraordinary economic takeoff. The trade surplus expanded and per capita income exceeded US$5,000. At this stage, the government committed itself to several goals: accelerating industrial upgrading, adjusting the industrial structure, speeding up industrial research and development, enhancing the production technologies of traditional industries, and promoting high-technology industrial development. Underlying these goals were moves to meet the soaring demand for globalization and liberalization. The primary emphasis was on promoting some highlighted technologies, developing basic scientific research, and providing better training for high-level technological manpower.

The Second National Science Conference was convened in 1982. The convention reviewed the outcomes of earlier development projects and proposed plans for the future. It also revised and formulated S&T development programs and strengthened the cultivation and recruitment of advanced science and technology personnel, so as to meet the needs for the economic transition in the course of national development. In the conference, "biotechnology", "electro-optics", "food technology", and "hepatitis prevention" were added to the key technological areas that were originally defined as "energy", "materials", "information", and "automation" in the Science and Technology Development Program. The Executive Yuan also issued the "Program for Strengthening the Training and Recruiting of High-level Technological Personnel" and established the National Tsinghua University Materials Science Research Center in order to foster indigenous development of science and technology.

Along with the establishment of the Science-based Industrial Park came the implementation of various financial, investment, and tax exemption measures, creating an environment highly conducive to the development of high-technology industries. The Institute for Information Industry (III) was founded in 1979 under the collaboration of Ministry of Economic Affairs and several private enterprises, aiming to improve the productivity and competitiveness of all industries through the use of information technology (IT). In 1980, it began organizing "Information Month", an IT products exhibition, for the private sector, attracting more than 18 million participants across Taiwan over the next 20 years, helping the end users without professional IT background understand and appreciate the use of IT through free information sessions. As a result of the government's effort on high-technology industry, in 1986, for the first time the textile industry, which had led other sectors in export sales for many years, gave its top seat to the electronics and information sectors.

Meanwhile, Taiwan's export-processing zones faced a major transition: the appreciation of the New Taiwan Dollar and the escalation of labor, environmental protection, and land rent costs. In addition, the Hsinchu Science-based Industrial Park had offered an especially attractive investment climate to high-technology industries, becoming a competitor to the export-processing zones. All of the above reasons made the zones expand their scope from a completely manufacturing base to an integrated operation base, combining service sector and manufacturing sector to differentiate the function of the Science-based Industrial Park (see next chapter).

In order to build stronger groundwork for basic scientific research in a variety of fields, the government further established the Synchrotron Radiation Research Center, the Development Center for Biotechnology, and the Application Center for Precision

Instruments. Moreover, a marine research ship was also built and deployed. In 1986, the Third National Science and Technology Conference was held, mapping out the "Ten-year Long-term Science and Technology Development Plan", and defining objectives and strategies for the future national science development with the hope that Taiwan's technological capacity would reach a certain level comparable with those advanced countries in a decade. This plan laid out four major objectives, six major strategies, and the first quantitative national targets for manpower and funding. Apart from the eight existing key areas of technology, "disaster prevention", "synchrotron radiation", "marine science and technology", and "environmental science and technology" were also designated as key areas.

3.1.5 Science and Technology Policies in the 1990s

During the 1990s when those advanced countries heavily engaged in S&T development, Taiwan adapted to changes and trends as well. The Fourth National Science and Technology Conference, convened in 1991, drafted a "Twelve-year Long-term National Science and Technology Development Program" to be implemented between 1991 and 2002, as well as a more detailed "Six-year Mid-term National Science and Technology Development Program" for the period from 1991 to 1996. These plans explicitly set up the nation's mid- and long-term goals for S&T development.

In 1996, the Fifth National Science and Technology Conference was convoked, the objectives for technological development in the 21st century were articulated in this conference, and the concrete proposals were made consisting of the related budgets, the legislation of scientific development, the advanced technological research, and the high-tech industrial development. Also, the balance of science and the humanities was first mentioned in the conference. The key stresses of this conference included: first, the government's science and technology budget should be allowed to grow at a steady rate; second, a legal foundation for the development of science and technology should be established; third, the promotion of national-level projects and cutting-edge basic research should be strengthened; fourth, sustained, focused support should be provided for the development of high-tech industries; and fifth, science and technology should be better reconciled with the humanities and social sciences.

As a result of the Fifth National Science and Technology Conference, the first "White Paper on Science and Technology" was issued in 1997 to serve as a structural blueprint for the transformation of the nation into one based on science and technology. It not only restated those policies that had been promulgated but also added new contents to materialize its ideology. The goals of the White Paper were to build Taiwan as an Asia-Pacific regional research stronghold, a high-tech manufacturing center, and ultimately a technologically advanced nation. The main strategies included: (1) maintaining a steadily growing R&D budget and continue to improve manpower qualifications; (2) integrating utilization of R&D resources and mobilize universities' R&D capability; (3) promoting frontier research projects and national projects; (4) developing key industrial technologies; (5) developing more science parks to speed up the realization of research findings; (6) implementing the National Information Infrastructure (NII) program; (7) achieving sustainable development and improving public welfare through research and development; (8) establishing a sound legal basis for scientific and technological policies; (9) harmonizing science/technology and the humanities; (10) strengthening international cooperation and promoting interchange with mainland China; (11) broadening S&T education and public awareness; (12) strengthening defense technology R&D and promote civilian-defense cooperation.

In 1998, the government further approved the "Measures for Promoting a S&T Nation" to make the blueprint, namely, the "White Paper" more practical. This policy specified the mid- and long-term goal of S&T budget and personnel engaging in S&T and drafted the strategies for achieving those goals that encompassed the White Paper. The "Basic Law of Science and Technology" was also passed in the same year and went into effect in January 1999 to formulate a legal framework for S&T development.

In January 1999, ten years of space program development paid off with the successful launch of the nation's first-ever satellite, ROCSAT-1. Taiwan has ambitiously developed space technology and nurtured the domestic satellite component industry, ushering into a new era for space observation and research.

By 1996, the export-processing zones had completed their transition, having developed high-tech value-added industries, adjusted export-processing functions, and set up exclusive zones for warehousing and transshipment. Productivity was boosted by engaging manufacturing industries with related pre- and post-manufacturing businesses. In 1998, exports from these zones totaled US$7.27 billion, making export-processing zones an important pillar for economic and industrial technological development alongside science-based industrial parks.

In 1999, the Legislative Yuan passed the "Basic Law of Science and Technology". It was the first basic law in Taiwan, and Taiwan became the second country[10] that enacted basic law on S&T. Hereafter, the government was obliged to propose "The Prospects and Strategies of S&T Development and the Present Situation" every two years and "National S&T Development Plan" every four years. To frame "The Plan", the government should consult with the Academia Sinica, S&T-related departments, industrial sectors, and other organizations, and the drafted plan should be discussed in the National S&T Conference. The first plan was promulgated in 2001. The intent behind this plan was to guide the country's entrance into the so-called "knowledge economy age". Its overall goals comprised strengthening the knowledge innovation system, boosting industry's competitive advantage, improving citizens' quality of life, promoting sustainable development, improving nationwide technological standards, and reinforcing the country's autonomous defense capability. In other words, it is sought to bring the country into the knowledge economy age through the application of technology, improve the country's international competitiveness, and transform Taiwan into a Green Silicon Island[11].

[10] Japan was the first country that enacted basic law on S&T in 1996.

[11] "Green Silicon Island" was brought up in President Chen Shui-bian's inauguration speech on May 20, 2000, who proposed to develop Taiwan into a "green silicon island" to maintain Taiwan's economic competitiveness as well as a sustainable national development, thereby ensuring a balance between environmental conservation and economic development.

Table 3-1 Major S&T Policies, Regulations, and Laws between 1959 and 2001

Year	S&T Policies and Institutions
1959	Guidelines on Long-term National Science Development Programs Long-term National Science Development Council
1964	The Sino-American Science Cooperation Committee
1965	Statutes on the Establishment and Regulation of Export-processing Zones Statutes on Technological Cooperation
1966	The Sino-American Cooperation Committee in Humanities and Social Sciences
1967	Science Development Steering Committee Long-term National Science Development Council was replaced by the National Science Council Chungshan Institute of Science and Technology
1968	Four-year National Scientific Development Programs The Sino-American Bilarteral Agreement on Science and Scholarly Cooperation
1973	Industrial Technology Research Institute was founded
1978	The First National Science and Technology Conference
1979	Science and Technology Development Program Hisnchu Science-based Industrial Park Institute for Information Industry (III) was founded.
1980	The Executive Yuan recruited senior scholars and experts from abroad to serve as science and technology advisors. Each year, a science and technology advisory conference and a mid-year consultation conference were held. The "information month" exhibition was held by III each year ever since.
1982	The Second National Science and Technology Conference
1983	Program for Strengthening the Training and Recruiting of High-level Technological Personnel
1984	The Development Center for Biotechnology
1986	The Third National Science and Technology Conference Ten-year Long-term Science and Technology Development Plan The Synchrotron Radiation Research Center
1991	The Fourth National Science and Technology Conference Twelve-year Long-term National Science and Technology Development Program Six-year Mid-term National Science and Technology Development Program
1996	The Fifth National Science and Technology Conference
1997	White Paper on Science and Technology
1998	Measures for Promoting a S&T Nation
1999	Basic Law of Science and Technology
2001	National Science and Technology Development Plan

Source: The author.

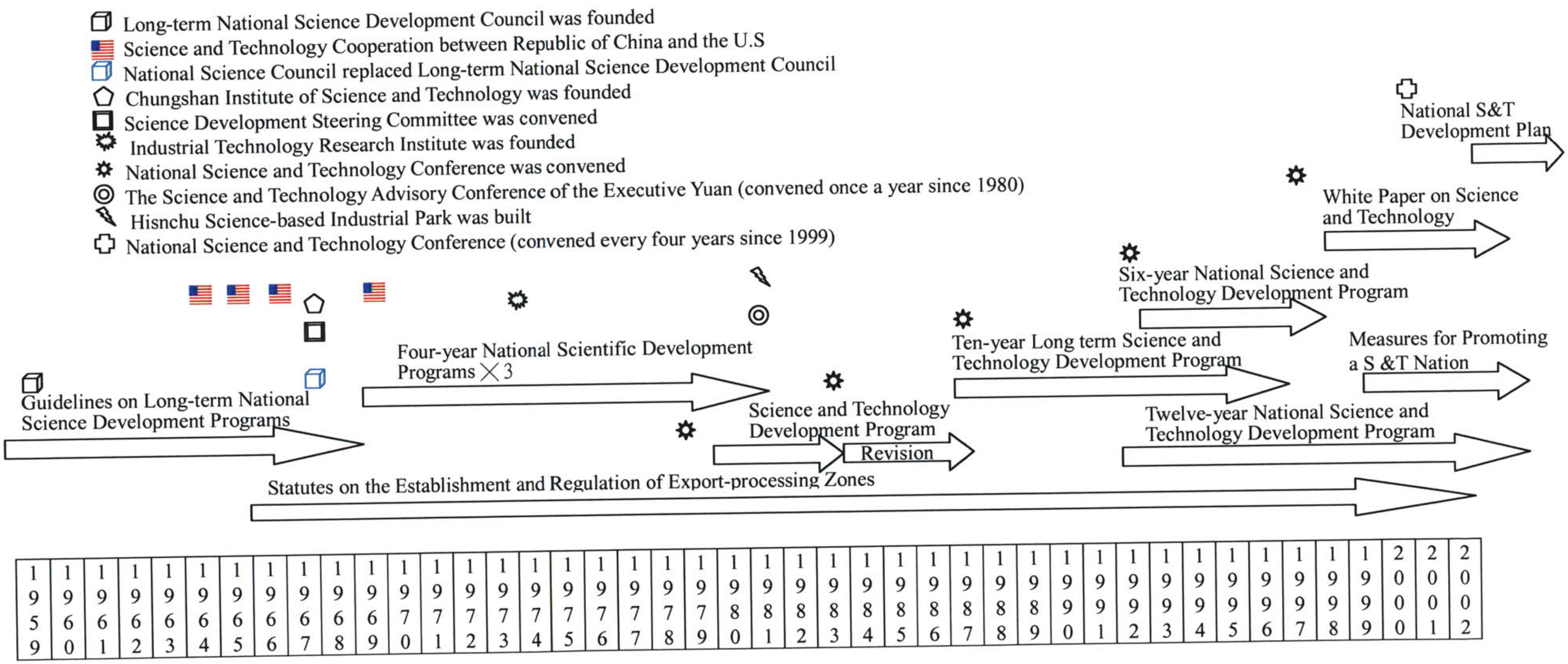


Figure 3-1 Events related to Science and Technology Policies in Taiwan

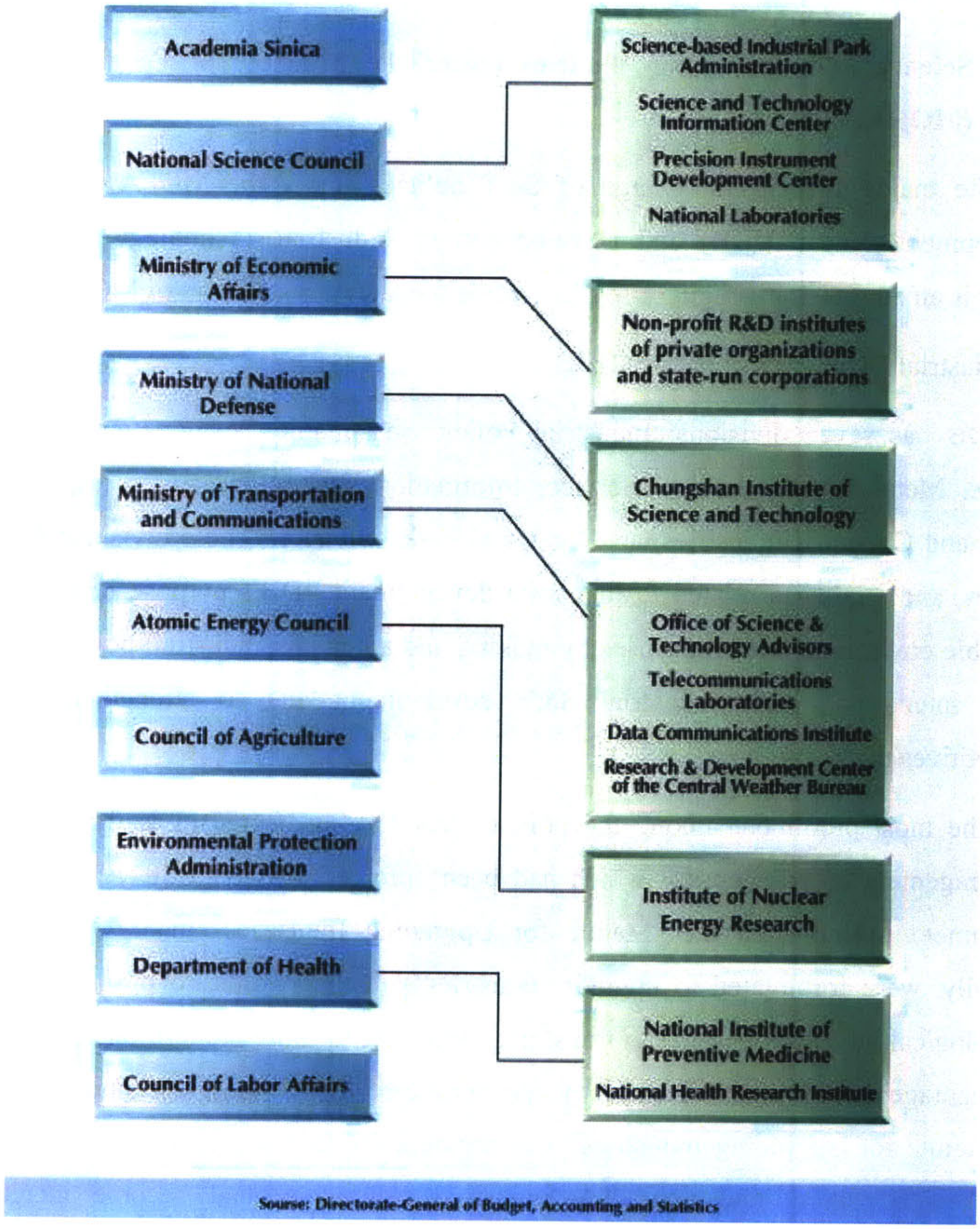


Figure 3-2 S&T Policies Related Institutions and Organizations

3.2 Select Science and Technology Policies in the Last Decade

3.2.1 Science and Technology Policies under the Ministry of Economic Affairs (MOEA)

The major agencies in charge of S&T policies under the MOEA are Industrial Development Bureau (IDB) and Development of Industrial Technology (DOIT). The former is an administrative unit of MOEA, while the later is a staff unit of MOEA.

1. Industrial Development Bureau (IDB)

IDB has seven divisions: Industrial Policy, Sustainable Development, Knowledge Service, Metal and Mechanical Service, Information Technology Industries, Consumer Goods and Chemical Industries, and Industrial Parks Division. These divisions formulate policies, and strategies related to industrial development. IDB's purpose is to provide a favorable environment for industries by making and amending industrial policies, most of which intend to foster industrial S&T development and to strengthen industrial competitiveness.

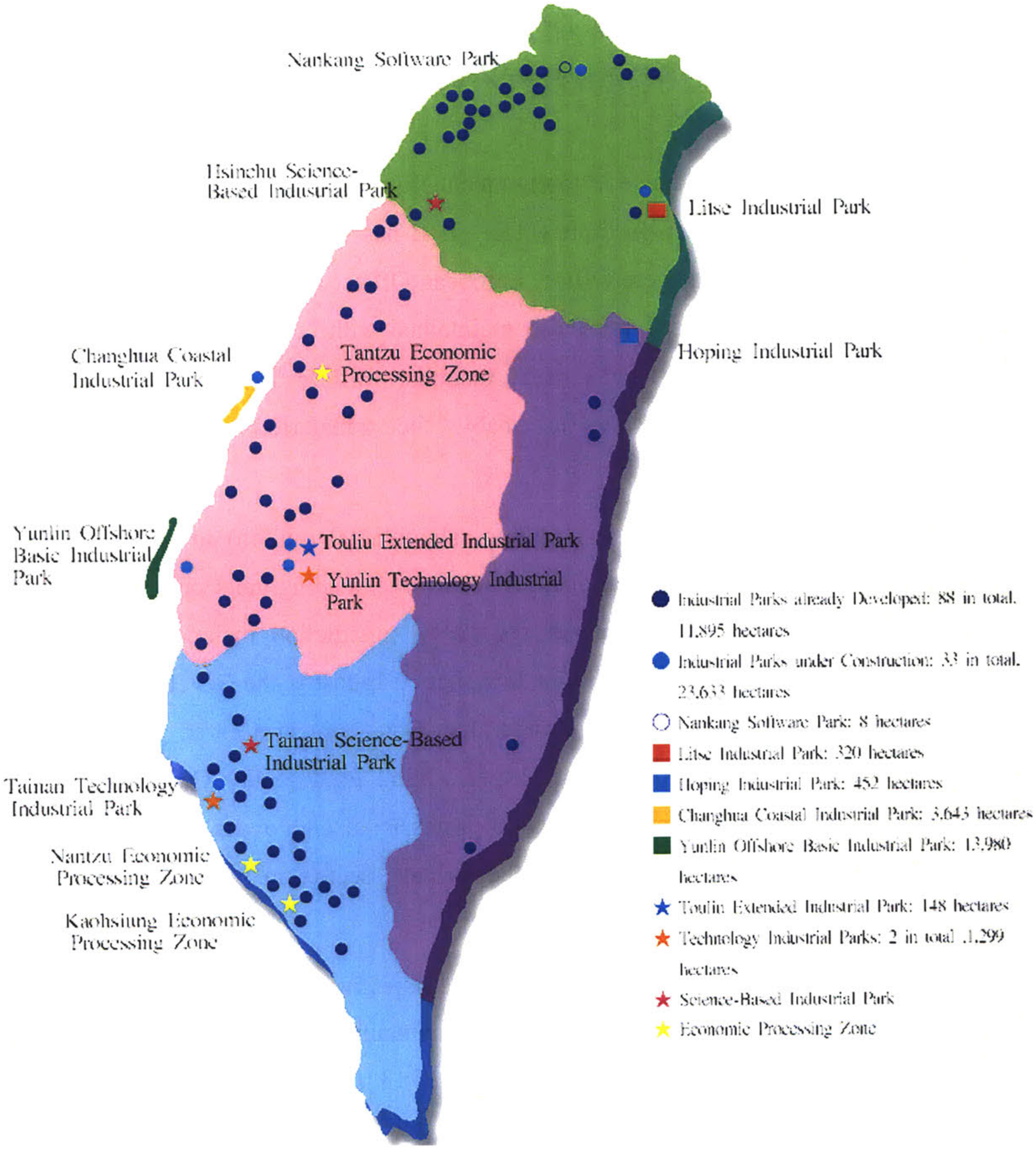
The most prominent among the policies that IDB in charge of is the "Statute for Encouragement of Investment" which had been enforced for about 30 years before the government promulgated the "Statute for Upgrading Industries" in 1990. These two, generally, were formulated to upgrade industries, in other words, to promote industrial technological advancement and to transform industries to more modern ones, by creating an advantageous tax regime backed by appropriate financial measures. Since 1990 when the "Statute for Upgrading Industries" was announced, Taiwan's economy had been in a period of transition, and upgrading industrial technology had become increasingly important. Consequently, on December 31, 1999, the President announced an amendment to the "Statue for Upgrading Industries" which aimed to facilitate overall economic development, to foster investment, and to introduce new technologies for emerging industries, and to solve problems in acquiring land for industrial use.

In order to spur the S&T development, this statute provided incentives mechanism for companies that were willing to devote themselves to S&T development, for instance, increasing their R&D expenditure, enhancing their production technology, and so on. The following is an excerpt that presents incentive mechanism in terms of tax reduction and low-interest loans from the contents of the Statute.

A. Incentives for Automation
  (a) Expenditures for purchasing automated production technology and equipment can be deducted from a company's current year income tax at the following rates: 10% for automated production technology, 20% for domestically produced equipment and 10% for imported equipment.
  (b) A company can receive a low-interest loan based on an investment plan for the purchase of automated equipment and machinery.
B. R&D Incentives
  (a) A company can enjoy a 25% tax credit against income tax payable for any expenditure for developing new products, improving production technology, advancing technology for provision of services, or improving the manufacturing process.
  (b) Equipment and instruments exclusively used for R&D, experiments or quality inspection can be depreciated over a two-year period.
  (c) Private companies engaged in R&D of new industrial products may apply for loans to cover basic R&D expenditures.
  (d) Professional consultation and financial assistance for developing new products or new production technology are available to companies engaged in traditional industries.
  (e) Manufacturing machinery and equipment, apparatus and equipment exclusively used for research, experiment and quality inspection that are not manufactured domestically can be imported duty-free with approval of the MOEA.
C. Incentives for Personnel Training
  Up to 25% of expenditures for personnel training which is provided by a company itself or by an outside institute and which is relevant to the company's business activities may be credited against the company's income tax payable for the current year.
D. Incentives for Emerging Industries
  (a) A credit of up to 20% of the capital investment amount made by a corporate investor in emerging industries can be applied against the corporate income tax payable; in case of an individual investor, the credit is up to 10% against the individual's consolidated income tax payable.
  (b) Alternatively, a company in an emerging industry may choose to be exempted from income tax for a five-year period. This exemption requires that shareholders waive their investment tax credit by passing such resolution at a shareholders' meeting within two years from the date of first payment of the stock subscription price by its shareholders.
E. Incentives for Technology-related Industries

In the aspect of land use, the statute also assisted the enterprises in land acquisition, planning, development, and management. Over the past 30 years, 88 industrial parks covering a total area of 11,895 hectares were completed, and 33 new parks with a total area of 23,633 hectares are currently under construction. Another 18 parks with a total area of 3,225 hectares are on the agenda. Among the completed industrial parks, 55 are under the direct supervision of the IDB and now accommodate 10,329 factories employing 470,000 manufacturing workers. These people serve as the critical force driving both regional development and the growth of Taiwan's manufacturing sector. These industrial parks also serve as the industrial cluster, sharing high-quality infrastructure and acquiring the agglomeration effects of increasing returns to scale.

In addition to the IDB's efforts on constructing new industrial parks, it also encouraged local governments and private enterprises to set up industrial parks on their own. Besides, IDB is also committed to designing information technology parks to accommodate the expansion of the software industry, a pollution-free and high value-added industry. The Nankang Software Park, located in Taipei, has been a milestone for the nation's software industry. Plus the Hsinchu and Southern Taiwan Science-based Industrial Park as well as three more parks under construction, built by The National Science Council, in accordance with the Statute for Administration of Science-based Industrial Parks, all these industrial parks are shown as Figure 3-3.



Source: IDB, MOEA, R.O.C.

Figure 3-3 Industrial Parks in Taiwan

In addition to the statutes, IDB also provided training program to further upgrade the quality of the work force that is necessary to meet the industrial and individual companies' needs. In collaboration with Council of Labor Affairs on labor training program, IDB worked closely with universities/colleges and research organizations to provide both professional and on-the-job training for the current employees in the manufacturing industry. About 100,000 in-service people and 22,000 high-level technicians attended these sessions each year.

Also, IDB provided assistance in foreign technology transfer. In cooperation with the Industrial Technology Research Institute (ITRI), IDB has set up four bases of operation: North America Company, Japanese Office, European Office, and Russian Office, and also closely cooperative relationships were also maintained with certain agencies in Canada, Holland, the United Kingdom, Israel and Australia,. Efforts are made to obtain the advanced foreign technologies and to enable the transferred technologies to be commercialized.

IDB recently provided NT$3,498 million (about $100 million) to finance various research institutes and private industrial associations in extending the scope of their R&D projects. Major research agencies under the IDB's jurisdiction include the Industrial Technology Research Institute, Institute for Information Industry, the Development Center for Biotechnology, the United Ship Design and Development Center, China Textile Institute, Metal Industries Development Center, China Productivity Center, and Food Industry Research Institute. With over 10,000 professional employees, these specialized agencies have immensely worked with the private sector in the development of state-of-the-art technologies.

In IDB's 2002 report, it pointed out its future objectives for industrial development (see Table 3-2). Manufacturing growth rate should maintain 6.2% in 2006; total production value should get to $4,100 billion compared to the $2,713 billion in 2000, while production value per employee should increase $72 thousand in 6 years; the ratio of R&D expenditure against revenue should reach the level of 2.5% as opposed to 1.27% in 1999; and the ratio of skilled technical personnel to total employees should get to 20%, 6.5% increase from that in 2000.

Table 3-2 Overall Objectives for industrial development

Item / Year	2000	2006
National Economic growth rate (%)	6.0	6.2
Manufacturing growth rate(%)	7.96	6.2
Total production value (US$ billion)	2,713	4,100
Production value per employee (US$ thousand)	110	172
Ratio of R&D expenditure against revenue (%)	1.27*	2.5
Ratio of skilled technical personnel to total employees (%)	13.5	20.0

Sources: 1. GNP of Taiwan, R.O.C., Monthly Bulletin of Earnings and Productivity Statistics, Cross-Century National Construction Plan, Taiwan Institute of Economic Research, and national Science Council, Executive Yuan. 2. The 2006 figures are based on predictions of Taiwan Institute of Economic Research commissioned by IDB.
* 1999 figures

2. Development of Industrial Technology (DOIT)

The predecessor of DOIT was the Office for Science and Technology Consultation, founded in 1979 in accordance with the "Science and Technology Development Program" for the purpose of enhancing industrial technology. In 1993, it was reorganized as Department of Industrial Technology (DOIT) based on the "Regulations for Establishing the Office of Science and Technology Advisors of the MOEA". The primary mission of DOIT is to enhance industrial technology and accelerate industrial upgrading. Its tasks consist of developing innovative technologies, assisting in setting up new industries, helping industries to develop key technologies and components to upgrade the traditional industries, and establishing the mechanism and standards to test and certificate good models.

Owing to the government's diversification of its focus on the R&D – from the advanced technology development to industrial technology development, the Technology Development Program (TDP) was implemented under the DOIT in 1979. From then on, the government set up a budget and delegated tasks to research institutes, such as ITRI, in an effort to developing industrial technology and enhancing industrial competitiveness. Beginning in 1997, the TDP has been gradually opened up to industries to encourage private enterprises to take part in technological innovations and applied research. The "Incentive Schemes for Enterprise to Develop Industrial Technologies" were formulated consequently. In February, 1999, the "Industrial TDP", the "Small Business and Innovation

Research Program", and the "IT Applications Promotion Project" were implemented one after another. Adequate financial resources were offered in accordance with the program, and all collaborated innovations under this program belong to the businesses' intellectual property so as to encourage private sector's active participation in scientific and technological R&D and to enhance enterprises' R&D technological capabilities. Furthermore, the MOEA enacted, in 2001, the "Implementation Guidelines for the Academic TDP", strengthening the cooperation between the academia and industries.

DOIT also provided domestic as well as foreign companies and universities with incentives for establishing R&D Centers in order to enhance their innovation capabilities within Taiwan. The objective of the "Industrial Technology Innovation Center Program" was that by 2006, there will be more than 40 R&D centers established by domestic enterprises, more than 30 R&D centers established by multinational companies, and more than 35 R&D centers established by universities. The incentive mechanism will be provided through tax incentives, subsidies to technological projects, relaxation of the employment quota of specialists from China, and a one-stop service window.

In addition, DOIT sorted out the service industries that are in relation to manufacturing's R&D and innovation activities, for example, those industry that adds value to a company's intellectual property, such as brokerage, price appraisal, and so forth, that offers service for industrial technology projection, industrial design, etc., and that helps create a level playing field for S&T development. Those enterprises were treated as the companies within the TDP, hence, sharing the same benefits as them.

3.2.2 Science and Technology Policies under the Council for Economic Planning and Development (CEPD)

Beyond those policies that are more explicitly known as S&T polices, there are also policies that facilitate S&T development, but are of no explicit S&T labels on them. Council for Economic Planning and Development (CEPD)[12] has been responsible for the

[12] The main function of CEPD is to draft overall plans for national economic development; to evaluate development projects, proposals, and programs submitted to the Executive Yuan; to coordinate the economic policymaking activities of related ministries and agencies; and to monitor the implementation of development projects, measures, and programs.

macro environment for Taiwan's economic development. Its main responsibility does not concentrate on S&T development; nonetheless, it has proposed some policies germane to S&T and has had significant effects, especially on fostering human capital and planning infrastructure.

In 1997, CEPD formulated "21 Century Human Capital Development", mainly focusing on life-long training, on-the-job training, and exploring potential labor force in order to meet the human capital needs of its previous policy "Developing Taiwan as an Asian-Pacific Regional Operation Center" promulgated in 1995. This policy is a comprehensive policy regarding the measures to enhance the quality and the quantity of overall human capital development. Although its targeted goal was not toward S&T development, it provided the same base for the future S&T development in some sense.

The advent of the Internet age has propelled the CEPD to frame new policies to upgrade the nation to get abreast of the world trend. Consequently, at the end of 1997, the Executive Yuan passed the "National Information Infrastructure (NII) Development Plan" for the joint construction of the domestic Internet infrastructure and the penetration of the Internet education by both the government and the private sector. The program encompassed eight major tasks: strengthening regulatory system, accelerating network construction, popularizing Internet education, extending information application, fostering Internet-related industries, strengthening research and development, extending international cooperation, and preventing Internet pornography and crime. The aim was to bring the efforts of government as well as the private sector together to accelerate the Internet infrastructure building, to disseminate knowledge of network connection, to provide an all-round legal system, and to promote applications and services of information networks.

The "Plan to Revitalize Traditional Industries[13]" formulated in 1999 was comprehensive favorable provisions, support, and assistance in areas of loans, taxation, labor, marketing, and R&D to revitalize the so-called traditional industries, as opposed to the high-technology industries. This policy focused on improving the competitiveness of

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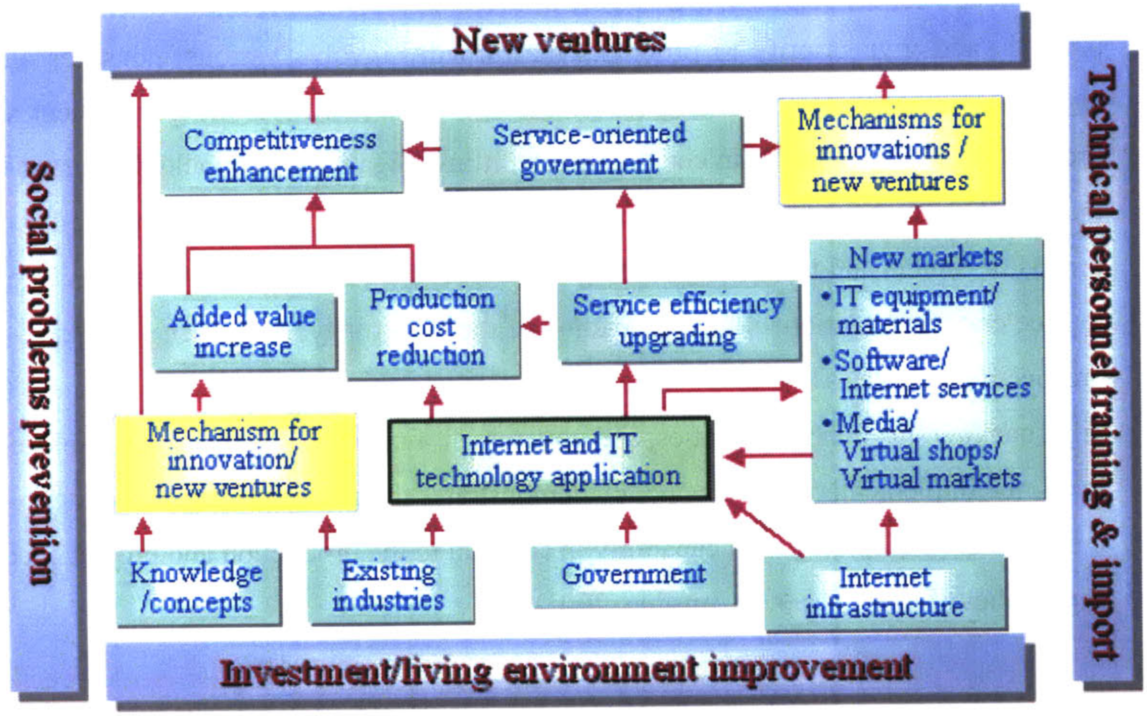
[13]Traditional industries include food and beverages, tobacco, textile mill products, wearing apparels and accessories, leather and fur products, wood and bamboo products, furniture and fixtures, pulp, paper, and paper products, printing. processings, and chemical materials

traditional industries under the threats of the so-called "high-technology manufacturing" in competition of government's resources. This policy implied that the government paid attention not only to the high-technology industries which intuitively had direct contribution to the S&T development but also to the traditional industries which are not the rising stars in the stock market anymore but could still make fair contribution to the S&T development and transform themselves toward modern firms by altering their operation and management toward more knowledge-intensive ones.

"Developing Taiwan as a Knowledge-based Economy" was proposed in 2000 with a vision of building Taiwan's economy based on the production, distribution, and use of knowledge and information. This policy mainly designed measures to encourage innovation of private sector, to foster new ventures, to disseminate the use of information and communication technology, to construct an environment supportive to the Internet use, to modify the educational system in order to meet the personnel needs, to establish a service-oriented government, and to prevent social problems arising from the course of the transformation of economic structure. Figure 3-4 shows the measures for knowledge-based economy development.

Recognizing the growing trend for the enterprises to develop global logistics management, the government was obliged to help businesses establish an environment favorable to the global logistics operation. In 2000, CEPD made an overall review of the status quo of Taiwan, including the existing niches and the projected problems while developing Taiwan as a global logistics center and proposed the "Global Logistics Development Plan", suggesting that Taiwan should strengthen its e-commerce, goods and service flow, and infrastructure. The objectives were to help eliminate problems encountered by enterprises when they develop of global logistics, to build Taiwan to become a vital hinge in the international supply chain, and to develop high-value-added entrepot by using Taiwan's existing comparative advantages in manufacturing.



Source: Council for Economic Planning and Development, Executive Yuan, R.O.C.

Figure 3-4 Measures for Knowledge-based Economy Development

The "Challenge 2008: Six-Year National Development Plan" was the newly launched comprehensive six-year national development plan. It was designed to cater for things that Taiwan will need to transform itself into a "green silicon island." The total expenditure under the plan was approximately US$75 billion. The major goals of the plan concerning S&T were (1) to develop at least 15 products or technologies that rank among the world's best; (2) to increase R&D expenditures to 3% of the GDP; (3) to expand the number of broadband Internet users to over 6 million. The plan included three major reforms: political, financial, and fiscal, and ten major investments, of which that relate to the S&T development were (1) cultivating E-generation manpower with good IT, English, and creative skills; (2) developing an international base for R&D and innovation; (3) developing high value-added industries; (4) creating a digital Taiwan.

The "Encouragement of Industrial Innovation R&D" was launched on July, 2002. This policy basically defined that the industrial innovation and research and development may be divided into two areas: the R&D of technologies, and the development of products.

This policy specified that the government must embark on prospective programs and projects, and give priority to programs that broadly involve various industries and are highly advantageous to technological development. Furthermore, the government should provide assistance to banks in conducting credit investigation and should encourage banks to provide enterprises with loans under the collateral of intellectual property rights. Incubator centers and technology trading centers should be set up as soon as possible so as to accelerate the creation and dissemination of the technology. Moreover, in order to foster prospective industries and to energize capital markets, the restrictions on retirement funds, bills, banking, insurance, securities, and government funds shall be moderately relaxed. All in all, the implementation of this policy demonstrates the government's resolution to foster the national firm's innovation capability in addition to the production and project execution capabilities (Table 1.2, pp. 4, Amsden, 2001).

3.2.3 Science and Technology Policies under the National Science Council (NSC)

This council is directly subordinate to the Executive Yuan and was set up to replace the Long-term National Science Development Council since 1969. As the counterpart of National Science Foundation (NSF) in the U.S., NSC has been specifically responsible for the overall planning and promotion of the development in S&T in Taiwan. The tasks of NSC consist of 3 aspects: funding academic research; developing science-based industrial parks, and the most important of all, promoting national S&T development, which includes planning national S&T development, drawing up long and mid-term plans, reviewing and scrutinizing government's S&T policies, surveying S&T development status quo, and enforcing S&T policies.

National Research Programs are ongoing programs under NSC, encompassing different aspects: Genomic Medicine, Nanoscience & Nanotechnology, Pharmaceuticals & Biotechnology, National Digital Archive Program, Agricultural Biotechnology, National Telecommunication Development Program, Hazards Mitigation, National Science and Technology Program for e-Learning, and so on (for more detailed information, see Table 3-3). Each team appoints a program manager to be fully in charge of that program and to organize the working team. Enterprises are allowed to take part in one of the programs under the government's assistance and guidance.

A number of laws, measures, and regulations were also drafted by the NSC: The "Basic law of Science and Technology" (1999) was one of them; others including the "Points for Applying for the Subsidization of Special Topic Project Expenditure" (1999), the "Property Right and Application of the Government's S&T Achievements", the "Procedures of Inviting International S&T Experts" (1997), the "Scholarships for Ph.D. Students", and etc. were all drawn up by it.

Table 3-3 National Research Programs

Title of Program	**Objectives**	**Participants**	**Duration**	**Budget**
National Research Program for Technologies against Natural Disasters	To analyze in-depth and understand the natural and manmade factors causing disasters such as earthquakes, typhoons and heavy rain in Taiwan and to keep abreast of disaster-preventing technologies and have the same implemented in disaster-preventing systems so as to reduce tangible or intangible losses caused by disasters.	Ministry of Communications and Transportation, Ministry of Economic Affairs, Ministry of the Interior, Public Construction Commission, Ministry of Education, Environmental Protection Administration, Dept. of Health, Council of Agriculture, National Science Council, Ministry of Finance	1998 ~2001 2002 ~2006	1 billion 3,080 million
National Research Program for Telecommunications	· To enhance coordination of the R&D works among various government agencies, and improve the R&D efficiency of telecommunications · To nurture relevant telecommunications technical manpower · To develop key technologies (such as broadband Internet and wireless communications), and establish the future competitive advantages of the country	Ministry of Economic Affairs, Ministry of Education, National Science Council, Chunghwa Telecom Research Institute	1998 ~2003	14,400 million

Title of Program	Objectives	Participants	Duration	Budget
	· To increase the productivity and competitiveness of telecommunications service industry and communications industry · To upgrade the bandwidth and quality of the Internet, and make international exchange about the development so as to fulfill the purpose of establishing the NII			
National Research Program for Agricultural Biotechnology	· To develop technologies and S&T resources relating to indigenous agrobiological technology products that have market potential to help build the agrobiological technology industries in Taiwan · To build a national R&D and application system so as to guarantee a sustainable development of the agricultural biotechnology industry in Taiwan and promptly upgrade the national agricultural biotechnologies · To promote and integrate high-end biotechnological researches aiming at industrial development, and help the agricultural biotechnology industry in Taiwan to develop and become the R&D hub in the Asia-Pacific region	Academia Sinica, Council of Agriculture, National Science Council	1998 ~2001 2002 ~2004	800 million 730 million
National Research Program for Pharmaceutical and Biological Technologies	· To promote target-oriented R&D activities of pharmaceutical and biological technologies · To establish the infrastructure and peripheral facilities to accelerate the commercialization of the R&D results	National Science Council, Department of Health, Ministry of Economic Affairs, National Health Research Institute	2000-2002	1,700 million

Title of Program	Objectives	Participants	Duration	Budget
National Research Program for Genomic Medicine	· To establish core facilities and build a technical platform for the R&D of emerging biotechnology industries · To establish transgenic technologies for three common diseases · To facilitate the prevention, diagnosis and treatment of diseases; to install clinical experiment facilities for gene treatment and establish 3 to 5 modes of mutant mice with respect to human diseases to facilitate the screening of new medicine · To establish a database of biological information on genomes to support the national development of knowledge-based economy; and to establish academic forums and provide social education on sciences and technologies of genomic medicine	Academia Sinica, Department of Health, National Science Council, Ministry of Economic Affairs	2002 ~2004	7,500 million
National Research Program for Digital Collections	· To digitalize the national archive collections, and establish a national digital collection system · To promote the humanistic, social, industrial and economic developments in Taiwan	Academia Sinica, National Science Council, Ministry of Education, Council for Cultural Affairs, Council for Archives, National Palace Museum, National Taiwan University	2002 ~2006	2,830 million

Source: Adapted from "Explanations of the Policy on "Encouragement of Industrial Innovation and Research and Development"", CEPD and NSC, MOEA, Executive Yuan, 2001

In addition, the NSC has signed memorandums of understanding (MOU) or agreements for bilateral cooperation with S&T related organizations in both industrialized and developing countries. For the time being, the NSC has formally established collaborative ties with Australia, Austria, Belgium, Bolivia, Canada, the Czech Republic, Finland, France, Germany, Hungary, Indonesia, Ireland, Japan, Jordan, the Republic of

Latvia, the Republic of Lithuania, the Netherlands, Norway, the Philippines, Poland, Russia, Saudi Arab, the Slovak Republic, South Africa, Sweden, Switzerland, the Ukraine, the United Kingdom, and the U.S.. Through exploratory visits, bilateral seminars, and joint research projects, the NSC acquires the information about the opportunities to further collaboration, shares the research results with those foreign institutes, and thus, obtains feedback and learns from them.

Chapter 4 Government-led Science and Technology Development

In this chapter, the relationships between the S&T policies and Taiwan's technological development will be carefully examined, and if there is some technological development accumulated along the historical path, this development will certainly relate to its economic development. Based on the S&T policies presented in the previous chapter, firstly, some of the S&T policies, not all, will be selected arbitrarily based on the author's discretion, and each policy impact and the individual policy effects will be discussed, and then, the economic growth attributes will be explored to see if they fit in the pictures that are constructed in the first section which has been outlined, followed by a discussion of contending views of sustainable growth. Finally, an overall review of the S&T policies will be examined, including the merits, the defects, and the aspects that should be improved in the near future.

4.1 Specific S&T Policy Effects

1. Export-Processing Zones

Since the first Export-Processing Zone in Kaohsiung was established in 1965, this policy has been implemented for thirty nine years. These zones have been the primary milieus of foreign exchange accumulation and the state-of-the-art foreign technology transfers. By providing efficient management in the zones and preferential tax incentives, the zones created a favorable environment to attract firms to agglomerate in the zones, and set up an earliest prototype for the later industrial parks and science-based parks. From the outset, the zones agglomerated a number of manufacturing firms and drove the tremendous export growth in Taiwan, leading Taiwan's economic development to the so-called export-led growth[14]. The dramatic increase of the industrial exports in the past decades, shown as Figure 4-1, has something to do with the establishment of these Export-Processing Zones. The export value share of the EPZ from 1967-2002 is about 5.7% for the base as total export value and 5.9% for the base as industrial export value,

[14] Export-led growth was contended by many scholars and many literatures have argued that it was the major contributor to Taiwan's economic growth and made Taiwan become one of the four tigers in the East Asia. I would leave this to be discussed in the following chapter.

respectively. Compared to the area (see Table 4-4) that occupies the total area of Taiwan (3,600 km^2), the share is 0.0023%, which implies that EPZ is high value added.

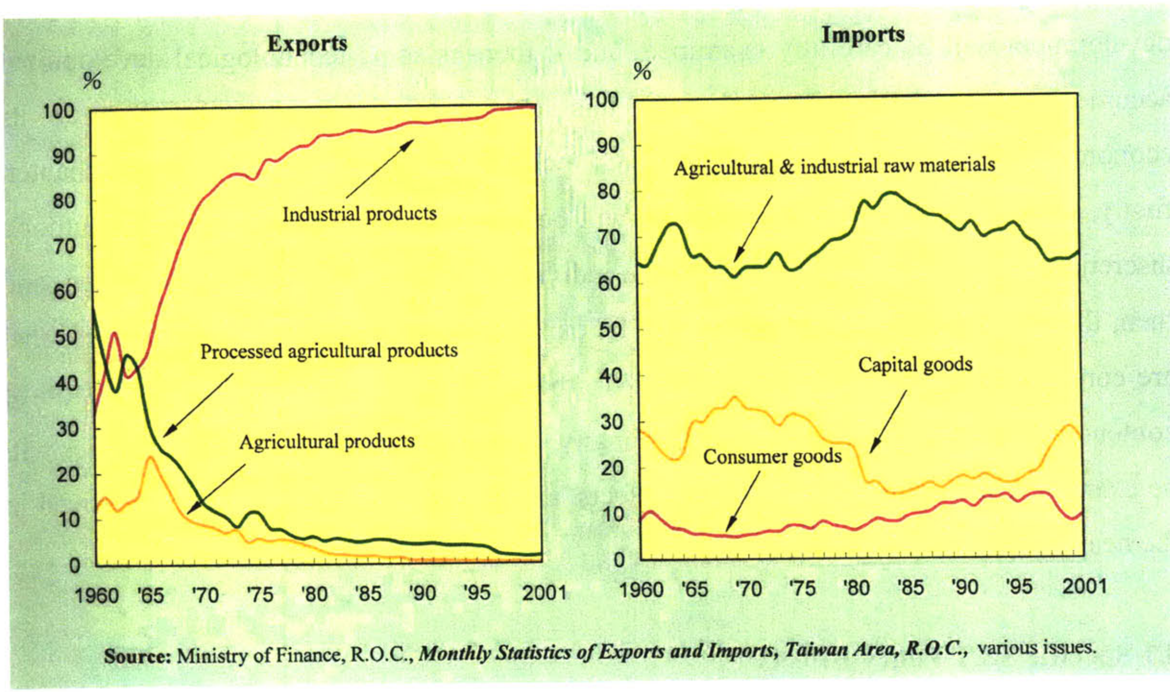


Figure 4-1 Trade Composition from 1960 to 2001

Firms that locate in these zones possess some characteristics: (1) Big businesses contribute most of the business turnover in the zones. By looking at Table 4-1, in Nantze zone, there were only 11 firms out of 96 firms whose turnover exceeded $100 million in 1995, but their turnover had accounted for 78.8% of that in the whole zone. In addition, the firms whose turnover exceeded $20 million were only 27.08%, while their turnover is 92.2%. Same in the other two zones listed in the Table. (2) Electronics and precision machinery are the primary industries. Table 4-2 shows there were 17 firms' turnover exceeding $100 million, among which, 16 firms belonged to electronics and precision machinery industries; also, 10 firms fell into the category of the turnover between $50 million and $100 million, of which 7 were in that industry; in the group – turnover between $20 million and $50 million, 12 out of 27 firms were in that industry, followed by precision machinery manufacturing. (3) Most of the firms are foreign-owned or joint venture. By examining the ownership of the firms in Table 4-3, only 11 firms out of 54 firms, whose turnover was greater than $20 million, were completely owned by Taiwanese in 1995. The rest of the firms were either joint ventures or foreign-owned firms, of which the Japanese venture accounted for the highest proportion, followed by Hong Kong's.

Table 4-1 Firm Structure in the Zones I, 1995

Zone	**Nantze Zone**		
Turnover ($ million)	**>100**	**50-100**	**20-50**
Number of the firms	11/96	4/96	11/96
Percentage of the turnover	78.8%	7.1%	6.3%
Percentage of the employees	53.4%	13.0%	12.1%
Zone	**Kaohsiung Zone**		
Turnover ($ million)	**>100**	**50-100**	**20-50**
Number of the firms	4/93	4/93	6/93
Percentage of the turnover	50.2%	18.3%	14.0%
Percentage of the employees	26.2%	15.9%	32.3%
Zone	**Taichung Zone**		
Turnover ($ million)	**>100**	**50-100**	**20-50**
Number of the firms	2/46	2/46	10/46
Percentage of the turnover	37.3%	14.8%	32.3%
Percentage of the employees	26.7%	11.7%	38.5%

Source: Adapted from Economic Processing Zone, Ministry of Economic Affair, Taiwan http://portal.epza.gov.tw/www/Eng/a01/a01-3.htm

Based on what have been discovered so far, those characteristics display high technology components. Given that most of the enterprises in the export-processing zones are big businesses, foreign-owned/joint venture firms in electronics and precision machinery industries, the technological capabilities of those big, foreign firms are rather abundant by exploiting the scale economy. Running the plants in these zones, those firms not only create spillover effects in terms of new ideas and technology, with extension to products, but also train their employees, most of whom are local Taiwanese, who later could be the founders or chief characters of start-ups. Moreover, given that those firms are mainly in the electronics and precision machinery industries, which belong to technology-intensive industries, whether the technology is mature or developing, the technology transfers are vivid in these zones.

Table 4-2 Firm Structure in the Zones II, 1995

Turnover ($ million)	Nantze Zone	Kaohsiung Zone	Taichung Zone
>100	Electronics and electronic machinery equipment manufacturing (11)	Electronics and electronic machinery equipment manufacturing (4)	Precision machinery manufacturing (1), Electronics and electronic machinery equipment manufacturing (1)
50-100	Electronics and electronic machinery equipment manufacturing (2), plastic product manufacturing (1), machinery equipment manufacturing (1)	Electronics and electronic machinery equipment manufacturing (4)	Precision machinery manufacturing (1), Electronics and electronic machinery equipment manufacturing (1)
20-50	Electronics and electronic machinery equipment manufacturing (6), metal product manufacturing (3), Jewry manufacturing (1), wearing apparels and accessories (1)	Electronics and electronic machinery equipment manufacturing (1), furniture and fixtures (1), metal product manufacturing (1), wearing apparels and accessories (3)	Electronics and electronic machinery equipment manufacturing (5), Precision machinery manufacturing (4), musical instruments manufacturing (1)

Source: Adapted from Economic Processing Zone, Ministry of Economic Affair, Taiwan http://portal.epza.gov.tw/www/Eng/a01/a01-3.htm

In addition to technology transfers, the export features of the firms in these zones are especially critical to the technological development. In order to export, that is, to compete in the global market, those firms in the zones are needed to be competitive in terms of product quality and quantity, or sometimes, speed of providing buyers the products in time, to compete with global competitors and to meet the high-standard requirements from the foreign buyers. In order to do that, those firms have to manage to upgrade their technologies.

The Export-Processing Zones had been contributing to economic growth in terms of the export value and technology transfers in the past decades. However, due to the vast changes of Taiwan's economic structure, the soaring labor costs, and the division of labor with the science-based parks, the Export-Processing Zones strived to transform the roles playing in the past. Since the last decade, the Zones have been actively implementing the Warehouse Transshipment Special Zone Plan in order to reposition itself and revise its functions in support of CEPD's plan – the "Developing Taiwan as an Asian-Pacific Regional Operation Center", initiated in 1996. This plan's ambition was to create Taiwan as the Asian Pacific Operation Center, and in accordance with the plan, the Export-Processing Zones should be upgraded to a high-value-added global logistic center in the first place. Therefore, a new plan was formulated, and the "Warehouse Transshipment Special Zone Plan" was the plan partially in lieu of the Export-Processing Zones.

Table 4-3 Firm Structure by the in the Zones III, 1995

Turnover ($ million)	Nantze Zone	Kaohsiung Zone	Taichung Zone
>100	Taiwan (4), Hong Kong – Taiwan(2), US – Taiwan (1), Japan – Taiwan (1), Hong Kong – overseas Chinese (U.S.) (1), Holland (1), Japan (1), Hong Kong – U.S. – Taiwan (1), Japan -- Switzerland (1)	Japan (3), US – Taiwan (1)	Japan (1) 、Japan – Switzerland (1)
50-100	Japan (2), U.S. (1), Hong Kong – Japan (1)	Japan (3), Taiwan (1)	Taiwan (1), Hong Kong – Japan (1)
20-50	Japan – Taiwan (4), Japan (2), Hong Kong – Japan (1), Japan – Hong Kong (1) 、Hong Kong – France – Japan – Taiwan (1), Taiwan (1), Hong Kong – Overseas Cantonese (1)	Taiwan – U.S. (2), Taiwan (1), U.S. – Malaysia (1) 、U.S. – Overseas Cantonese – U.K. Canada (1), Overseas Cantonese – U.K. – Taiwan (1)	Japan – Taiwan (3), Taiwan (3), U.S. (1), Taiwan – overseas Chinese (U.S.) (1), Japan – Hong Kong (1), Taiwan – overseas Chinese (U.K.) (1)

Source: Adapted from Economic Processing Zone, Ministry of Economic Affair, Taiwan http://portal.epza.gov.tw/www/Eng/a01/a01-3.htm

The Zones have increased its area from 192 hectares to the current 469 hectares (Table 4-4) and expanded to ten zones since the implementation of the "Warehouse Transshipment Special Zone Plan". The pre and post functions of the manufacturing and services were introduced into the zone such as research and development, designing, assembling, testing, inspection, warehousing and logistics, trade and the related industries. The efforts included constructing facilities for convenient storage and shipment as well as standardizing operation, firm, and delivery services, and so on. These efforts were made to reach the goal – a high-value-added global logistic center so that the plan concentrated on shortening both the time and money costs on transportation. For instance, the shipment of cargos offshore from Fuzhou or Xiaman, China to Kaohsiung, Taiwan needs 6 days in average. With the implementation of this plan, the traveling time is saved up to 5.5 days. Other things being equal, the traveling costs are trimmed off, too (see Table 4-5).

Table 4-4 Land Area of Export-Processing Zones

Zone	**Land Area (hectares)**
Taichung Zone	26.2
Chungkang Zone	177.0
Touliu Fabric Zone	268.0
Nantze Zone	97.8
Kaohsiung Zone	72.0
Chengkung Logistics Park	8.4
Hsiaokang Airfreight Logistics Park	54.5
Linkuang Zone	9.0
Kaohsiung Software Technology Park	7.9
Pingtung Zone	124.1
Total	844.9

Source: Adapted from Economic Processing Zone, Ministry of Economic Affair, Taiwan http://portal.epza.gov.tw/www/Eng/a01/a01-3.htm

Table 4-5 Transformed Export Processing Zones – Warehousing and Transportation Service Center

Item for comparison	Travel time for vessel	Cost on freight
Before the operation of the center	From Fuzhou, Xiaman via a third territory (Hong Kong or Singapore) to Kaohsiung would need six days in average.	Fuzhou to Kaohsiung via Hong Kong 20-feet container：$38040-feet container：$560Xiamen to Kaohsiung via Hong Kong20-feet container：$45040-feet container：$600
After the operation of the center	Fuzhou, Xiamen to Kaohsiung directlyFuzhou→Kaohsiung：11-12hours Xiamen→Kaohsiung：11hours	Fuzhou direct to Kaohsiung20-feet container：$30040-feet container：$500Xiamen direct to Kaohsiung20-feet container：$34040-feet container：US$500

Note：The freight from Fuzhou, Xiamen though Hong Kong is not included.
Source: Economic Processing Zone, Ministry of Economic Affair, Taiwan. http://portal.epza.gov.tw/www/Eng/a01/a01-6.htm

2. Measures for Promoting a S&T Nation

The "Measures for Promoting a S&T Nation" was promulgated in 1998. The details of this policy specified its mid- and long-term goals in two aspects: (1) in the aspect of S&T expenditure for the mid-term goals – the total R&D expenditure should achieve the level of 2.5% of the GDP in 2000, among which the government should account for 45%, which is 1.13% of the GDP, while the private sector should account for 1.37% of the GDP; at the same time, the basic research expenditure should not be smaller than 15% of the total R&D expenditure, whereas the technological development spending should be greater than 50%; R&D investment in manufacturing should reach 2% of its sales amount in that year; (2) in the aspect of S&T expenditure for the long-term goals – the total R&D expenditure should reach the level of 3% of the GDP in 2010, among which the government should account for 40%, which is 1.2% of the GDP, while the private sector should account for 60%, which is 1.8% of the GDP; the basic research expenditure should maintain 15%, whereas the technological development expenditure should be more than 55%; R&D investment in manufacturing should reach 3 or 4% of its sales amount in that year; (3) in the aspect of S&T manpower for the mid-term goals – the total R&D personnel (excluding graduates from vocational schools) should achieve the level of 52,500 in 2000, that is, 25 R&D personnel per 10 thousand people, among whom masters and PhDs should account for 50%, and masters will be the main force in industries; (4) in the aspect of S&T manpower for the long-term goals – the total R&D personnel (excluding graduates from vocational schools) should achieve the level of 75,000 in 2010, that is, 35 R&D personnel per 10 thousand people.

With these policy goals, it is feasible to examine whether these goals were met under the implementation of the policy for the time being. By comparing the mid-term goals of the "Measures for Promoting a S&T Nation" and the status quo in 2000 (shown as Table 4-6), three of the objectives are achieved: technological development expenditure, R&D personnel in terms of scale (absolute value) and ratio (relative value), graduate schools graduates that are doing R&D. Among them, technological development expenditure accounted for 59.6%, with 9.6% higher than the projected one; total R&D personnel were about 137 thousand, almost three times more than the objective; the graduate schools graduates that are doing R&D was 50.1%, 1% more than the goal. However, both public and private sector R&D expenditure share of the GDP, the basic research expenditure of the total R&D expenditure, and manufacturing R&D investment share of the sales did not meet the goals. Other than the doubt about the policy effectiveness, possible explanations could be the economic boom in 2000, which drove up the GDP as well as sales. It is true that in 2000 Taiwan's economy scaled new heights – the index of Taiwan's stock market skyrocketed ten thousand points for several times, which has never happened in the following years. With the extraordinary economic boom, the R&D expenditure did not, and needed not, completely follow the soaring cash inflow

Table 4-6 Examination of the Effectiveness of the "Measures for Promoting a S&T Nation"

	Mid-term Goals	Status quo in 2000
Total R&D expenditure share of the GDP	2.5%	2.05%
Government share of the GDP	1.13%	0.77%
Private sector share of the GDP	1.37%	1.28%
Basic research expenditure of the total R&D expenditure	15%	10.4%
Technological development expenditure of the total R&D	50%	59.6%
Manufacturing R&D investment share of the sales	2%	1.1%
Total R&D personnel	52,500 (2.5/thousand)	137,622 (6.2/thousand)
Masters and PhDs share of the total personnel	50%	29.4%+20.7%=50.1%

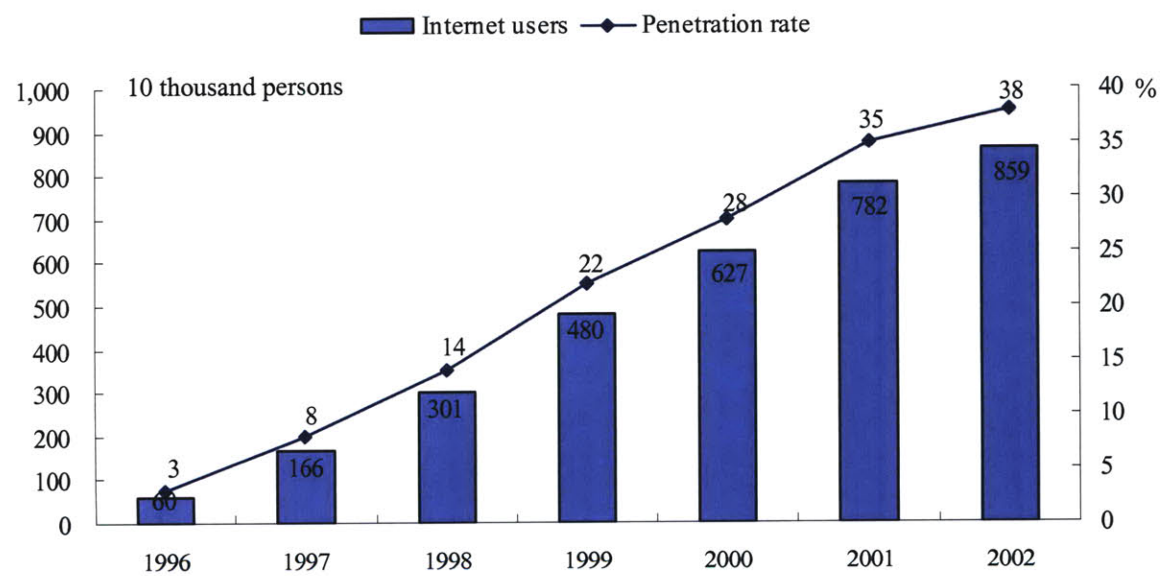
* Shaded areas are the mid-term goals that were achieved in 2000.

Source: 1. "Measures for Promoting a S&T Nation", Executive Yuan, 2000, http://www.ey.gov.tw/planning_old/pq870402-1.htm; 2. Indicators of Science and Technology, Republic of China, 2002.http://www.nsc.gov.tw/tech/pub_data_main.asp

3. National Information Infrastructure Development Plan (NII)

NII task force was established early in 1994 before the "National Information Infrastructure Development Plan" was formally promulgated in 1997. When first promulgated, NII Development Plan mainly stressed nine strategies and eight essentials to put into effect, mainly regarding the government's role to provide a better ICT infrastructure, complemented by broad strategies in terms of education, legal system, international cooperation, and social safety net considerations. The plan roughly mentioned the general purpose – to set up websites that provide information in Chinese, to promote the application and services that can be provided via the Internet, and ultimately to transform Taiwan into the hub of the Internet networks in Asia Pacific Region as well as the center of Chinese information provider. The specific objective was that at the end of 1999, the Internet users would reach at 3 million, at least.

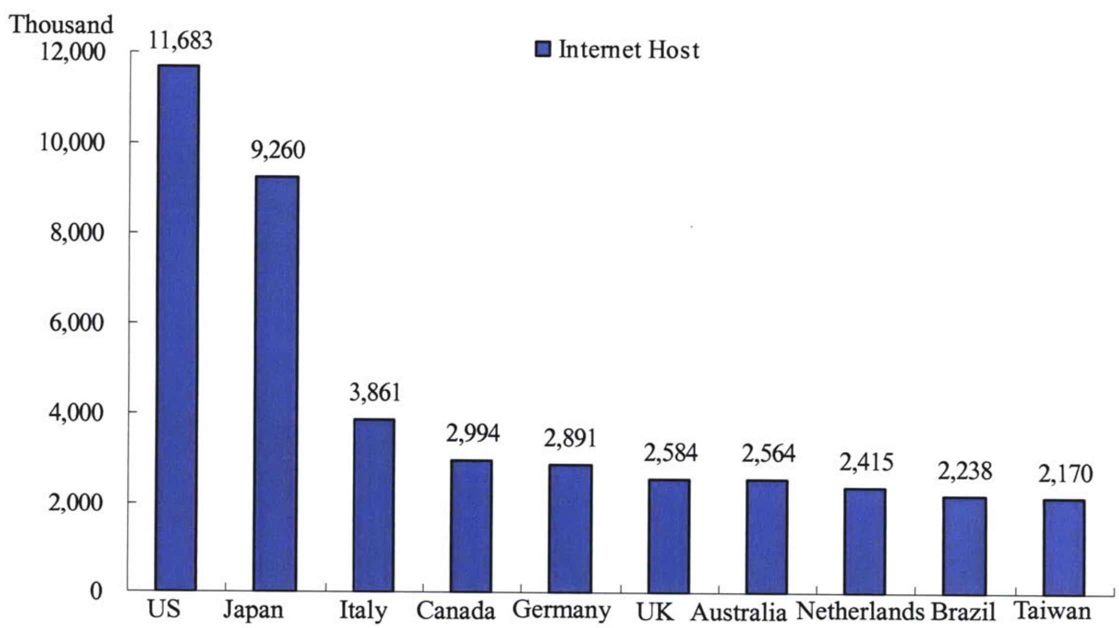
The implementation of this plan resulted in reaching the goal of "three million Internet users by 1999" ahead of the schedule (see Figure 4-2). As a matter of fact, the number of the Internet users has reached 3 million in 1998. In addition, the promotion of an NII-related legal system has brought about a completion of reviewing 22 bills and 11 administrative orders, containing the Access to Government Information Law, Telecommunications Law, Banking Law, and Consumer Protection Law, in a comprehensive sense.



Note: Data were obtained at the end of each year.
Source: http://www.find.org.tw/0105/howmany/img_howmany/20030220-1.jpg

Figure 4-2 Internet Users and Penetration Rate

To examine the Internet infrastructure, the number of Internet Host in a specific country is usually used as one of the indicators to represent a nation's network service capacity. Internet host is the mainframe of servers that connect to the Internet and provide all Internet services. Figure 4-3 shows the numbers of the Internet Host of the top ten nations in the world that were surveyed by the Internet Software Consortium. By January, 2003, The U.S. had 11.7[15] million Internet hosts, ranking number one, followed by Japan – $9.3 million. Taiwan ranked 10th in the world with 2.2 million Internet hosts. However, this figure was underestimated because it did not include the servers under ".hinet.net", domain possessed by the top internet service provider – Chunghua Telecom Company in Taiwan[16]. However, if the Asia Pacific Region is singled out, then Taiwan ranked 3rd in this region, with Japan and Australia ahead. In this regard, the policy objective of both "NII" and the "Global Logistics Development Plan" implemented by the CEPD – tuning Taiwan into the hub of the Internet networks in the Asia Pacific Region is plausible.



Note: Data were obtained at the end of each year.
Source: Internet Software Consortium http://www.isc.org/ds/faq.html

Figure 4-3 Internet Hosts Statistics, January, 2003

[15] This figure underestimated because it only gauged the servers under .us, .edu, .gov, and .mil only, and excluded those under .net and .com.

[16] If .hinet.net is included, then the number of Internet host in Taiwan will exceed that in Italy and will rank 3rd in the world and 2nd in the Asian Pacific Region. However, the same thing could happen in the other countries, like the U.S. and Taiwan, so the definition should be clear when a comparison is made.

4. Assistance in Foreign Technology Importation

This policy was implemented by DOIT, MOEA, which further authorized ITRI to help carry out it via its connection to its foreign footholds – North America Company, Japanese Office, European Office, and Russian Office, and by way of its cooperative counterparts in Canada, Holland, the United Kingdom, Israel, and Australia so as to effectively acquire international technological resources, to facilitate international technology transfers, and to take part in international R&D cooperation of prospective technologies.

The enterprises who need this assistance may get the service easily by visiting ITRI web site for an inquiry or connection or by contacting ITRI service centers available in the northern, middle, southern, and eastern part of Taiwan. If the firms have substantive needs, they may directly contact the international planning center of the ITRI.

The results of this policy implementation bore fruitful consequences. During the period from January 1997 to June 2001, 432 cases of technology transfer opportunities were introduced, among which 73 cases of technology transfers or commercialization were accomplished; in addition, 136 cases of prospective cooperation opportunities were introduced, 128 research consultants or technological specialists were recommended, and 20 important international seminars were held in Taiwan.

5. Technology Development Program

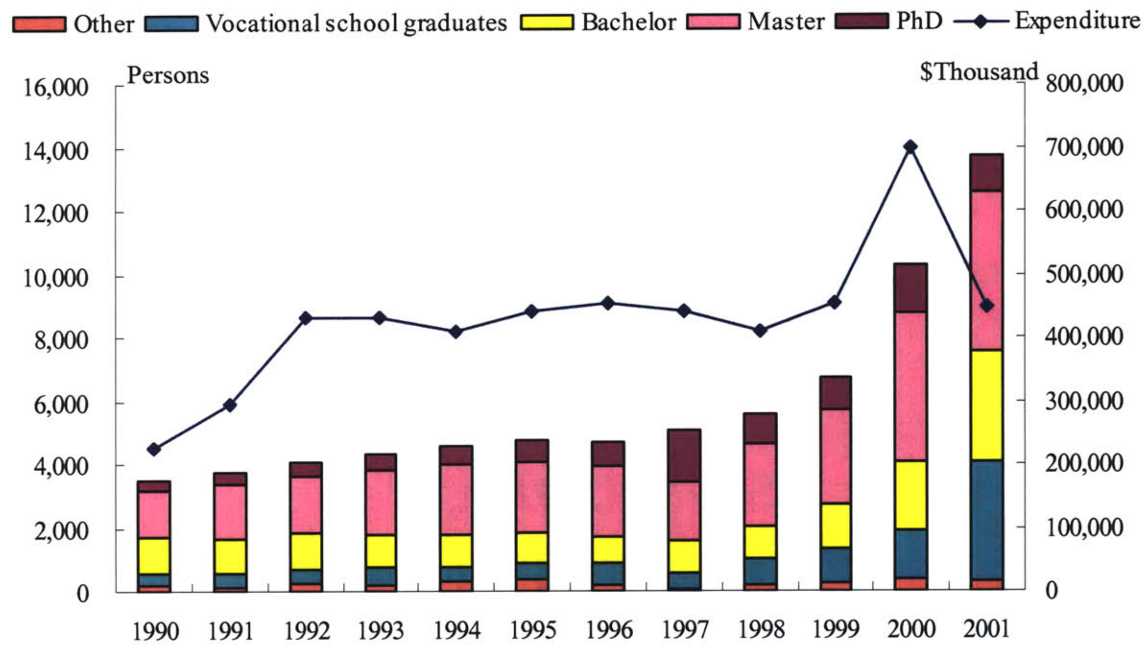
TDP has been implemented for years under the DOIT, MOEA. The way that this program was implemented was that the MOEA set up the program budget each year and contracted to research institutes, private enterprises, and universities to conduct special R&D projects for industrial technology.

The statistics shows that up until 2001, TDP has spent approximate 5.14 billion dollars on this program since 1990 and employed about 13,715 personnel in 2001. Table 4-7 and Figure 4-4 show the exact amounts cum manpower and the input structure that the TDP has been invested. For the total expenditure, year 2000 reached the peak at 700 million dollars. For the personnel, the people hired by this program increased sharply especially in the recent three years due to the "Measures for Promoting a S&T Nation" enforced in 1998 and the "Basic Law of Science and Technology" promulgated in 1999, both of which intensified the implementation of the TDP.

Table 4-7 Total Inputs of TDP

Year	Expenditure ($Thousand)	Personnel Input								
		Education					Title			
		PhD	Master	Bachelor	Vocational school graduates	other	Researcher	Associate Researcher	Assistant Researcher	Other
1990	226,977	319	1,445	1,158	386	163	793	1,377	978	323
1991	296,518	380	1,684	1,133	397	147	778	1,315	1,132	516
1992	430,880	442	1,765	1,142	495	225	595	1,215	1,356	912
1993	430,531	516	2,010	1,022	542	220	613	1,518	1,365	814
1994	408,493	512	2,228	1,012	502	289	983	1,520	1,268	770
1995	439,883	658	2,265	920	529	369	1,549	1,714	890	595
1996	452,496	733	2,226	877	640	220	1,563	1,747	858	536
1997	442,711	1,661	1,843	1,031	495	76	1,661	1,843	1,031	574
1998	409,586	934	2,594	1,051	801	189	1,950	1,860	1,171	586
1999	453,255	1,070	2,956	1,407	1,069	256	2,293	2,221	1,459	790
2000	699,860	1,548	4,677	2,163	1,514	412	3,062	3,308	2,529	1,407
2001	448,899	1,151	5,023	3,490	3,726	325	2,974	3,910	4,040	2,793

Source: TDP Achievements database http://tierwebs.tier.org.tw/tier/itis.htm



Source: TDP Achievements database http://tierwebs.tier.org.tw/tier/itis.htm

Figure 4-4 Structure of TDP Inputs in terms of Personnel and Expenditure

Table 4-8 shows the TDP implementation results, all S&T-related papers and thesis published domestically or abroad was 6,206 and 1,583, respectively, in 2001. The patents registered within Taiwan reached 2,958 by totaling up the cases from 1990 to 2001, while the patents registered abroad arrived at 2,109 cases. Total imported technology amount to 1,276 cases and about 123 million dollars; total result transfer got a grand total of 1,847 cases, and the number of transferred firms were up to 4,361 within the 12 years. Technology transfers under the TDP were 5,380 cases. And in 2001, this program had assisted leading new products innovation up to 211 cases, and from 1997 to 2001, there were 371 cases of leading new products innovation guided and assisted by this program. In addition, during the same period of time, 2,424 cases were promoted by the TPP to be invested and put into production, and the production value added up to 15 billion dollars!

Table 4-8 TDP Performance between 1990 and 2001

All values are in $thousand

Year	Thesis	Papers	Seminars		Patents		Cooperative Research		Imported Technology		Results Transfer		Technology Transfer	Leading Products Assistance		Assisting Investment & Production		
			No.	Participants	Domestic	Foreign	Case	Firm	Case	Value	Case	Firm	Case	Case	Firm	Case	Firm	Value
1990	729	1,484	695	572,248	N/A	N/A	N/A	N/A	49	N/A	56	64	56	N/A	N/A	N/A	N/A	N/A
1991	788	2,290	780	55,749	85	26	83	151	377	N/A	85	171	168	N/A	N/A	N/A	N/A	N/A
1992	1,150	2,821	858	64,245	144	56	158	365	137	N/A	335	465	493	N/A	N/A	N/A	N/A	N/A
1993	1,538	3,572	747	42,014	146	57	251	692	16	N/A	225	356	476	N/A	N/A	N/A	N/A	N/A
1994	1,391	3,717	783	42,340	157	134	N/A	465	13	2,596	N/A	605	N/A	N/A	N/A	N/A	N/A	N/A
1995	1,397	4,000	913	62,658	154	164	N/A	542	34	8,984	N/A	664	N/A	N/A	N/A	N/A	N/A	N/A
1996	1,422	4,041	934	64,526	175	151	N/A	609	79	24,712	N/A	683	N/A	N/A	N/A	N/A	N/A	N/A
1997	1,627	4,726	1,106	71,094	238	190	197	231	51	11,487	326	352	836	42	N/A	490	606	2,779,281
1998	1,630	4,685	971	84,447	262	222	183	239	49	12,073	165	204	768	39	39	516	637	3,298,283
1999	1,505	4,163	549	60,274	244	300	43	49	53	19,712	183	212	835	38	39	439	509	3,024,993
2000	1,721	4,942	685	91,550	499	476	14	16	135	23,234	275	316	1,080	41	41	547	610	2,452,597
2001	1,583	6,206	678	68,174	854	333	31	32	283	20,410	197	269	668	211	211	432	483	3,538,386

Source: TDP Achievements database http://tierwebs.tier.org.tw/tier/itis.htm

6. Science-based Industrial Park

The Hsinchu science based industrial park was built in 1980 in accordance with the "Statute for the Establishment and Administration of Science-based Industrial Park" promulgated in 1979. The Park was a deliberate effort of the government, so to speak: (1) the government chose the site where the two major universities – Tsinhua and Chiaotung University and the research institute – Industrial Technology Research Institute (ITRI) were located in; in addition, the site is about 75 kilometers (47 miles) away from the capital, Taipei (refer to Figure 3-3), and 50 kilometers (31 miles) distance from the international airport, all connected by the highways, so that the land use didn't compete with the crowded capital area and at the same time the traffic is convenient to travel between the Park, the capital, and the airport; (2) since its establishment, the government has invested approximately $912 million in the Park's infrastructure, including water and electricity supply, environmental protection, transportation, telecommunication network and so forth; (3) the government offered firms attractive terms for setting up a business, as well as a range of taxation benefits and allowances, including low-interest loans, R&D matching funds, tax benefits, and special exemption from the tariffs, commodity, and business taxes (the detailed information is listed in the Appendix); (4) three national laboratories were established within the Park – National Center for High Performance Computing, Synchrotron Radiation Research Center, and National Space Program Office; (5) the government also built a high-quality enclave/community within the park, containing industrial, residential, and recreation areas that constitute a favorable living and working environment to attract elites to the Park; (6) one-stop service is offered through the Park Administration – the government representative in the Park, which in charge of the affairs regarding government services, such as park admission, tax exemption application, and so forth.

The private firms, the national laboratories, the ITRI, the universities, and the government agencies work hand in hand. Those firms located in the Park not only formed a network per se to exchange information implicitly and explicitly, to speed up the service and commodity flows, and to attract the attention of the world buyers, but also collaborate with the government, the universities, and the research institute. Also, they formed the international strategic alliance through partnership with the world leading firms, which is a main spur to the innovation of domestic firms. This Park is virtually a microcosm of national innovation system (NIS), which needs to be expanded to the nationwide level.

Table 4-9 shows the overall features of the firms located in the Park. The number of the firms increased from 7 in 1980 to 335 in 2002; up to 2002, the Park has created 100 thousand job opportunities and accumulated $27.8 billion capital. The aggregate turnover reached the peak at $298 million in 2000, but was still high even in the economic downturn at $204 million in 2002. The R&D/sales ratio was 7.3 % in 2001, the latest year that the data is available. Labor productivity in the Park has a steep increasing trend: from 1986 to 2002, the labor productivity increased 4 times.

Table 4-9 The Park Features

Year	Number of firms	Employees	Capital ($million)	Turnover ($million)	R&D /Sales (%)	Patents		Labor Productivity ($thousnad)
						domestic	foreign	
1980	7	--	33	--	--	--	--	--
1981	17	--	19	--	--	--	--	--
1982	26	--	31	--	--	--	--	--
1983	37	--	50	0.75	--	--	--	--
1984	44	6,490	81	2.40	--	--	--	--
1985	50	6,670	103	2.63	--	--	--	--
1986	59	8,275	151	4.49	--	--	--	54.47
1987	77	12,201	334	8.66	--	--	--	71.45
1988	94	16,445	553	17.14	5.1	--	--	104.23
1989	105	19,071	1,068	21.17	4.6	--	--	110.98
1990	121	22,356	1,588	24.40	5.4	--	--	108.96
1991	137	23,297	2,055	28.98	6.0	--	--	124.21
1992	140	25,148	2,496	34.57	5.4	--	--	137.50
1993	150	28,416	2,536	48.90	4.9	--	--	172.09
1994	165	33,538	3,534	67.21	4.6	226	--	200.34
1995	180	42,257	5,579	113.01	4.2	532	234	267.41
1996	203	54,806	9,415	115.85	5.6	621	376	247.65
1997	245	68,410	13,112	139.42	5.9	1,021	566	203.76
1998	272	72,623	15,267	136.05	7.1	904	788	187.47
1999	292	82,822	19,163	201.73	5.4	1,260	1,276	243.60
2000	289	102,775	22,242	297.61	4.2	2,366	--	289.51
2001	312	96,293	25,414	195.65	7.3	2,991	--	203.25
2002	335	98,616	27,786	203.64	--	--	--	206.51

Source: Adapted from 1. 20-year Anniversary Special Issue, 2000. http://www.sipa.gov.tw/1/in7/index-in7-4.htm 2. Hsinchu Science-based Industrial Park Statistics, 2002. http://www.sipa.gov.tw/en/report-2.html

Taking a further step by looking at the profiles of the firms in the Park, those firms located in the Park can be divided into six industries: integrated circuits (IC), computers and peripheries, telecommunications, optoelectronics, precision machinery, and biotechnology. In 2001, the IC industry outnumbered the other industries in almost all categories – company number, employee, sales, R&D expenditure, R&D/sales ratio, R&D personnel, and domestic patents – except for R&D personnel/employee ratio. Computers/peripheries, telecommunication, and optoelectronics followed the IC industry, had fairly significant figures in almost all categories. Biotechnology industry had only 19 companies and 712 employees in 2001, but its R&D/sales and R&D personnel/employee ratios were the highest, showing that the development of the biotechnology industry in the Park was in its early stage in addition to its unique feature of the industry – intensive R&D are needed.

Table 4-10 Firm's Profiles Breakdown by Industries, 2001

Industry	Company	Employee	Sales ($million)	R&D ($million)
IC	123	58,518	11,158	1,015
Computers/Peripheries	51	13,363	4,771	133
Telecommunication	57	6,753	1,661	77
Optoelectronics	51	16,173	1,848	189
Precision machinery	11	843	142	6
Biotechnology	19	712	38	9
Total	312	96,362	19,618	1,429
Industry	R&D/Sales (%)	R&D Personnel	R&D personnel /Employee	Domestic Patents
IC	9.14	4,915	8.40	2,420
Computers/Peripheries	6.12	1,662	12.44	366
Telecommunication	4.64	1,170	17.33	31
Opto-electronics	4.26	1,096	6.78	145
Precision machinery	2.83	48	5.69	26
Biotechnology	20.03	132	18.54	3
Total	7.29	9,023	9.36	2,991

Source: Adapted from 1. Hsinchu Science-based Industrial Park Statistics, 2002. http://www.sipa.gov.tw/1/in1/index-in1.htm

If the Park's contribution to the overall science and technology is examined, the R&D expenditure would be the foremost indicator to be examined. As shown in Table 4-11, the R&D expenditure by the firms simply within the Park had reached 10% of the total R&D

expenditure within the whole nation in 1991, the earliest year when the data are available. And the share continued increasing until 40% in 2000, the latest data that are available. Within this area that accounts for 0.18% of the land area in Taiwan yielded 40% of the total R&D expenditure, the S&T activities in the Park in tremendously intensive.

Table 4-11 R&D expenditure in Hsinchu Science-based Industrial Park

Year	Total R&D ($million)	R&D in the Park ($million)	Share (%)
1988	--	67	--
1989	--	96	--
1990	--	128	--
1991	1,635	157	9.59
1992	1,980	177	8.95
1993	2,235	239	10.67
1994	2,492	315	12.66
1995	2,718	475	17.47
1996	2,907	649	22.33
1997	3,348	854	25.50
1998	3,332	952	28.57
1999	3,738	1,197	32.03
2000	3,969	1,574	39.66

Source: 1. Indicators of Science and Technology, National Science Council, Executive Yuan, 2001. 2. Science-based Park Statistics, 2001.

As a result of the intensive S&T activities, the efforts added up to a ferment of the S&T development, carrying Taiwan to a position as the world major supplier in the global market. Table 4-12 listed the top three Taiwan products in the global market in 1999. The market share ranked 1st were IC foundry services and IC packaging, in terms of production value; Compact Disk-Recordable (CD-R), hub systems for networks, modems, LAN cards, and ABS resin, in terms of production volume; and hand tools in terms of export value. Second place products and services included IC designing, MASK ROM, graphic cards, scanners, LEDs, chip sets, motherboards, polyester filament, nylon fiber, TPE, sewing machinery, bicycle transmission systems, screw nuts, shoes & leather machinery, PC cameras, and digital cameras. The third ranking products and services were PCB, desktop PCs, monitors, polyester cotton, PVC, PTA, bicycles, and wood-making machinery.

Table 4-12 Top Three Taiwan Products in the Global Market, 1999

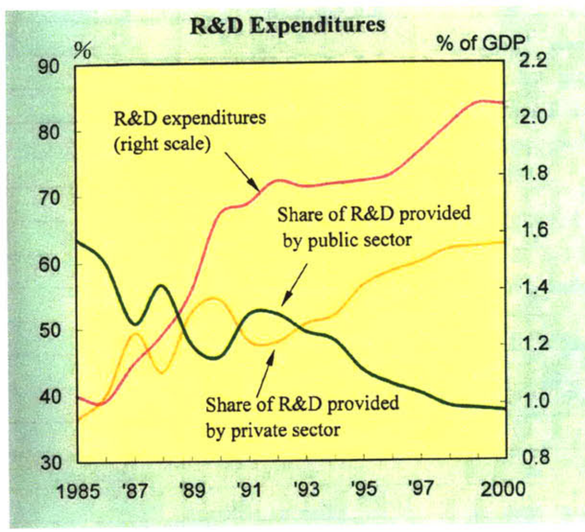
Product/Service	Production Value		Production Volume		Export Value	
	$Million	Share (%)	Million	Share (%)	$Million	Share (%)
Ranked No. 1						
1. IC Foundry Services	4,349	64.6				
2. IC Packaging	1,701	29.0				
3. Notebook PCs	11,073		9.7	49	10,740	
4. CD-R			1,676.3	73.3		
5. Hub Systems for Networks	412.8	27.4	42.569 ports	64.7	392.4	26
6. Modems	914	19.6	34.68	50	780.6	16.8
7. LAN Cards	344.9	8.7	29.22	45.8	314.8	7.9
8. ABS Resin	940		1.016 tons	23.3		
9. Sewing Machines of the Household Type	266		2.506			
10. Hand Tools					1,109	16.4
Ranked No. 2						
1. IC Designing	2,299	19.6				
2. MASK ROM	338	35.5				
3. Graphic Cards	636		13.937	30.9	536.5	
4. Scanners	294		7.03	29.2		
5. LEDs	542.1	30				
6. Chip Sets			53	43.5		
7. Motherboards			36.051	35.8		
8. Polyester Filament	1,560	16	1.671 tons	17.1	226	
9. Nylon Fiber	678	9	0.36 tons	9.5	157	
10. TPE	142		0.196 tons			
11. Sewing Machinery	424		2.78			
12. Bicycle Transmission Systems	75					
13. Screw Nuts					1,569	14.5
14. Shoes & Leather Machinery					134	17
15. PC Cameras			1.386	46.2		
16. Digital Cameras			1.5	21.4		
Ranked No. 3						
1. PCB	3,375	9.27			2,352	6.4
2. Desktop PCs	7,216	5.3	19.457	19.6		
3. Monitors	3,539		12.829	12.9		
4. Polyester Cotton	746	12	0.943 tons	12.3	111	
5. PVC	818		1.397 tons	6.3		
6. PTA	1,178.22		2.787 tons	10.6		
7. Bicycles	906		7.23		760	
8. Wood-Making Machinery					728	12.8

Note: Products mentioned above originated in Taiwan; overseas products are not included.
Source: Adapted from 2001 Development of Industries in Taiwan, Republic of China, Ministry of Economic Affairs (MOEA), Taiwan, R.O.C..

4.2 Evidence of Government-led Growth

1. R&D expenditure

In the initial years of development, the government was the major investor of the S&T. The trend of R&D expenditure from 1985 in Figure 4-5 shows that the R&D expenditure was mainly from the government prior to 1988. After 1988, the share of R&D provided by the private sector began to exceed the share provided by the government or public sector.



Source: Indicators of Science and Technology, National Science Council, Executive Yuan, 2001

Figure 4-5 Composition of R&D Expenditure from 1985 to 2000

Table 4-13 shows the recent S&T-related projects contracted out by the government, mainly by the National Science Council (NSC) from 2000 to 2002. Within these three years, basic research and applied research accounted for the lion's share, followed by technological development, while commercialization accounts for the smallest share, showing that the government's efforts have been made on more uncertain or risky part of the S&T activities, whereas leaving those profit-making portions to the private sector. Within those research projects, academic subsidy accounted for the largest share in terms of cases, while contracted research accounted for most of the budget in terms of amount.

Table 4-13 S&T-related Research Projects Execution During 2000-2002

Year	2000		2001		2002	
	Pieces	**Amount ($)**	**Pieces**	**Amount ($)**	**Pieces**	**Amount ($)**
Basic Research	14,792	528,555	8,485	238,246	8,937	931,500
Applied Research	12,344	519,607	7,249	334,244	7,840	2,033,497
Technological Development	1,468	705,666	1,040	407,216	1,255	910,643
Commercialization	12	5,386	15	5,052	8	4,165
Others	75	31,824	74	148,998	126	192,014
Total	**28,691**	**1,730,190**	**16,863**	**1,133,755**	**18,166**	**4,071,818**
Self Research	702	64,568	871	137,992	1,307	773,686
Contracted Research	1,604	933,325	1,436	613,045	1,397	1,804,982
Academic Subsidy	26,315	647,612	14,446	342,358	15,368	382,062
Cooperation	70	84,685	110	40,360	94	354,620
Total	**28,691**	**1,730,190**	**16,863**	**1,133,755**	**18,166**	**3,315,350**

Source: Government Research Bulletin http://www.grb.gov.tw/index.jsp

2. Spin-offs and technology transfers

One of the major players in Taiwan's S&T development was the Industrial Technology Research Institute (ITRI), a quasi-governmental agency as well as a non-government organization, founded by the government in 1973. Starting from 3 government-donated laboratories – Union Industrial Research Laboratories, Mining Research & Service Organization, and Metal Industrial Research Institute, ITRI so far features seven laboratories[17] and eleven centers[18]. Although ITRI is a non-government organization, it was initiated by the government and has been carrying out many government's projects since its establishment.

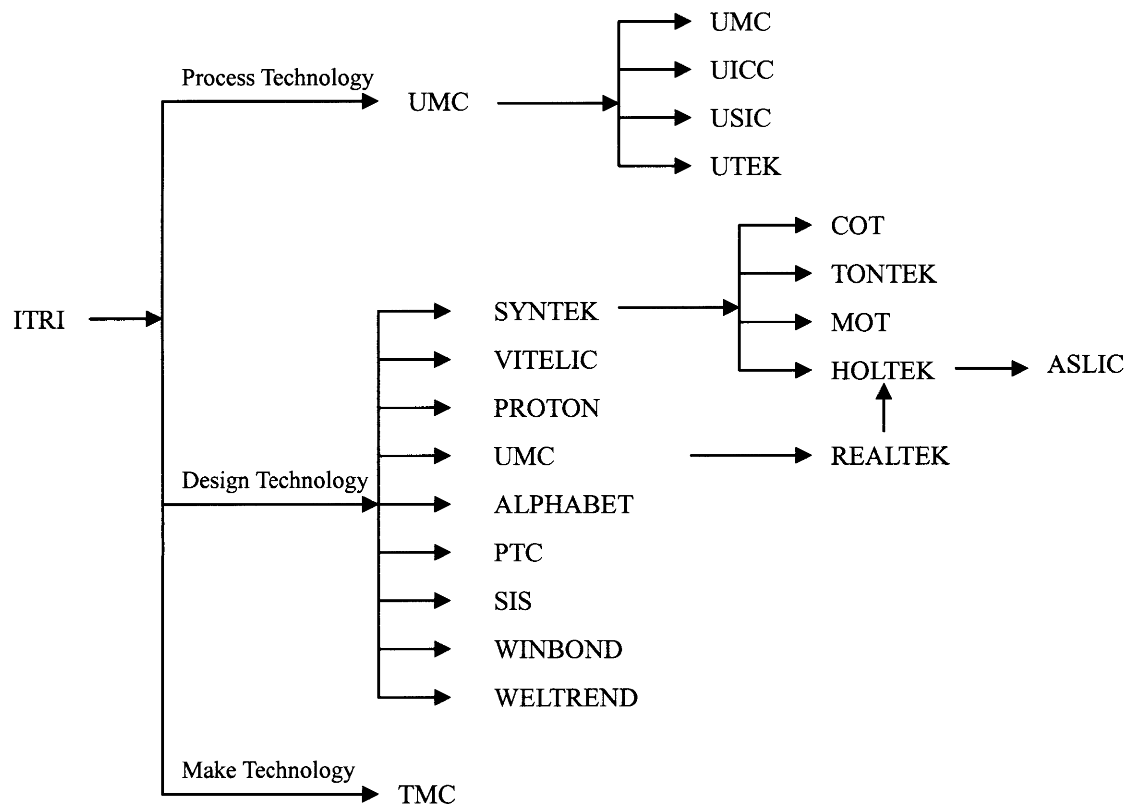
Beginning with the transfer of 7-micron CMOS IC processing and design technology from RCA in 1976, the ITRI helped establish the foundations of Taiwan's semiconductor

[17] Opto-Electronics & Systems Laboratories, Computer and Communications Research Laboratories (CCL), Materials Research Laboratories (MRL), Union Chemical Laboratories (UCL), Mechanical Industry Research Laboratories (MIRL), Energy & Resources Laboratories (ERL), and Electronics Research & Service Organization (ERSO).

[18] SoC Technology Center, Biomedical Engineering Center (BMEC) Center for measurement standards (CMS), Center for Aviation & Space Technology (CAST), Center for Environmental, Safety and Health Technology Development (CESH), ITRI Nanotechnology Research Center (NTRC), Industrial Economics and Knowledge Center (IEK), Technology Transfer and Services Center (TTSC), Information Technology Service Center (ISC), Administrative Service Center (ASC), Accounting Resource Center (ARC).

industry. After three-year research and adaptation of the transferred technology, in 1979, the United Microelectronics Corporation (UMC) was started up, with the first 4-inch wafer fab manufactured in Taiwan under the assistance of the ITRI. Years later, Taiwan Semiconductor Manufacturing Company Ltd (TSMC) was established in 1987, becoming the first producer of the 6-inch wafer fab in Taiwan. TSMC later not only became a first-ranking semiconductor manufacturer in Taiwan but also turned into the world's largest independent semiconductor foundry. In 1988, another company, Taiwan Mask Corporation (TMC) was established with the support of ITRI, setting up the first mask fab in Taiwan. In 1989, Mirle Automation Corporation was spun off, being the leading firm in automation integration systems and manufacturing industry. In 1994, ITRI transferred the first 8-inch wafer fab technology and spun off the Vanguard International Semiconductor Corporation (VIS).

Not only its mission statement speaks out that technology transfers are one of its important tasks, but also since ITRI is one of the subordinate agencies under the Technology Development Program (TDP), it has the responsibility to transfer technologies to the private firms. The major tasks of technology transfer for ITRI is to acquire foreign technologies in technologically advanced countries, adapt them and/or innovate new add-ons, and then disseminate the adapted technologies to the industries or firms that need those new technologies and convince them to invest in those technologies, other than spin-off new firms. Take the most successful example of the semiconductor industry in Taiwan, ITRI disseminated process technology to the UMC, design technology to nine firms, and mask technology to TMC. These firms later became the origins of secondary technology diffusion, bringing the story of the Taiwan semiconductor industry genealogy full-cycle (Mathew and Cho, 2000). For detailed technology transfer information, please refer to Figure 4-6. Table 4-14 shows the ITRI's technological output regarding technology transfers, service contracts, patents awarded, and technology-related conferences and training programs. Each year, there were over 300 technologies were transferred to the industries and about 400 to 500 companies obtained the technologies. The ITRI also provided general service to industries. In 2001, about 30.5 thousand firms received the services from it. The patents received by the ITRI increased over the years: in 2001, it reached the peak of 862 patents. As a major player in Taiwan's S&T development, it also hosts technology-related conferences and training programs. Each year there were more than one thousand activities being held and the attendees were 78 thousand in 2001.



ITRI: Industrial Technology Research Institute
UMC: United Microelectronics Corporation
UICC: United Integrated Circuit Corporation
USIC: The United Silicon Incorporation
UTEK: UTEK Semiconductor Corporation
SYNTEK: Syntek Design Technology Ltd
TONTEK: Tontek Design Technology Ltd.
HOLTEK: Holtek Semiconductor Incorporation
ASLIC: Aslic Microelectronics Corporation
Source: Adapted from Mathews and Cho (2000).

VITELIC: Mosel Vitelic
PROTON: Proton
REALTEK: Realtek Semiconductor Corp
ALPHABET:
SIS: Sis Hyperstreaming Technology
WINBOND: Winbond electronics Corporation
WELTREND: Weltrend Semiconductor, Inc.
TMC: Taiwan Micropaq Corporation

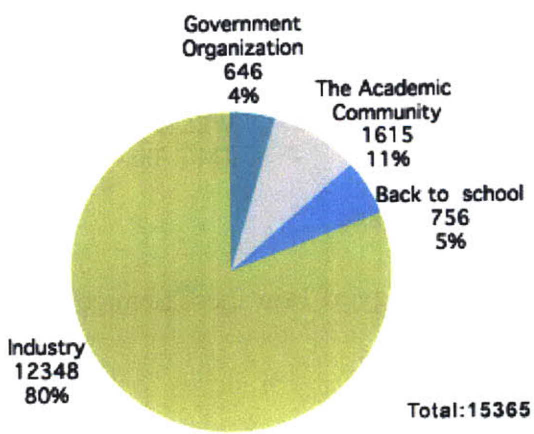
Figure 4-6 Genealogy of Taiwanese Semiconductor Firms

Table 4-14 ITRI's Technological Output from 1997-2001

Item		1997	1998	1999	2000	2001
Technology Transferred to Industries	**Case**	332	361	353	314	337
	Company	499	582	538	457	471
Service Contract	**Case**	1,019	1,046	1,124	969	1,159
General Service to Industry	**Company**	27,811	27,099	27,827	28,431	30,427
Patent Awarded	**Case**	548	559	537	640	862
Technology Conference & Training Program	**Case**	957	998	1,485	1,229	1,148
	Attendees	68,918	76,265	96,036	73,959	78,336

Source: ITRI, Taiwan.http://www.itri.org.tw/eng/about/operation/technologyoutput.jsp

Alongside with the technology transfers, ITRI also recruited and cultivated experienced human capital that possessed professional technological knowledge. Those human capital later switched their jobs mostly (about 80%) to the industries (shown as Figure 4-7), utilizing their technological skills and knowledge learned from the ITRI in the industries. Up until May 2002, over 15,000 employees have left the ITRI, most of whom joined private sectors, especially the IC industry. There were approximately 4,900 ITRI employees later joining the private firms in the Hisnchu Science-based Industrial Park. Many of them became high-level decision-makers and managers, or even CEOs. Morris Chang, the current president of TSMC, who once was the president of ITRI, is one of them.



Source: ITRI, Taiwan. http://www.itri.org.tw/eng/about/impact/impact-human.jsp?tree_idx=0300

Figure 4-7 ITRI's Human Resources Dissemination, 1973-2001

Aside from the ITRI, the aforementioned TDP is effective for technology transfers. Table 4-15 shows that the cases of technology transfers during the last decade, plus the imported technologies as well as TDP result transfers, which include technology transfers and technology authorization grants that are in accordance with the procedures of the "Principles of Managing TDP accomplishments" and the "Cooperation with Industries on Initial Stage of Technology Transfers" implemented by MOEA. There were 283 technologies imported and valued at $20 million under this program in 2001. 668 technologies and 197 results were transferred in the same year.

Table 4-15 Technology Transfers under TDP

Year	Imported technology		Technology transfer	TDP result[1] transfer	
	Cases	Amount($thousand)	Cases	Cases	Number of firms
2001	283	20,410	668	197	269
2000	135	23,234	1,080	275	316
1999	53	19,712	835	183	212
1998	49	12,073	768	165	204
1997	51	11,487	836	326	352
1996	79	24,712	N/A	N/A	683
1995	34	8,984	N/A	N/A	664
1994	13	2,596	N/A	N/A	605
1993	16	N/A	476	225	356
1992	137	N/A	493	335	465
1991	377	N/A	168	85	171
1990	49	N/A	56	56	64

Note: 1. including technology transfers and technology authorization grants that are in accordance with the procedures of the "Principles of Managing TDP accomplishments" and the "Cooperation with Industries on Initial Stage of Technology Transfers"
Source: TDP Achievements database http://tierwebs.tier.org.tw/tier/itis.htm

3. Human Capital

Human capital is a significant factor of S&T development. It is imperative but is a long-term investment. Therefore, human capital has been the major consideration along the course of Taiwan's S&T policies evolution. At the very beginning of the S&T policy formulation, education was mentioned as a chief foundation for the future S&T development. Since then, almost each single S&T policy enacted by the government touched upon education issues. Consequently, the Ministry of Education (MOE), usually in collaboration with other S&T authorities adjusted and amended the educational policies in line with those S&T policies.

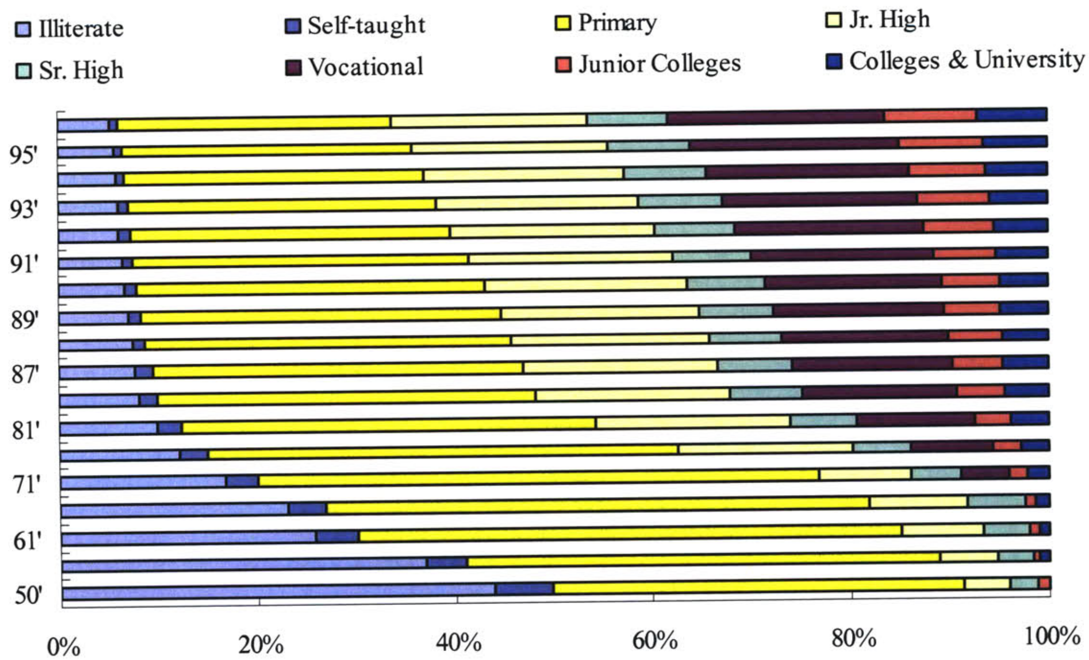
For general education, six-year compulsory education mandating every person should accept the elementary school education for six years had been implemented since 1944. In 1968, the compulsory education was extended to nine years. The rationale behind this policy was to support the upsurging human capital demands when the economic planning by the CEPD entered the fifth stage. The nine-year compulsory education became the solid basis of manpower for the development of capital-intensive industries.

The educational attainment in Taiwan is shown as Figure 4-8. Illiteracy rate dropped from 44% in 1959 to 5.34% in 1996. College and university graduates raised form 0.98% in 1956 to 7.06%. Vocational school graduates accounted for 4.7% in 1971, while in 1996 it accounted for 21.9%.

Driven by both industrial as well as S&T policies, education reforms never paused. However, the focus changed over time. The nine-year compulsory education was a momentum for Taiwan's industrial structure to shift from labor-intensive industry era toward capital-intensive industry era. The next momentum would be higher education reforms to shift from capital-intensive industry era to knowledge-intensive industry one.

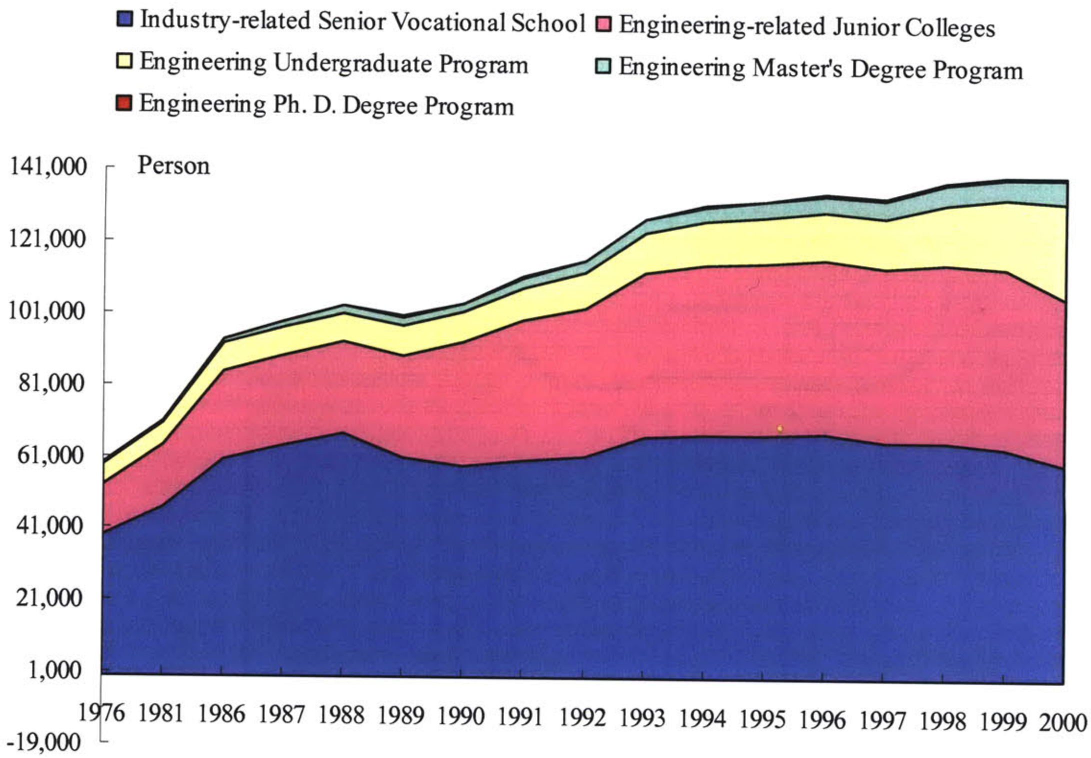
Higher education in terms of school number grew slowly between the 1950s and 1970s due to the government's prohibition from the establishment of private schools. However, since the 1980s, the government unleashed the restrictions. Private capital flew in and the number of schools mushroomed. In 2001, there were 135 universities and colleges as opposed to 25 universities and colleges in 1976.

If the education structure is examined from the industrial manpower breakdown (shown in Figure 4-9), the lion's share of the human capital during 1976-2000 were the industry-related senior vocational school and engineering-related junior college graduates. As the population increased overtime and the industrial structure adjusted along with government's industrial policies, the shares of these two were diminishing, showing that the decreasing supplies of these two as a reflection on industrial demand. On the contrary, the graduates from the engineering undergraduate programs and master programs augmented, especially in 1998 the when the undergraduate program graduates increased significantly in lieu of the decrease of junior college school graduates.



Source: Ministry of Education, Taiwan.

Figure 4-8 Educational Attainment of Population Aged 6 and Above form 1950 to 1996



Source: Ministry of Education, Taiwan http://140.111.1.22/english/index.htm

Figure 4-9 Education Structure of Industrial Technology Manpower, 1976-2000

4. State-owned Enterprises

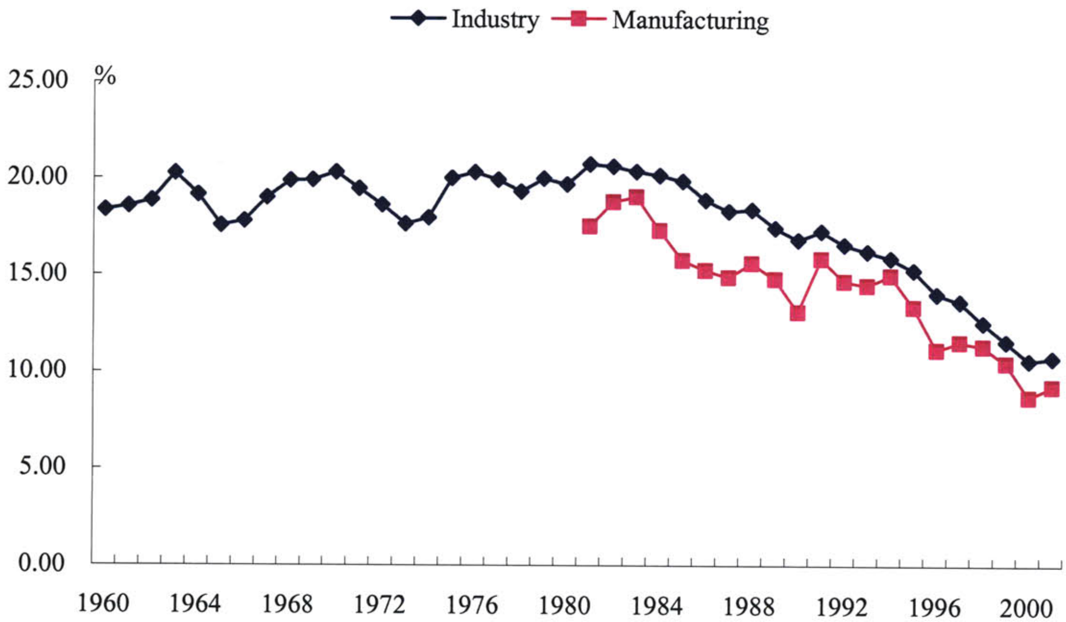
State-owned enterprises (SOEs) played a vital role in the developmental course of S&T in Taiwan. At the initial stage of development, under the fierce global competition from the industrialized countries, the firms in the developing countries were difficult to accumulate abundant capital and capabilities to grow big. Especially in Taiwan, most of the firms were formulated in the form of small and medium enterprises (SMEs). The S&T activities, such as R&D and other S&T investments, were particularly costly to the SMEs, not mention to the painstakingly plunge into considerable spending on S&T activities.

Moreover, some industries, such as petroleum refining, were critical to the downstream firms in petrochemical and textile industries, while those industries, though vital, bore extremely high risks that no private firms would willing to enlist in them. In the petroleum refining industry, for instance, Taiwan per se had little petroleum production and the crude oil supply was heavily relied on imports, which means the prices highly hinged upon the world prices and the foreign suppliers' contracts. Therefore, SOEs undertook the production of such industries as described above, owing to the supporting role that the government conferred.

The SOEs in Taiwan as a whole started up with the missionary role as those SOEs in other countries, but some of them ended up with good performance in terms of gross domestic product. As shown in Figure 4-10, the gross domestic product of the SOEs in all industries accounted for almost one-fifth (18.4%) of the all industries' gross domestic product in 1960, and the gross domestic product of the SOEs in manufacturing accounted for 17.5% in 1981, while the gross domestic product of the SOEs in all industries reached all time high at 20.8% in the same year. Despite the shares of the SOEs' GDP in terms of all industries as well as manufacturing are decreasing over time in the recent 2 decades, for the most part, indicating the ongoing liberalization and privatization in Taiwan, rather than the inefficiency of the SOEs, SOEs have built up the basic industries and laid the foundations for the development of other industries along the historical path. In 2001, though the shares declined to 10.8% and 9.3%, respectively, they were still one-tenth of the base.

Regardless of the conventional concern of the inefficiency of SOEs, the SOEs in Taiwan at large did create positive impacts on S&T development, such as the Chinese Petroleum Corporation (CPC) and the China Steel Corporation (CSC) prior to their privatization. First of all, the most trivial is that their large scaled productions resulted in economies of scale; secondly, the soft budget endowed with them props to undertake risky innovative activities that may bring about lucrative products once the experiments succeed. Thirdly, the relatively high wages and stable working environment attracted high-quality human capital. Lastly, the abundant profits helped them diversify into other businesses that private sector had no incentives to engage in[19]. As a result, the SOEs contributed, directly and indirectly, considerable share of the S&T development in the past.

[19] This is different from Korea, where the government "encouraged" the private firms, particularly big business group, Chaebol, to diversify with high tax incentives or subsidies.



Source: Directorate General of Budget Accounting and Statistics, Executive Yuan, R.O.C..

Figure 4-10 SOEs' Gross Domestic Product Share from 1960 to 2002

Chapter 5 Productivity, Competitiveness, and Economic Growth

As discussed in Chapter 2, economic growth can be explained by many aspects: institutions – the quality and the layout of socio-political arrangements (North and Thomas 1973), international trade – trade openness versus closed economy (Sachs and Warner, 1995, World Bank, IMF, WTO, and OECD), laws – English Common law versus French, German, or Scandinavian Civil law legal origin (La porta et al), social capital – social trust and civil traditions (Putnam, 1993, Fukuyama, 2000), regime type – democratic or autarchy (Przeworski and Limongi, 1993), the role of the state – free market or almighty government (Shleifer and Vishny, 1999, Stiglitz, 1998, Amsden, 1989 and 2001), geography – natural resources and locations, and, of course, technological capabilities – innovation and productivity (Schumpeter, 1968, Chandler, 1997, Amsden, 1989 and 2001).

Each growth account has its own rationale behind it and is not mutually exclusive, namely, may interrelate to each other. For Taiwan's growth account, I would argue that geographical location is certainly favorable, for it is located on the western coast of the Pacific Ocean, in between the Taiwan Straits and China, with Japan to the north and the Philippines to the south; international trade has been the engine of growth, but has little to do with the complete trade openness; institutions play a role in its economic development, because institutions have provided dependable property rights, managed conflict, maintained law, and aligned economic incentives with social costs and benefits; all in all, except for the geographical location that is exogenous to the growth, the government is the initiative that led the international trade and institutional settings through public policies.

However, to discuss the growth determinates in all aspects will be far beyond the scope of this thesis. Rather, the focus will be the S&T-related activities and their output or outcomes that accounts for the growth. The measurement of S&T development will be productivity, or efficiency, and competitiveness at two levels – industrial as well as national competitiveness. Therefore, in this chapter, productivity in Taiwan will be explored in the first section, followed by the discussion of technological competitiveness in the second section. And then, industrial as well as national competitiveness will be discussed in the third section, followed by the international comparison. The last section will be a summing-up.

5.1 Productivity and Technological Change

5.1.1 Definition

Productivity is defined as output per unit of input. Productivity growth occurs when higher productive efficiencies are achieved (Gee, 1987). Hence, productivity can be calculated as GDP or GNP per capita, in a broad sense. In the neoclassical model, the inputs include labor, capital, and, sometimes, land. Therefore, productivity can be interpreted in terms of labor and physical capital, expressed as output/L or output/K.

Robert Solow (1957) tried to separate the growth caused by technological change and adopted total factor productivity (TFP) as a surrogate of the productivity induced by technological progress. This model is later called Solow-Swan growth model. This model is based on an aggregate production function in Cobb-Douglas form for the nation. Namely, the output is expressed as a function of the stock of capital (K), employment (L), and time (t).

$$Q_t = A_t F(K_t, L_t) = A_t K_t^{\alpha} L_t^{\beta} \qquad (1)$$

and then

$$A_t = \frac{Q_t}{F(K_t, L_t)} \qquad (2)$$

A_t represents the technology level and is referred to as exogenous[20], disembodied[21], and Hicks-neutral[22] technical progress (Felipe, 1997), measured by how output changes as time elapses with the inputs held constant. To do the real calculation among different economic units, equation (2) can be rewritten as

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[20] Exogenous technical progress implies that technology is superimposed on the system, in the sense that A_t is assumed to grow over time for no stated reason, and determined outside the economic system considered.

[21] Disembodied technological change is a type of exogenous technical progress in which technical change does not require new inputs, and the production function maintains the same form as time elapses.

[22] Hicks-neutral implies that at points on the expansion path, the rate of technical substitution is independent of time, and that for a given ratio of factor prices, technological progress does not influence the proportions in which capital and labor are combined. In other words, a neutral invention is one which, with given factor proportions, raises the marginal product of labor in the same proportion as the marginal product of capital.

$$\phi_t = \frac{dA_t}{dt} = q_t - \frac{K_t}{Q_t}\frac{\partial Q_t}{\partial K_t}k_t - \frac{L_t}{Q_t}\frac{\partial Q_t}{\partial L_t}l_t \qquad (3)$$

where q_t, k_t, and l_t denote the growth rates of output, labor, and capital, respectively, and ϕ_t is the rate of total factor productivity growth.

By assuming perfect competition and profit maximization, the equation (3) can be expressed as

$$\phi_t = q_t - \alpha_t k_t - (1-\alpha_t)l_t \qquad (4)$$

where α_t and $1-\alpha_t$ are the capital and labor shares. This is the so-called "Solow residual".

If the data are discrete, Tornquist index is adopted. Thus, (3) and (4) can be rewritten as:

$$\phi_{t,t-1} = \ln\frac{Q_t}{Q_{t-1}} - \Theta_L \ln\frac{L_t}{L_{t-1}} - \Theta_k \ln\frac{K_t}{K_{t-1}} \qquad (5)$$

where

$$\Theta_L = \frac{\theta_L + \theta_{L-1}}{2} \quad \text{and} \quad \Theta_K = \frac{\theta_K + \theta_{K-1}}{2}$$

However, the Solow-Swan growth model has been attacked by many scholars because of its assumptions of perfect competition, constant returns to scale, procyclical features, exogenous technological progress, nil cost of technology, and so on (see Chapter 2). Consequently, a rapid expansion of the literature on new models of economic growth and technological measurements emerged. Attempts to endogenize technological change began with Arrow (1962) but were formally explored by Romer (1986, 1990) and Lucas (1988). The overall concepts can be expressed as the following production function:

$$Q = F(A, X) \qquad (6)$$

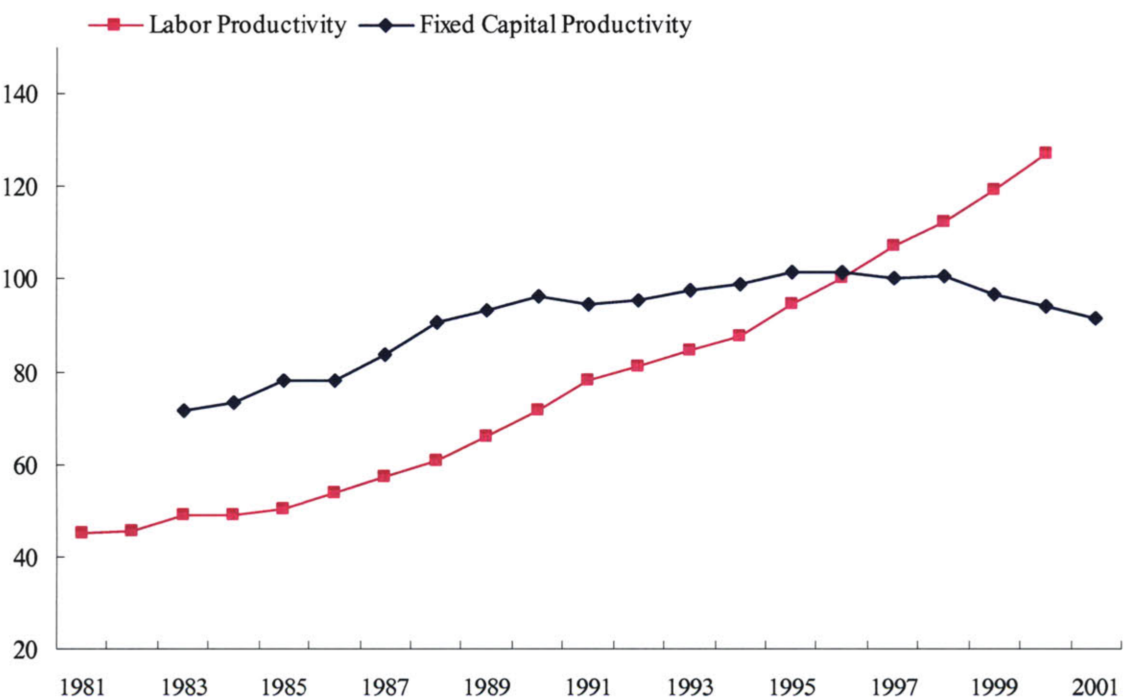
where A represents the technology, which is nonrival, and the vector X represents the rival inputs, such as labor, physical capital, and human capital. The production function is increasing returns to scale, compared to the constant returns to scale assumption in the old growth model.

$$\lambda Q > F(\lambda A, \lambda X) \qquad (7)$$

This model suggests that the technological progress can be further achieved by investments in R&D, education, and other S&T activities.

5.1.2 Empirical Productivity Data

The labor productivity and capital productivity in Taiwan over time are shown as Figure 5-1, labor productivity in 2001 had been tripled since 1981 when the data are available, with 5.3% annual average growth rate[23], while fixed capital productivity[24] increased rather slowly at a 1.29% annual average growth rate.



Source: 1. Capital productivity data – National Statistics, Taiwan, ROC. http://www.stat.gov.tw/main.htm; 2. Labor productivity data – AREMOS, Taiwan.

Figure 5-1 Labor and Fixed Capital Productivity Index (1996=100), 1981-2001

If manufacturing is singled out to be examined, still, labor productivity grew rapidly

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[23] Annual average growth rate is calculated according to the definition in World Bank: $r=\exp((\ln(p_n/p_1))/n)-1$

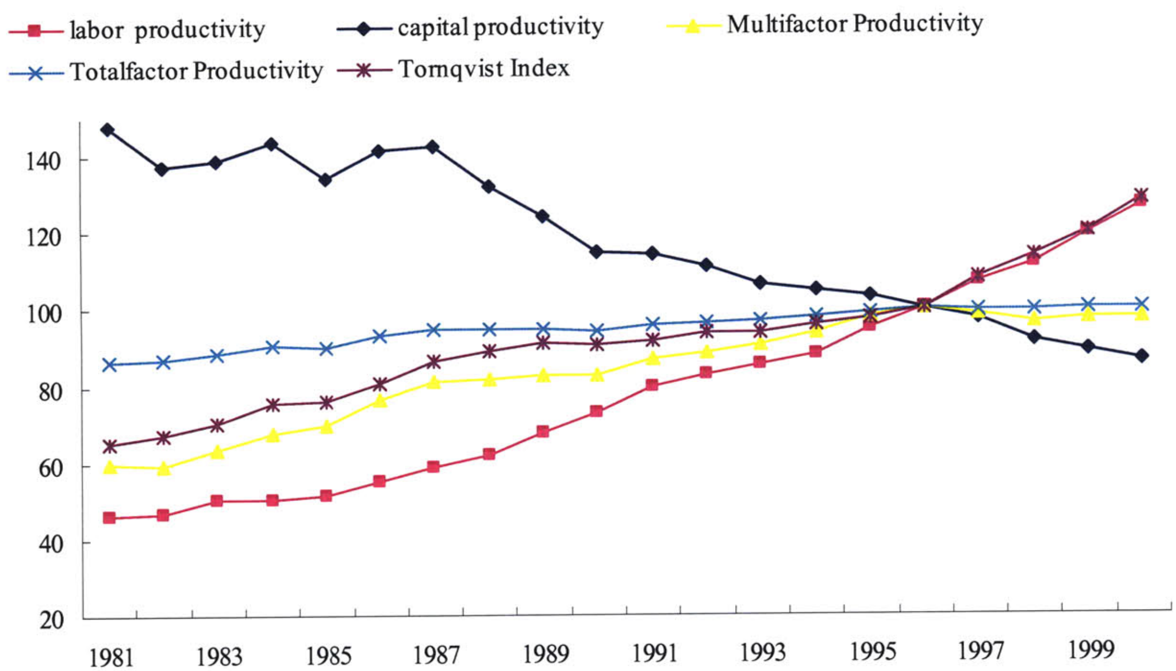
[24] Gross Fixed Capital Productivity (GKP): GKP = $GDP_R/gK(t)$, GKPI = $GDPI_R/gK(t)I$, where GKP refers to gross fixed capital productivity; GKPI refers to index for gross fixed capital productivity; GDP_R refers to real gross domestic product; $GDPI_R$ refers to index for gross domestic product; and gK(t)I refers to index for mid-year real gross fixed capital stock in t period.

and significantly during 1981 and 2000, with annual average growth rate of 5.15% (Table 5-1), while fixed capital productivity decreased with annual average decreasing rate of 2.65%; total factor productivity of Taiwan's manufacturing, as defined in the previous section, grew at 0.72% annual average growth rate. Multifactor productivity, a supplementary reference to total factor productivity when the inputs taken into account are more than capital and labor, increased in a larger scale than total factor productivity with 2.48% annual average growth rate. Tornquist index, adopted when the data are discrete, increased with annual average growth rate of 3.46%.

Table 5-1 Manufacturing Productivity Indexes, 1981-2000

	Labor Productivity	Capital Productivity	Total Factor Productivity	Multifactor Productivity	Tornqvist Index
1981	46.43	147.90	86.8	59.81	65.10
1982	46.87	137.53	87.28	59.44	67.06
1983	50.45	138.83	88.68	63.57	70.18
1984	50.33	143.87	90.62	67.93	75.81
1985	51.48	134.51	90.48	69.74	76.27
1986	55.25	141.39	93.40	76.79	80.99
1987	58.95	142.55	94.88	81.22	86.69
1988	62.05	132.1	94.85	82.00	89.21
1989	67.69	124.53	94.89	82.86	91.36
1990	72.79	114.91	94.64	82.74	90.54
1991	79.71	114.48	96.18	87.19	91.72
1992	82.65	111.02	96.56	88.74	93.76
1993	85.38	106.23	97.19	90.89	93.70
1994	88.36	105.09	97.93	94.02	95.96
1995	94.86	103.31	99.09	97.92	97.54
1996	100.00	100.00	100.00	100.00	100.00
1997	106.96	97.68	99.93	98.44	108.21
1998	111.69	91.81	99.70	96.37	113.92
1999	119.56	89.22	100.26	97.37	120.15
2000	126.88	86.51	100.16	97.56	128.52
Annual Growth Rate	5.15%	-2.65%	0.72%	2.48%	3.46%

Source: AREMOS, Taiwan Economic Data Center.



Source: AREMOS, Taiwan Economic Data Center.

Figure 5-2 Manufacturing Productivity Index (1996=100), 1981-2000

Due to the fast growth of East Asian countries and the revival of interest in growth theory – the development of the new growth model during the late 1980s, a lot of literature began to examine the total factor productivity in the four tigers, namely, Hong Kong, Singapore, South Korea, and Taiwan. Some of the results show that there was not much TFP growth in these countries. The main source of the growth was mere resource reallocation by the authoritarian governments and this kind of growth contributed by input expansion is not sustainable (Krugman, 1994). Regardless of the criticism, Taiwan's TFP growth rates calculated by the literature (shown as Table 5-2) are of relatively larger value than those of the other countries, namely, Singapore, in particular, and Korea (Ikemoto, 1986; Fischer, 1993).

TFP measurement later was seriously criticized by many assmilationists, who stressed that what made the East Asian countries' performance special was how sell they mastered foreign technology, because technology is not "manna from heaven" (exogenous) and there is "learning by doing" existing in reality. In addition, TFP accounting also suffered from serious measurement problems, for most technological progress must be embedded in new inputs, that is, what Nelson (1981) pointed out "attribution problem"; the assumptions are not realistic, and if one of them is changed, this will yield radically different outcomes (Fishlow et al. 1994). Nonetheless, before any other measurements to be developed, TFP concepts may after all be accepted as one of the measurements for growth accounting reference.

Table 5-2 Literature Gauging Total Factor Productivity in Taiwan

Author	Period	Annual Rate TFP (%)	% Output Growth
Chen (1977)	1955-60	3.1	59.5
	1960-66	6.0	65.1
	1966-70	1.8	22.6
	1955-70	4.3	53.6
Ikemoto (1986)	1970-80	4.8	50.0
	1970-75	4.3	48.1
	1975-80	5.2	51.1
Fuscher (1993)	1961-88	1.7	--
World Bank (1993)	1960-89	4.2	--
	1960-89	3.9	--
	1960-90	3.8; 1.3	--
	1960-89	0.8[1]	--
Kawai (1994)	1970-80	5.1	--
	1980-90	3.9	--
Lindauer and Roemer (1994)	1965-90	4.9	--
Marti (1996)	1970-85	2.2	--
	1970-90	2.1	35.7
Bosworth et al. (1995)	1960-70	1.4	21.0
	1970-80	1.1	18.0
	1980-86	1.8	40.0
	1986-92	2.5	42.0
Collins and Bosworth (1997)	1960-94	2.0	34.5
	1960-73	2.2	32.4
	1973-94	1.8	34.6
	1973-84	0.9	18.4
	1984-94	2.8	50.0

Note: 1. Technical efficiency
Source: Felipe, 1997.

5.2 Technological Competitiveness

Technological change and productivity upgrading per se prophecy the competitiveness of industries and the whole nation. To examine the S&T's impacts on both industrial and national competitiveness, technological competitiveness could be quantified by several measurements, and the indicators gauged by those measurements could be used as surrogates of the technological competitiveness level. In this sense, R&D expenditure, R&D expenditure ratio, and R&D personnel are usually the fundamental indicators to examine the technological competitiveness.

This section sets out from the industrial technological competitiveness to see to what extent has the technological competitiveness been at the industrial level in Taiwan. Table 5-3 shows these three indicators across different industries from 1997 to 2001. In terms of R&D expenditure, the "electronic parts and components" as well as the "computer, communication, video & radio electronic products" were the top R&D spending industries among manufacturing, followed by the "transport equipment & repairing" as well as the "electrical machinery, supplies & equipment & repairing" industries with a huge gap in absolute values. In terms of R&D ratio (R&D/sales), the "electronic parts and components" still ranked top 1 among manufacturing in the selected years, followed by the "precision, optical, medical equipment, watches & clocks" and the "computer, communication, video & radio electronic products" in 2001. In terms of R&D personnel, the "computer, communication, video & radio electronic products" possessed most R&D researchers; and the "electronic parts and components" owned 14,448 R&D researchers.

By aggregating each industry according to different technology intensity, the technological competitiveness among high-technology, medium-high-technology, medium-low-technology, and low-technology industries will be more clear-cut. Here, technology intensity is classified into four categories in accordance with OECD's classification (1997). Based on this definition, high-technology industry includes aerospace (SITC 3845), computers, office machinery (SITC 3825), electronics-communications (SITC 3832), pharmaceuticals (SITC 3522). Medium-high-technology industry includes scientific instruments (SITC 385), motor vehicles (SITC 3843), electrical machinery (SITC 383-3832), chemicals (SITC 351+352+3522), other transport equipment (SITC

3842+3844+3849), non-electrical machinery (SITC 382-3825); Medium-low-technology industry consists of rubber and plastic products (SITC 355+356), shipbuilding (SITC 3841), other manufacturing (SITC 39), non-ferrous metals (SITC 372), non-metallic mineral products (SITC 36), fabricated metal products (SITC 381), petroleum refining (SITC 351+354), ferrous metals (SITC 371); low-technology industry comprises paper printing (SITC 34), textile and clothing (SITC 32), food, beverages, and tobacco (SITC 31), Wood and furniture (SITC 33).

Table 5-4 shows the indicators of the industries classified by high-, medium-high-, medium-low-, and low-technology. R&D expenditure percentages show that R&D expenditures were spent in the sequence along with technology intensity and increased over time. Within the high-technology industry, the high share of R&D expenditure was almost all contributed by the "electronics-communications" and the "computers, office machinery". The "aerospace" and "pharmaceuticals" had the smallest R&D expenditure shares. This was so due to the absence of intensive development led by the government until the last decade. For example, the National Space Program Office was just established at the end of 1991 as a governmental agency to execute the national space program. Among the medium-high-technology industry, scientific instruments had the lowest R&D percentage, but the "electrical machinery" and the "chemicals" both had relatively high R&D expenditure shares.

Among the medium-low-technology industry, the "rubber and plastic products", the "other manufacturing", the "non-ferrous metals", and the "petroleum refining" all had more than 2% share of the R&D expenditure in 1990. However, except for the "rubber and plastic products" that increased to 3.71% in 1998, the others were all diminishing. Three implications lie behind this phenomenon: (1) the industries belonging to this category per se do not need high shares of R&D in order to survive in the market, so they either keep the regular R&D expenditure whose shares are gradually eaten up by the other industries that exact high R&D expenditure to maintain their cutting edge; (2) some businesses in those industries moved off-shore due to the soaring labor costs in Taiwan, and accordingly the R&D were spent in other places; (3) other businesses following the government's suggestion – "Keeping Roots Home" moved their factories, but kept their headquarters in Taiwan, investing in R&D, but these amount was not enough to increase their shares.

Within the low-technology industry, surprisingly, the "textile and clothing", and the "food, beverages, and tobacco" had high shares of R&D expenditure, although they were decreasing over time. Nonetheless, even in 1998, the share of the "textile and clothing" – 2.59% was still higher than many industries in the medium-high- and medium-low-technology industries, implying that the so-called "low-technology" or "mature" industry is also doing something innovative to keep their competitiveness in the global market.

R&D personnel shares among the industries roughly share the same trend with the R&D expenditure shares. However, the increase or decrease scale seems to lag behind the R&D expenditure. This could be conjectured as the relative rigid feature of employment compared to expenditure.

Table 5-3 Technological Competitiveness Indicators of all Industries from 1997 to 2001

	R&D Expenditure (N.T.$ Million)					R&D as Percentage of Sales (%)					R&D Researchers (persons)				
	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001
Manufacturing	89,724	103,505	112,240	115,622	119,898	1.16	1.26	1.26	1.14	1.26	41,263	43,466	46,618	46,558	47,129
Food & beverages	1,895	1,995	1,967	1,794	1,627	0.43	0.45	0.42	0.39	0.39	909	1,069	1,276	999	831
Tobacco	118	102	129	117	157	0.38	0.40	0.54	0.51	0.74	23	22	27	29	38
Textiles mills	1,438	1,768	1,847	1,711	1,325	0.32	0.39	0.39	0.35	0.29	868	1,125	850	789	607
Apparel, clothing Accessories & other textile product	410	234	194	210	230	0.30	0.17	0.15	0.15	0.18	164	362	103	112	140
Leather, fur & allied products	449	912	1,061	1,185	943	0.61	0.79	0.93	1.11	0.94	172	251	412	384	248
Wood & bamboo products	42	71	9	13	6	0.08	0.16	0.02	0.03	0.02	26	43	28	35	4
Furniture & fixtures	446	361	489	213	214	0.58	0.50	0.68	0.30	0.32	265	134	169	169	108
Pulp, paper & paper products	421	327	587	224	283	0.29	0.24	0.40	0.14	0.18	264	250	471	275	116
Printing & related support activities	71	203	200	168	75	0.10	0.24	0.23	0.18	0.08	74	194	160	95	107
Chemical material	3,399	3,070	4,853	3,662	3,816	0.75	0.64	0.92	0.56	0.63	1,117	1,280	1,571	1,081	1,092
Chemical products	2,886	3,091	3,733	3,559	3,352	1.47	1.45	1.67	1.55	1.56	1,782	1,941	2,076	1,710	1,583
Petroleum & coal products	2,085	2,343	16	1,161	1,194	1.11	1.17	0.01	0.44	0.48	199	188	21	165	17
Rubber products	694	791	585	387	327	0.94	1.24	0.91	0.58	0.52	321	298	423	311	252
Plastic products	2,896	3,309	3,087	2,168	2,062	0.78	1.00	0.91	0.59	0.60	1,182	1,259	1,102	639	494
Non-metallic mineral products	1,014	697	786	639	496	0.44	0.29	0.32	0.28	0.23	448	385	450	303	180
Basic metal	1,694	1,294	1,196	1,141	1,276	0.26	0.21	0.19	0.17	0.20	580	631	531	298	383
Fabricated metal products	2,152	2,017	1,783	1,086	1,164	0.43	0.45	0.39	0.24	0.27	1,443	1,049	1,172	701	568
Machinery &	3,643	3,732	3,966	3,954	3,975	0.79	0.70	0.69	0.62	0.67	2,035	2,592	2,613	2,654	2,246

	R&D Expenditure (N.T.$ Million)					R&D as Percentage of Sales (%)					R&D Researchers (persons)				
	1997	**1998**	**1999**	**2000**	**2001**	**1997**	**1998**	**1999**	**2000**	**2001**	**1997**	**1998**	**1999**	**2000**	**2001**
equipment & repairing															
Computer, communication & video & radio electronic products	51,432	27,849	31,917	31,656	30,714	2.39	2.20	2.06	1.69	1.76	23,291	13,665	13,650	15,311	15,548
Electronic parts & components	--	30,968	34,845	42,299	49,872	--	3.21	2.95	2.42	3.05	--	9,087	11,701	13,596	14,448
Electrical machinery, supplies & equipment & repairing	--	5,211	5,586	6,731	6,247	--	1.18	1.19	1.36	1.35	--	2,640	3,253	3,047	3,243
Transport equipment & repairing	9,851	10,097	10,808	8,586	6,390	1.82	1.66	1.79	1.43	1.14	3,141	3,300	2,872	2,287	2,440
Precision, optical, medical equipment, watches & clocks	1,451	1,716	1,495	2,055	2,992	1.75	1.85	1.31	1.54	2.40	1,003	934	989	1,119	1,684
Other industrial products	1,237	1,348	1,101	902	1,162	0.73	0.80	0.67	0.52	0.72	717	754	699	450	599
Computer Systems Design Services	2,112	2,981	3,209	3,776	3,988	3.65	4.06	3.36	3.06	2.99	1,941	2,565	3,601	3,079	3,431
Other Non-manufacturing	4,131	4,936	5,149	4,441	4,278	1.74	0.57	0.55	0.42	0.44	1,326	1,591	1,584	1,883	1,336

Source: Indicators of Science and Technology, Republic of China, 2002. http://www.nsc.gov.tw/tech/index.asp

Table 5-4 Technological Competitiveness Indicators for Industries of Different Technology Intensity, 1990, 1995 and 1998

	R&D Expenditure (%)			R&D Personnel (%)		
	1990	**1995**	**1998**	**1990**	**1995**	**1998**
All Industries	**100.00**	**100.00**	**100.00**	--	--	--
Manufacturing	**92.17**	**97.49**	**97.23**	**100.00**	**100.00**	**100.00**
High-technology	**44.39**	**50.76**	**57.25**	**39.55**	**52.49**	**53.38**
Aerospace	0.09	0.07	0.51	0.11	0.02	0.08
Computers, office machinery	16.14	15.79	17.98	14.39	19.38	20.68
Electronics communications	0.83	1.15	1.25	2.21	1.41	1.47
Pharmaceuticals	27.33	33.75	37.50	22.84	31.68	31.15
Medium-high technology	**25.15**	**25.87**	**24.03**	**30.83**	**29.08**	**28.01**
Scientific instruments	0.40	1.49	1.74	0.90	1.98	2.43
Motor vehicles	4.78	4.89	6.17	4.96	4.22	5.84
Electrical machinery	8.36	7.26	6.65	10.11	9.25	7.81
Chemicals	7.05	5.76	4.34	8.17	5.09	5.55
Other transport equipment	2.47	1.72	2.42	1.88	1.42	1.72
Non-electrical machinery	2.08	4.76	2.71	4.80	7.12	4.66
Medium-low-technology	**13.29**	**13.46**	**10.64**	**13.48**	**11.62**	**11.90**
Rubber and plastic products	2.73	3.53	3.71	3.19	3.30	3.64
Shipbuilding	0.23	0.14	0.07	1.13	0.11	0.05
Other manufacturing	2.62	1.34	1.21	1.61	1.29	1.74
Non-ferrous metals[1]	2.59	3.30	1.40	1.72	2.57	1.41
Non-metallic mineral products	0.76	1.26	0.61	1.22	1.34	1.09
Fabricated metal products	1.81	2.25	1.54	3.75	2.24	3.50
Petroleum refining	2.55	1.65	2.10	0.86	0.77	0.48
Ferrous metals	--	--	--	--	--	--
Low-technology	**9.34**	**7.39**	**5.31**	**16.15**	**6.81**	**6.70**
Paper printing	0.76	0.72	0.45	1.91	1.29	0.82
Textile and clothing	4.47	3.60	2.59	8.31	2.48	2.92
Food, beverages, and tobacco	4.03	2.63	1.88	5.54	2.66	2.26
Wood and furniture	0.09	0.44	0.39	0.39	0.38	0.71

Note: 1. Basic metals consist of ferrous and non-ferrous metals is used in lieu of non-ferrous metals.
Source: Adapted from "A Study on Industrial Technology Competitiveness in Taiwan", Taiwan Institute of Economic Research, 2000.

Almost all industries except for the "leather, fur, and allied products" are net technology importers (see Table 5-5). Particularly, the "textiles mills, wood & bamboo products, the "furniture & fixtures", the "printing & related support activities", and the "petroleum & coal products" are pure technology importers. The vivid technology imports could be attributed to, in most part, the government's policies that render tax incentives to import production technology or energy-saving technology (refer to Chapter 3), for instance, as addressed in the "Statute for Upgrading Industries"; and the policies that progressively promote international technology transfers and encourage enterprises' participation in international R&D cooperation of prospective technology, as stated in the "Assistance in Foreign Technology Importation" (also refer to Chapter 3). In addition, the highest technology trade deficit was the "electronic parts & components". It heavily imported technology from abroad because this industry has been famous for its original equipment manufacturing (OEM), and technology importing has been the major channel connecting the domestic manufacturers and the foreign buyers. Besides, Taiwan's networks of small-scale firms did not automatically import substitute high-technology components through the cogeneration of technology since they were too far behind the world technological frontier to do so (Amsden and Chu, 2002). Therefore, technology has to rely heavily on imports.

Table 5-5 Import and Export Value of Technology by Industry, 2000

$Thousand

Industry	**Import**	**Export**	**Balance**
Food & beverages	8,494	468	-8,026
Tobacco	0	0	0
Textiles mills	7,220	0	-7,220
Apparel, clothing Accessories & other textile product	1,436	438	-998
Leather, fur & allied products	--	37,432	37,432
Wood & bamboo products	69	--	-69
Furniture & fixtures	299	0	-299
Pulp, paper & paper products	7,500	377	-7,123
Printing & related support activities	2,186	--	-2,186
Chemical material	66,339	286	-66,052
Chemical products	43,374	778	-42,596
Petroleum & coal products	1,192	0	-1,192
Rubber products	1,868	222	-1,646
Plastic products	11,180	869	-10,311
Non-metallic mineral products	14,367	368	-13,999
Basic metal	10,407	487	-9,919
Fabricated metal products	7,521	582	-6,939
Machinery & equipment & repairing	17,449	492	-16,958
Computer, communication & video & radio electronic products	210,023	55,650	-154,373
Electronic parts & components	738,573	18,616	-719,957
Electrical machinery, supplies & equipment & repairing	37,423	2,024	-35,399
Transport equipment & repairing	94,653	1,279	-93,373
Precision, optical, medical equipment, watches & clocks	15,990	3,087	-12,903
Other industrial products	6,569	2,964	-3,605
Other Non-manufacturing	--	--	--
Total	1,304,314	126,473	-1,177,841

Source: Indicators of Science and Technology, Republic of China, 2002. http://www.nsc.gov.tw/tech/index.asp

Broadening the scope from industrial level to national level, national technological competitiveness will be of our interest in the rest of the section. Table 5-6 shows several technological indicators between 1997 and 2001. Nationwide R&D expenditure was 205 billion N.T. dollars, $6,065 million, accounting for 2.16% of GDP, in 2001. Researchers in 2001 were up to approximate 90 thousand, that is, 39.9 people per 10 thousand people. There were 10,635 academic papers that belong to the category of science, either abroad or domestic, were published, while 5,103 engineering papers were published in 2001.

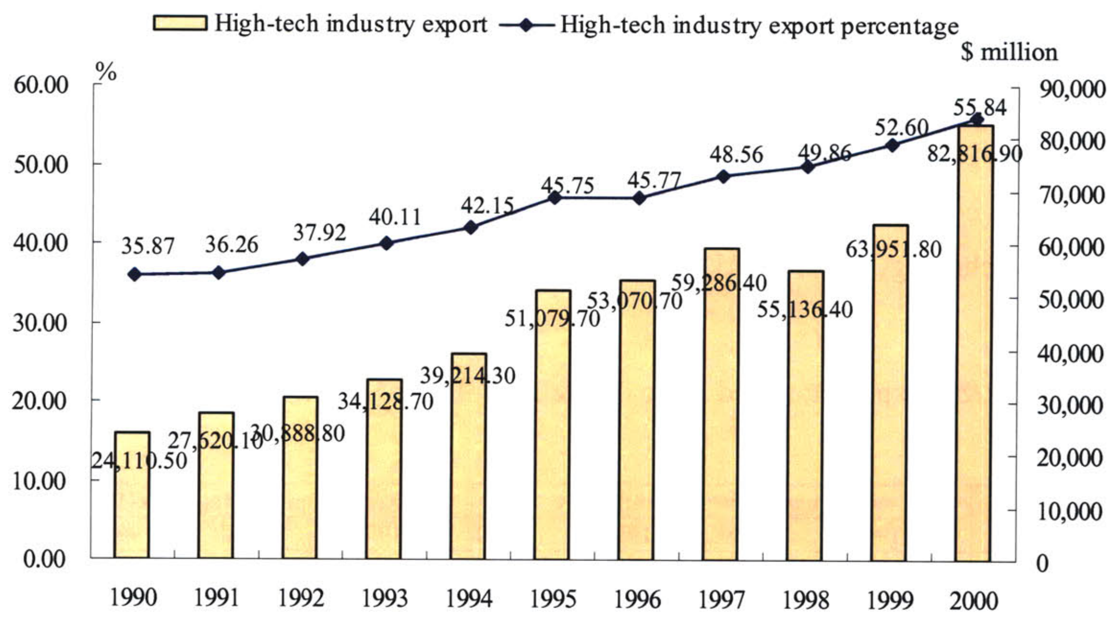
There are several ways looking at patents. In this table, patents approved in Taiwan were 21,906 cases in 2001, including approved foreign applications – 7,397 cases and approved domestic applications 1,611 cases; Taiwanese applied patents that were approved in the U.S. were 5,371 cases, excluding cases of new design. The most recent statistics shows that Taiwan was granted the U.S. patents for 6,730 cases in 2002, ranking 4th in the world, lagging behind the U.S. – 97 thousand cases, Japan – 36 thousand cases, German – 12 thousand cases, but followed by France, the U.K., South Korea, Canada, Italy, Sweden, and the other countries. Government's S&T budget increased almost 6% in average each year. In 2002, the budget was arranged at 56.4 billion N.T dollars (about $1.63 billion), accounting for roughly 4% of the total central budget of that year.

Table 5-6 S&T Indexes from 1997 to 2001

Item		1997	1998	1999	2000	2001
R&D	Expenditure ($million)	5,453	5,277	5,904	6,328	6,065
	R&D/GDP (%)	1.88	1.97	2.05	2.05	2.16
Researchers	Researcher (person)	76,588	83,209	87,454	87,394	89,118
	Researcher/10,000 population	35.30	38.00	39.70	39.30	39.90
Papers	Science	7,755	8,605	8,944	9,203	10,635
	Engineering	4,839	4,026	4,690	4,878	5,103
Patents	Domestic	9,008	8,478	11,280	17,503	21,906
	U.S.	2,057	3,100	3,693	4,667	5,371
Government S&T Budget ($million)		--	1,228	1,389	1,508	1,529

Source: Indicators of Science and Technology, Republic of China, 2002. http://www.nsc.gov.tw/tech/index.asp

Since Taiwan's exports have been credited as the engine of growth. In fact, trade very significantly matters for technological development (Hobday, 1995 and Westphal, 2001). Empirical studies also show that exporters are more productive than nonexporters (Aw et al., 1997). Foreign buyers are an important source of technology transfer as well as a driver that propels the exporters to acquire technologies, either by reverse engineering, by reinventing technology, by foreign licensing and assistance, or by inventing state-of-art technology in a few cases. In addition, the local firms that engage in exports catalyze the backward linkages, motivating the technological capabilities advancement of upstream firms. The second wave of globalization, namely, the shifting to the global distribution of industrial production, had given the firms in Taiwan an opportunity to ramp up and to exploit the second mover advantages (Amsden and Chu, 2003). The volume as well as the share of the high-technology manufacturing exports kept increasing (shown as Figure 5-3), which suggests that Taiwan has been taking the chance to become one of the global supply chains in high-technology industry, and at the same time, technological capabilities of these firms have been upgrading along with the increasing exports based on those reasons aforementioned.



Source: Directorate of General of Budget Accounting and Statistics, Executive Yuan, R.O.C.

Figure 5-3 High-technology Manufacturing Exports, 1990-2000

5.3 International Comparison

Without comparison, it is unclear what the relative status Taiwan is. Therefore, in this section, international comparison will be made to see how the technological competitiveness at both industrial and national level is situated in the global market.

5.3.1 Specific Indicators

1. R&D expenditure

Beginning by the R&D expenditure, and to avoid the bias of different scale according to the country size, the R&D expenditure as percentage of GDP is also considered. Table 5-7 shows that in 1999, Sweden's R&D expenditure/GDP ratio, 3.78%, was the largest among all the countries, followed by Finland (3.22%), Japan (2.94%), the U.S. (2.66%), and South Korea (2.47%). The ratios of Germany, France, Denmark, and the Netherlands in that year were also above 2%. The ratio in Taiwan was 1.88% in 1997, and climbed to

1.98% in 1998, while in 1999 and 2000 the ratios were above 2%. The ratios of the U.S. and Japan were obviously climbing, while the ratios of some of the EU countries were more fluctuant, but overall in a increasing trend, except Ireland. In contrast, the ratio of Taiwan rose rapidly and South Korea had very high ratio, both of which show that the catching-up countries had diverted their policy direction from heavy reliance on the borrowed technology toward R&D and self-innovation.

Table 5-7 R&D Expenditure and Ratio of R&D to GDP in Selected Countries, 1997-2000

Country	R&D expenditure ($million[1])				R&D as percentage of GDP (%)			
	1997	1998	1999	2000	1997	1998	1999	2000
U.S.A	212,950	227,329	244,700	265,322[4]	2.58	2.61	2.66	2.70[4]
Japan	90,754	91,035	92,774	98,222	2.83	2.94	2.94	2.98
Germany	43,150	44,997[3]	49,295	52,851[3]	2.29	2.31[3]	2.44	2.48[3]
France	27,992	28,675	30,350	31,410	2.22[5]	2.17	2.19	2.15[4]
UK	23,281	23,914	26,024	27,094	1.81	1.80	1.88	1.86
South Korea	16,182	14,507	15,793	19,060	2.69	2.55	2.47	2.68
Italy	13,137	14,205	14,355	--	1.05[5]	1.07	1.04	--
Canada	12,614	13,538	14,480	15,839[4]	1.70	1.79	1.80	1.84[4]
Sweden[6]	7,066	--	7,865	--	3.67	--	3.78	--
Netherlands	7,625	7,679	8,476	--	2.04	1.94	2.02	--
Australia	--	6,847	--	7,764	--	1.51	--	
Taiwan[2]	7,859	8,600	9,617	10,326	1.88	1.97	2.05	2.05
Spain	5,475	6,347	6,667	7,548	0.82	0.89[3]	0.88	0.94
Finland	2,954	3,298	3,893	4,392	2.72	2.89	3.22	3.37
Denmark	2,619	2,915	3,071	--	1.94	2.06[3]	2.09	--
Ireland[3]	1,040	1,080	1,170	--	1.29	1.26	1.21	--
Portugal	978	--	1,284	--	0.62	--	0.75	--

Note: 1. Recalculated by PPP (Purchasing Power Parity); 2. National defense R&D expenditure is excluded; 3. Estimate; 4. The value is provisional; 5. Break in series with previous year for which data is available; 6. Underestimated or based on underestimated data.

Source: 1. Indicators of Science and Technology, Republic of China, 2002. http://www.nsc.gov.tw/tech/index.asp; 2. Main Science and Technology Indicators, OECD, November, 2002.

2. R&D personnel

As to the aspect of R&D personnel, in 1997, the U.S., Japan, Germany, France, the U.K., and South Korea were the top six countries in the world regarding the absolute number of R&D personnel at national level (see Table 5-8). With the number of R&D personnel reaching at 76,588 in 1997 (83,209 in 1998), Taiwan became the 8th country that has the largest number of R&D personnel in the world and had the astonishing growth rate (8.8%, following South Korea's 10.45% and ranking 2nd). As to the industrial R&D personnel, Taiwan had 43,291 R&D employees in 1997 with an average growth rate of 9.57% from 1991 to 1997. The absolute number was not especially high, either, but the growth rate was even higher than South Korea and ranked 2nd, following Ireland.

Table 5-8 R&D Personnel in Selected Countries

Country	National R&D Personnel		Industrial R&D Personnel		National R&D Personnel per 10 thousand labor force		Industrial R&D Personnel per 10 thousand labor force	
	1997 (persons)	Average growth rate[1] (%)	1997 (persons)	Average growth rate (%)	1997 (persons)	Average growth rate (%)	1997 (persons)	Average growth rate (%)
Japan	695,623	2.99	404,232	2.89	102	2.11	60	2.41
U.S.A	--	--	918,600	2.78	--	--	67	1.58
Germany	235,792	-0.42	132,687	-1.02	59	-0.55	33	-1.44
France	155,302	3.04	70,698	2.89	60	2.41	28	2.60
UK	146,000	2.22	84,000	0.82	51	2.11	28	0.00
Taiwan	76,588	8.80	43,291	9.57	81	6.99	46	7.99
S. Korea	138,438	10.45	74,665	8.79	64	8.15	35	6.49
Canada	85,810	4.68	48,667	8.21	56	3.71	32	7.27
Italy	76,056	0.18	27,612	-1.14	32	0.53	12	0.00
Finland	21,149	7.08	8,675	9.01	83	7.10	34	9.25
Sweden	35,107	4.79	20,924	7.82	82	5.64	49	9.14
Ireland	7,807	7.14	5,098	15.67	51	4.57	33	12.82
Netherlands	38,055	5.33	17,302	8.36	50	3.79	23	7.38
Australia[2]	63,239	4.82	14,335	1.47	68	3.29	15	0.00
Belgium[3]	--	4.01	--	5.08	--	3.55	--	--
Spain	53,883	4.81	12,009	0.55	33	4.05	7	-2.20
Denmark	17,443	6.36	7,522	6.50	61	6.85	26	6.32

Note: 1. Average growth rate is annul average growth rate calculated from 1991 to 1997.
2. The average growth rates of Australia are calculated from 1991 to 1998.
3. The average growth rates of Australia are calculated from 1991 to 1995.
Source: Adapted from "A Study on Industrial Technology Competitiveness in Taiwan", Taiwan Institute of Economic Research, 2000

Absolute number is not a good measurement since the base of each country is dramatically different. Therefore, if the number of R&D personnel per 10 thousand labor force is used as an index, Taiwan was comparable to the OECD countries. In 1997, Taiwan had 81 R&D personnel per 10 thousand labor force, only below Japan's 102, Finland's 83 and Sweden's 82. From 1991 to 1997, the average annual growth rate of Taiwan, 6.99%, was higher than those of the OECD countries. As to the industrial R&D personnel per 10 thousand labor force, Taiwan had 46 people as opposed to 67 in Japan, 60 in the U.S., and 49 in Sweden, ranking fourth in the world, and the average growth rate from 1991 to 1997 was 7.99%.

3. Patents

Patents are usually adopted as one of the important indicators to the technological competitiveness. The patent statistics used here is issued by the United States Patent and Trademark Office (USPTO). Table 5-9 listed the utility patents[25] granted by the USPTO under high-technology industry as well as the whole nation of the selected countries. The growth of the number of granted patents in the U.S. from the period 1981-1989 to the period 1990-1999 indicates that technological progress had advanced at a stunning pace. The U.S. and Japan had outnumbered the other countries during both periods. The U.S. itself accounted for a relatively constant share of the total throughout the 1980s and the 1990s, approximately 40%. Japan grew more significantly than that of the Western European countries, whose patents increased only slightly. The most outstanding performers were Taiwan and South Korea. Taiwan in the 1990s had eight times the number of granted patents of that in the 1980s, while South Korea had 30 times. This shows that both Taiwan and South Korea are catching up in the field of technological development to maintain their high economic growth.

Same thing happens in the number of patents of high-technology manufacturing. The U.S. and Japan had the biggest numbers of granted patents for high-technology industry. In the 1990s, the number of patents of high-tech industry granted in the U.S. was 2.3 times the number in the 1980s. It had grown faster than the number of all patents, 1.7 times, from the period 1981-89 to 1990-1999. The shares of the U.S. showed a slight slide from the 1980s to the 1990s by 2%. Conversely, Japan's high-technology industry had a bigger share of patents than the overall utility patents and increased from 24.23% to 28.42%. The shares of high-technology industry patents granted to the European countries had notably

[25] Utility patent refers to the patent for invention. Other types of patents include design patents, plant patents, reissues, defensive publications, and statutory inventions registrations.

increased in the 1990s, compared to the overall granted utility patents. Taiwan and South Korea had performed equally well in the numbers of high-tech granted patens: Taiwan had 308 granted patents in the 1980s and quickly increased to 4,873 in the 1990s; South Korea in the 1980s had only 146 granted patents of high-tech industries but soared considerably in the 1990s to 8,587, just below a few countries – the U.S., Japan, Germany, France, and the U.K.. Most of the high-technology industry patents granted to South Korea and Taiwan concentrated on electronics and telecommunications industries.

Table 5-9 Utility Patents Granted by the USPTO at Industrial (high-technology) Level and National Level, 1981-1989 and 1990-1999

Country	High-technology Industry		Nation	
	1981-89	1990-99	1981-89	1990-99
USA	73,028	169,875	315,154	549,985
Japan	36,315	103,698	95,134	208,960
Germany	12,553	18,678	54,159	70,468
South Korea	146	8,587	417	12,627
UK	5,830	9,438	19,691	24,926
France	5,746	10,350	19,247	28,407
Canada	2,049	5,351	10,839	21,115
Taiwan	308	4,873	1,917	15,669
Netherlands	2,081	3,518	5,984	8,580
Israel	344	1,804	1,535	4,060
Sweden	1,167	2,366	6,426	7,927
Italy	2,005	3,328	7,745	12,060
Switzerland	2,054	2,658	9,757	6,348
Finland	198	1,124	1,510	3,699
Australia	418	1,141	2,793	4,669
Belgium	414	1,057	2,090	4,086
Denmark	262	807	1,351	2,485
Austria	476	759	2,604	3,502
Ireland	74	269	275	593
Singapore	4	363	56	545
China	35	190	125	583
New Zealand	55	155	409	592
Malaysia	1	38	15	122

Source: Adapted from "A Study on Industrial Technology Competitiveness in Taiwan", Taiwan Institute of Economic Research, 2000

4. High-technology manufacturing value-added

As shown in Table 5-10, the U.S. and Japan had the highest value added in manufacturing or its sub-category – high-technology manufacturing in 1997. Although Japan's expenditure in R&D and human capital investment still fell behind the U.S., as shown in Table 5-7 and Table 5-8, Japan's manufacturing value added was not much behind the U.S. This is because Japan had managed to reinforce its capabilities in product design and production, marketing, and management, which were not included in the R&D spending but helped increase its manufacturing value added. Germany's manufacturing value added ranked third in the world and was embodied mainly in medium-high technology and medium-low technology industries, such as motor vehicles and electrical machinery. France, the U.K., and Italy were in the third leading group, while South Korea, Canada, Spain and Taiwan were in the fourth.

Table 5-10 Manufacturing Value Added of Selected Countries in 1997

$million; %

Country	Manufacturing		High-technology		Medium-high-tech		Medium-low Tech		Low-technology	
	Value added	Growth rate	Value added	Growth rate	Value added	Growth rate	Value added	Growth rate	Value added	Growth rate
USA	1,378,860	1.59	220,748	1.37	440,263	2.91	298,623	1.63	413,810	0.19
Japan	1,057,112	0.05	155,307	0.03	360,607	0.32	292,223	0.17	252,789	-0.41
Germany	455,063	-1.98	44,312	-4.59	172,958	-1.69	146,198	-0.61	92,978	-3.09
France	268,916	0.07	32,712	0.61	77,463	0.14	77,386	-0.23	81,354	0.07
UK	230,585	0.75	32,123	-0.08	70,680	1.35	48,585	0.66	79,923	0.60
Italy	229,610	-2.07	14,674	-3.26	62,693	-1.59	65,889	-1.95	88,944	-2.17
South Korea	113,695	-1.35	21,032	3.81	32,973	1.14	35,137	-2.23	24,553	-5.96
Canada	101,953	0.51	10,910	2.74	30,195	2.58	21,353	-0.9	39,495	-0.69
Spain	92,975	0.15	6,842	1.41	29,736	2.09	28,424	0.73	29,411	-1.92
Taiwan	80,649	2.44	15,742	11.79	20,587	3.01	27,438	1.23	16,881	-1.95
Netherlands	65,207	0.92	8,560	0.59	15,465	0.94	18,767	0.23	22,121	1.41
Australia	53,788	1.87	3,522	3.02	11,996	3.11	16,726	0.55	22,004	2.45
Sweden	45,489	-0.02	4,808	2.75	15,179	0.58	10,565	-0.46	15,157	-1.08
Denmark	27,826	1.89	2,065	2.84	7,881	3.74	6,671	1.21	11,209	0.96
Finland	26,830	1.00	2,510	12.04	7,186	2.31	6,336	0.30	11,074	-0.90

Note: Growth rates are annual averages in 1991-1997 after being deflated using the US 1995 PPP (US 1995 = 100).

Sources: Adapted from “A Study on Industrial Technology Competitiveness in Taiwan”, Taiwan Institute of Economic Research, 2000

From 1991 to 1997, Taiwan's manufacturing value added grew 2.44% annually, higher than the OECD countries'. In particular, the growth rate of the value added of Taiwan's high-technology industry was 11.79%, lower than Finland's 12.04%, but higher than South Korea's 3.81%, Australia's 3.02%, and the other countries'. In fact, among Taiwan's manufacturing value added, shares of the high-technology industries had grown steadily from 9.61% in 1987 to 21.25% in 1998, while low-technology industries had slid considerably from 33.33% to 19.03% in the corresponding period. This was due to the fast pace of the structural adjustment in Taiwan's manufacture industry during the past ten years.

5. High-technology manufacturing exports

As shown in Table 5-11, high-technology manufacturing export was almost $40 billion in Taiwan in 1998, accounting for 36.44% of the whole manufacturing exports, the largest among the selected countries, followed by the U.S. – 31.57%, and the U.K. – 28.08%. Export concentration in Taiwan was fairly high on high-technology manufacturing owing to the fact that information, electronics and telecommunication industries constituted a lion's share of Taiwan's industrial structure. The percentages of high-technology exports grew from 23.20% in 1991 to 36.44% in 1998, among which export growth of the electronics products was the highest, i.e., 20.78%. The OECD countries, such as Finland, Netherlands and Sweden, also experienced very fast growth of high-technology exports by more than 10%. Exports in Finland and Sweden mainly concentrated on the electronics and telecommunication industries, while the Netherlands concentrated on the information industry.

In terms of annual average growth rate of exports, the growth of high-technology exports of the OECD countries and Taiwan during the period 1991-1998 was higher than those of the whole manufacturing industry and the other industries. Finland had the highest annual growth rate of high-technology exports, 25.39%, from 1991 to 1998, followed by Sweden – 13.38%, the Netherlands – 11.52%, Belgium – 10.72%, and Taiwan – 9.62%. In the last decade, Taiwan had experienced its rapid growth of high-technology exports at the expense of the other industries: medium-high-technology and medium-low technology industries grew only moderately, while low-technology industry declined.

Table 5-11 Export Share and Growth Rate of Manufacturing Industries in Selected Countries in 1998

%

Country	Manufacturing		High-tech		Medium-high		Medium-low		Low-tech	
	Export[1]	Rate[2]	Export	Rate	Export	Rate	Export	Rate	Export	Rate
USA	100.00	4.67	31.57	6.57	43.55	4.49	11.33	3.54	13.41	2.33
Japan	100.00	1.79	23.36	1.59	58.59	1.97	15.27	2.40	2.68	-2.77
UK	100.00	3.71	28.08	7.53	42.04	3.58	15.10	0.27	14.21	2.19
Germany	100.00	2.94	13.25	5.57	6.97	3.30	15.52	1.29	13.22	1.10
France	100.00	3.85	20.55	8.24	41.50	3.12	16.19	1.79	19.77	2.12
Taiwan	100.00	2.80	36.44	9.65	22.25	2.11	22.48	1.23	18.83	-3.07
Netherlands	100.00	1.73	23.41	11.52	37.00	2.46	15.92	-3.20	23.46	-1.64
S. Korea	100.00	3.42[3]	27.27	4.28	31.00	5.63	24.51	7.29	17.18	-4.79
Canada	100.00	6.00	12.27	6.78	46.38	6.76	16.29	4.81	24.94	5.06
Italy	100.00	4.06	7.92	3.91	40.99	4.72	22.78	3.71	27.76	3.49
Sweden	100.00	4.77	24.20	13.38	38.25	4.27	16.11	1.48	21.20	1.71
Belgium	100.00	4.96	9.06	10.72	42.13	5.80	24.41	1.45	20.76	3.59
Finland	100.00	6.52	20.13	25.39	26.80	6.71	18.23	3.71	34.63	2.64
Spain	100.00	7.42	8.03	7.75	48.59	8.24	20.76	5.22	22.11	8.06
Australia	100.00	3.00	10.38	6.18	22.15	6.29	27.87	1.13	39.49	2.06

Note: 1. Export refers to export share; 2. Rate refers to annual average growth rate from 1991 to 1997 after being deflated using the US 1995 PPP (US 1995 = 100); 3. South Korea's annual average growth rates are from 1994 to 1998.

Sources: Adapted from "A Study on Industrial Technology Competitiveness in Taiwan", Taiwan Institute of Economic Research, 2000

A careful comparison of every single indicator reveals the fact that Taiwan had been relatively short of inputs in industrial technology competitiveness, namely R&D expenditure and personnel. As for the outputs, Taiwan had the greatest comparative advantage in patents. However, the product value added at the production and marketing stage was of disadvantages vis-à-vis the other countries, even though high-technology industry exports claimed a high share. In this regard, apparently, the industrial S&T development in Taiwan was still manufacturing-oriented with greater emphasis on the "D" of the R&D, namely, the application of technology. R&D expenditure in the basic science and the innovation of new technologies were insufficient. Accordingly, Taiwan is more proficient in the manufacturing process of relatively low value added manufactures. Hence, Taiwan needs to be more focused on innovation and knowledge-intensive industrial technologies and to develop high value-added new industries. Moreover, innovation and R&D should be reinforced in the sector of critical parts and materials, with a better understanding of international marketing. By doing so, Taiwan will have the chance to enhance its capability at the two ends of the value chains and to gain the sustainable advantages in its industrial competitiveness.

5.3.2 Composite indicators

Composite indicators have been studied in the recent literature trying to quantify S&T activities and the resulting competitiveness, and, ultimately, economic growth. To create a new and better methodology as well as precisely calculate the figures of the indicator in each country are very important, but these will take another volume as this thesis and will be beyond the scope of this thesis. Therefore, the following context is based on the currently existing indicators and the figures calculated by the earlier studies.

Based on the methodology invented by the National Institute of Science and Technology Policy, Science and Technology Agency in Japan (NISTEP), competitiveness can be measured by six indexes: Input Competitiveness (IC) index, Output Competitiveness (OC) Index, Industrial Technological Performance (ITP) Index, and International Industrial Competitiveness Performance (IICP) index. Each index contains its own variables, shown as Table 5-12. Please refer to Wu and Lin (2000) for the methodology of these six indicators.

Table 5-12 Variables under Each Index

Index	Variables
1. ITC Index	Industrial R&D expenditure R&D expenditure of universities and research institutes Numbers of industrial R&D researchers Patent intensity Manufacturing value added High-technology industry value added High-technology export value
2. IC Index	Industrial R&D expenditure R&D expenditure of universities and research institutes Numbers of industrial R&D researchers
3. OC Index	Patent intensity Manufacturing value added

	High-technology industry value added High-technology export value
4. ITP Index	Industrial R&D expenditure R&D expenditure of universities and research institutes Numbers of industrial R&D researchers Patent intensity
5. IICP Index	Manufacturing value added High-technology industry value added High-technology export value

Source: Adapted from "A Study on Industrial Technology Competitiveness in Taiwan", Taiwan Institute of Economic Research, 2000

The values of each index in each selected country were calculated as shown in Table 5-13. ITC index is the composite index that considers R&D expenditure in industries, universities, and research institutes; numbers of industrial R&D researchers; patent intensity; manufacturing value added; high-technology industry value added and exports. The U.S. and Japan took the lead, followed by Germany, France, and the U.K. Taiwan ranked 7th, lagging behind South Korea, but ahead of Italy, Canada, the Netherlands, and the Nordic countries. IC index stands for the input perspective of technological potential. Taiwan ranked 9th, seemingly not good in the ranking, but it was 12th in 1991 (Wu and Lin, 2000). Compared to the past, it had had considerable improvement, as opposed to the stagnation of European countries. The OC index represents the output perspective of technological performance. Taiwan ranked 6th, lagging behind the U.S., Japan, Germany, the U.K., and France. ITP is an index measuring the relationship between technological investments and innovation capabilities. The situation here was rather similar to that of the IC index. Taiwan ranked 9th in 1997, but it also had had significant improvement compared to that in 1991. IICP index measures the degree of technological innovation applied to products value added and exporting capabilities. Taiwan ranked 8th, compared to the other countries.

Generally speaking, similar to the conclusion in section 5.3.1, Taiwan were more competitive in terms of output performance, namely, patents, high-technology manufacture valued added and exports, but had relatively weak performance in terms input performance, in other words, R&D expenditures and manpower. This is trivial because the scale and scope of those inputs – R&D spending and employees in those super industrialized countries have been essentially tremendous from the outset. For a late comer country, Taiwan has surpassed many other industrialized countries and has had larger scale of improvement compared to the other latecomer countries.

Table 5-13 Composite Indexes of Selected Countries in 1997

	ITC			IC			OC			ITP			IICP		
Country	Index	US=100	Rank	Index	US=100	Rank	Index	US=100	Rank	Index	US=100	Rank	Index	US=100	Rank
U.S.	0.9998	100.0000	1	0.9996	100.0000	1	0.9999	100.0000	1	0.9998	100.0000	1	0.9996	100.0000	1
Japan	0.9642	96.4393	2	0.9551	95.5482	2	0.9699	96.9997	2	0.9482	94.8390	2	0.9774	97.7791	2
Germany	0.6055	60.5621	3	0.5773	57.7531	3	0.6282	62.8263	3	0.5392	53.9308	3	0.6893	68.9576	3
France	0.4822	48.2296	4	0.4569	45.7083	4	0.5034	50.3450	5	0.4323	43.2386	4	0.5513	55.1521	5
U.K.	0.4769	47.6995	5	0.4100	41.0164	5	0.5319	53.1953	4	0.3980	39.8080	5	0.5877	58.7935	4
S. Korea	0.361	36.1072	6	0.3410	34.1136	6	0.3781	37.8138	7	0.3481	34.8170	6	0.3829	38.3053	7
Canada	0.3148	31.4863	9	0.3191	31.9228	7	0.3122	31.2231	10	0.3295	32.9566	7	0.2991	29.9220	10
Italy	0.3307	33.0766	8	0.3158	31.5926	8	0.3431	34.3134	8	0.3188	31.8864	8	0.3500	35.0140	8
Taiwan	0.3474	34.7469	7	0.2958	29.5918	9	0.3916	39.1639	6	0.3136	31.3663	9	0.4006	40.0760	6
Sweden	0.2866	28.6657	11	0.2952	29.5318	10	0.2808	28.0828	11	0.3033	30.3361	10	0.2687	26.8808	11
Netherland	0.3146	31.4663	10	0.2940	29.4118	11	0.3324	33.2433	9	0.3015	30.1560	11	0.3374	33.7535	9
Australia	0.2617	26.1752	13	0.2918	29.1917	12	0.2396	23.9624	14	0.2974	29.7459	12	0.2202	22.0288	14
Spain	0.2686	26.8654	12	0.2768	27.6911	13	0.2629	26.2926	12	0.2851	28.5157	13	0.2507	25.0800	12
Finland	0.2515	25.1550	14	0.2653	26.5406	14	0.2414	24.1424	13	0.2780	27.8056	14	0.2215	22.1589	13
Denmark	0.2498	24.9850	15	0.2651	26.5206	15	0.2387	23.8724	15	0.2766	27.6655	15	0.2196	21.9688	15

Source: Taiwan Institute of Economic Research.

Another set of composite indicators cited by this thesis would be the Technology-based Competitiveness Indicators (HCIs). Since 1987, Technology Policy and Assessment Center at Georgia Institute of Technology has been working on these indicators. HCIs are nation-level composite indicators that comprise four "input" and one "output" indicators. The data of HCI is mainly collected from two sources: expert opinion collection and statistical data. The detailed indicator calculation can be referred to Roessner et al, 2001. The definition of each indicator is as follows:

> **National Orientation (NO)** indicates a country's commitment to technology-based development along a number of dimensions: government policy, political stability, entrepreneurial spirit, and acceptance of the idea that development should be technology-based.
> **Socioeconomic Infrastructure (SE)** indicates the strength of each nation's educational system, mobility of capital, and encouragement of foreign investment.
> **Technological Infrastructure (TI)** captures the strength of a nation's scientific and engineering manpower, its electronic data processing purchases, the relationship of its R&D to industrial application, and its ability to make effective use of technical knowledge.
> **Productive Capacity (PC)** concerns capabilities to manufacture technology-intensive products. It combines the value of electronics production with three survey items related to manufacturing and managerial capabilities. Electronics production values exert considerable influence as they range widely.
> **High Tech Standing (TS)** measures current high tech production and export standing. TS incorporates three components – an expert opinion item (rating technology-intensive production), overall high tech exports, and the value of electronics exports.

Table 5-14 displays these indicators across the selected countries. From the table, Taiwan had good performance in NO and SE indicators, not bad performance in PC and TS indicators, but unfavorable status in TI indicator among the 33 selected countries. According to the results, Taiwan has already had potent government policies, stable political condition, vigorous entrepreneurial spirit, and stronger acceptance of the idea that development should be technology-based. Besides, the education system in Taiwan is rather sound, capital mobility is high, and encouragement of foreign investment is acceptable. However, the strength of a nation's scientific and engineering manpower, its electronic data processing purchases, the relationship of its R&D to industrial application, and its ability to make effective use of technical knowledge are rather weak. This conclusion is somewhat in accordance with the results inferred in the analysis of the previous composite indicators.

The U.S. overall has the most excellent performance in all indicators, except for the

NO indicator. This is not surprising because the U.S.'s growth has long been credited to its animated and dynamic private sectors, and government policies have been playing a minor supporting role, and this is also the explanation of why the NO indicators of East Asian countries, namely, Japan, South Korea, Singapore, and Taiwan, are generally higher than other countries in the table.

Table 5-14 Technology-based Competitiveness Indicators (HCI) and Country Rankings in Selected Countries

Country	NO				SE				TI				PC				TS			
	1993		1999		1993		1999		1993		1999		1993		1999		1993		1999	
USA	69.9	10	78.4	7-1	84.0	1	87.0	2	87.5	1	96.1	1	89.8	2	88.1	1	90.0	2	95.4	1
Japan	85.3	2	79.5	5	72.7	5	63.2	17	83.7	2	78.3	2	92.7	1	83.4	2	90.8	1	82.7	2
Germany	75.2	7	73.8	11	69.8	7	71.8	11	66.6	3	64.1	3	65.0	3	65.3	4	60.5	3	58.7	3
UK	63.2	16	72.4	13	65.6	11	78.0	4	57.5	6	59.8	4	49.0	11	53.6	10	49.3	4	53.8	4
France	74.2	8	75.4	9	63.8	14	71.7	12	60.0	4	58.0	6	56.1	4	65.5	3	45.6	5	48.0	6
Netherlands	68.5	11	68.9	16	67.7	9	74.2	6-1	54.4	9	53.1	10	50.5	10	56.0	5	35.1	7	38.7	8
Italy	59.2	20	63.1	24	53.6	21	59.7	20	50.5	10	48.4	13	51.8	9	47.1	16	31.5	9	26.2	17
Switzerland	71.5	9	66.0	21	62.0	17	60.5	19	55.4	8	54.8	8	53.4	6	55.6	7	32.5	8	32.8	11
Sweden	83.0	3	64.2	23	66.6	10	68.7	14	55.5	7	55.5	7	52.8	7	47.0	17	28.0	11	30.2	15
Spain	55.9	22	66.7	20	64.4	12	68.4	15	36.4	20	40.1	24	52.3	8	44.7	18	18.3	16	18.4	22-1
Ireland	--	--	92.2	1	--	--	75.6	5	--	--	48.0	14	--	--	55.9	6	--	--	32.7	12-1
Canada	60.1	19	78.5	6	78.3	2	91.7	1	49.5	11	53.5	9	48.1	12-1	52.8	11	24.0	14	35.4	9
Australia	66.8	13	78.4	7-2	63.9	13	83.2	3	45.8	12	53.0	11	41.3	17	51.6	12	15.6	19	19.5	21
South Africa	50.2	--	51.0	30	40.3	--	40.5	25	28.7	--	15.4	22	--	--	--	30	--	--	--	30
New Zealand	57.1	21	67.3	19	70.0	6	70.9	13	41.9	14	45.9	17	34.6	21	39.6	25-1	16.8	18	16.8	25
Russia	32.5	27	51.1	28	39.4	27	53.7	24	58.4	5	52.9	12	31.8	25	39.1	27	14.7	22	15.2	28
Poland	69.4	--	54.2	14	58.4	--	38.2	23	39.0	--	18.8	26	18.4	--	--	20	--	--	--	22-2
Hungary	66.7	14	73.7	12	54.0	20	60.9	18	41.4	16	43.0	20	36.8	19	42.2	23	15.4	21	20.9	18
Czech Republic	--	--	68.2	17	--	--	58.9	21-1	--	--	41.5	21	--	--	44.6	19	--	--	16.4	27
Singapore	92.7	1	87.9	4	73.5	4	71.9	10	40.5	17	38.9	25	54.6	5	53.7	8-1	35.8	6	51.5	5
South Korea	81.9	4	74.9	10	69.6	8	73.5	9	42.6	13	44.6	18	46.4	15	48.8	15	28.7	10	32.7	12-2
Taiwan	81.1	5-1	90.7	3	74.5	3	74.2	6-2	37.4	19	43.6	19	43.0	16	53.7	8-2	27.0	12	35.2	10
Malaysia	81.1	5-2	69.5	15	63.7	15	58.9	21-2	34.2	21	31.9	27	47.5	14	44.1	21	24.3	13	30.8	14
China	62.3	18	65.3	22	46.4	25-1	52.4	27	38.6	18	46.4	16	33.2	23-1	41.9	24	20.7	15	44.2	7
Thailand	67.5	12	50.7	29	51.0	22	46.5	31	26.7	23	20.5	32	33.4	22	30.6	29	17.2	17	16.6	26
Indonesia	62.5	17	53.9	27	49.5	23	43.8	32	25.3	25	19.2	33	24.8	27	23.7	33	11.0	27	14.0	31
Philippines	43.1	26	60.9	26	57.5	18	63.7	16	25.1	27	24.4	29	34.9	20	42.6	22	12.6	25	15.0	29
India	52.4	23	67.7	18	46.4	25-2	48.4	30	33.0	22	46.8	15	38.6	18	51.3	13	13.5	23	20.8	19
Mexico	47.9	24	41.8	31	47.7	24	40.4	33	25.2	26	21.8	30	27.2	26	24.8	31	11.6	26	19.8	20
Brazil	63.6	15	61.5	25	55.1	19	49.1	29	41.6	15	40.4	23	48.1	12-2	39.6	25-2	15.5	20	18.2	24
Argentina	45.0	25	41.3	32	63.2	16	53.3	26	25.5	24	27.5	28	32.2	23-2	31.0	28	12.7	24	11.3	32
Venezuela	--	--	39.8	33	--	--	49.4	28	--	--	21.3	31	--	--	24.3	29	--	32	7.7	33
Israel	--	--	92.0	2	--	--	74.1	8	--	--	58.2	5	--	--	50.6	14	--	--	29.5	16

Note: Figures in italics are the rankings.
Source: Adapted form "A Comparison of Recent Assessments of the High -Tech Competitiveness of Nations", Technology Policy and Assessment Center, Georgia Institute of Technology, 2001.

5.4 Summing-up

The ideal way of relating S&T development to the economic development is simply calculating how much the S&T activities have contributed to the whole economic growth. However, this seemingly simple calculation is infeasible. First, the definition of S&T per se is rather ambiguous. Second, even if it is well defined, the statistical data are scarce and hard to retrieve or do not even exist. The only way to conduct the research is to employ several surrogate indicators to show both the input and output aspects and to obtain the values to approximate the real situation and results and then to examine to what degree the S&T has been done, is ongoing, or has resulted in particular outcomes.

The indicators this chapter has employed include labor productivity, fixed capital productivity, total factor productivity, complemented by multifactor productivity and Tornquist index for productivity; for competitiveness, specific indicators comprise R&D expenditure as well as personnel, patents, technology trade, S&T budget, high-technology manufacturing exports and value added, and so on; composite indicators include HCIs, and so on. The purpose is to try to find some benchmark in the complicated and unmeasurable situation.

Simply put, from the messages that those indicators have conveyed, Taiwan has been having tremendous progress of S&T development since the 1980s, and the gap between it and the industrialized countries has been narrowed down and, in some cases, even excels a number of the advanced countries. However, the industrial S&T development in Taiwan is still manufacturing-oriented and no its own brand names, while with very few exceptions e.g. acer in PC industry. Taiwan has displayed its growth in high-technology manufacturing value added but the value is relatively low, mainly because the information and electronics industries in Taiwan engaged in Original Equipment Manufacturing (OEM), which is highly specialized and eventually will face fierce international competition from those newly industrialized countries whose labor costs are relatively cheap. Consequently, compared to those countries that concentrate on high-value-added critical parts and components and devote themselves to innovation and marketing, the value added created by the high-technology industries in Taiwan appears to be weak. This is a direction that both the government and the private sectors should manage to improve.

Given that the government has provided rather good S&T policies (as suggested in Table 5-14) in the past, the government surely will have the potential to provide another good S&T policies to provide the private sectors with incentives to conduct the “R” and divert to higher value added production and to create their own brand names in the future.

Chapter 6 Conclusion

Previous chapters have demonstrated how S&T have fostered the growth in the course of Taiwan's economic development, especially circa the last two decades in addition to the government's role played in the planning and the initiative of S&T activities embedding in the form of S&T policies. The message this thesis is planning to convey is that in Taiwan's case, the government's planning is the main force that leads not only major economic activities, but also new ideas and new domains that the private sectors are either incapable to engage in or have not thought of doing, for instance, some rather risky fields of S&T.

The lesson for the development issues drawn here is that for a developing country where the physical infrastructure is insufficient, people are poor and ill-educated, and businesses are uncompetitive in the global market whereas the domestic market size is small, in its initial stage of development, the government possesses the greatest opportunity due to the resources and power it owns and is the most appropriate role that can launch a momentum in its developmental course via policy implementation.

In turn, the follow-up question will be posed is what kind of policies is imperative for economic growth. The answer can be short: any policies that pursue knowledge augmentation. Why? The rationale lies in the growth motivity in those advanced countries: the proprietary knowledge underlies in the firm-level, mostly generated by private firms that face fierce market competition in the U.S., whereas originated under the lead of the government in Japan, as a prominent latecomer country. Therefore, government polices regarding this sort, namely knowledge acquisition and augmentation are classified as S&T policies and are imperative for a country that strive to scale up economic growth.

Without government's intervention, the firms in developing countries are difficult to acquire the technology they need. Technology buyers cannot find suppliers in the technology market. Even though there are suppliers, technology transfer per se is costly and incomplete[26]. Therefore, it is very crucial for government's intervention embodied in subsidy/tax incentives to lower the costs or in foreign technology cooperation programs to

[26] Amsden (2001): Technology is "tacit" and never completely codifiable, the best technology transfer rarely achieves productivity parity between buyer and seller.

act as a medium providing transfer opportunities and, at the same time, to offer resource pool of expertise so as to lessen the incompleteness of technology transfer as well as to generate the economies of scale to benefit the firms affiliated with the programs..

6.1 Taiwan's Extraordinary Experience

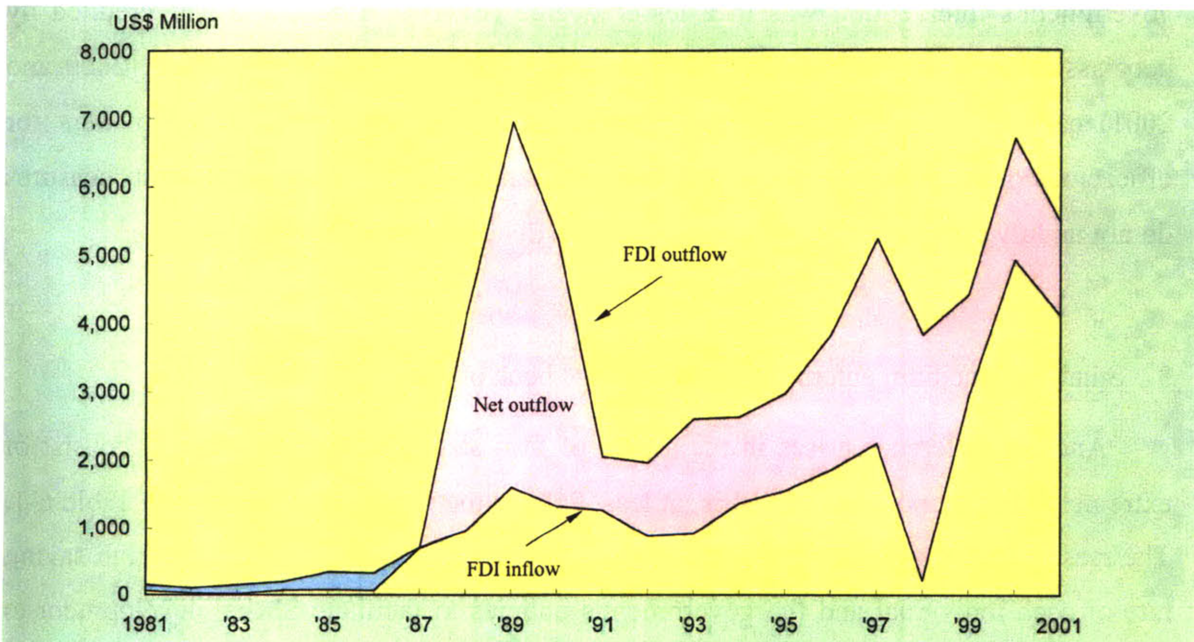
Taiwan's experience presents a extraordinary case of S&T development in relation to economic development. Although the first S&T policy, the "Guidelines on Long-term National Science Development Programs" was initiated in 1959, not until the recent decades have the rather conspicuous results burgeoned out. Consequently, S&T policies are a long-term endeavor as well as investment. In addition, the scope of S&T is so far-reaching that not only those policies with S&T's titles count, but also those industrial, infrastructural as well as educational policies that foster the technological capabilities of firms, industries, and the whole nation should be considered. Therefore, S&T planning are a comprehensive and long-term agenda.

Literature on Taiwan's S&T development, or in a broader sense, economic development is usually embedded in a nexus of Asian NIEs, because of the similarities within these economies, yet Taiwan's developmental experience has its own unusual features:

1. Foreign direct investments (FDIs) are vital to the initial stage of technology acquisition, but are not eminently viewed as the dominant source of technology of local firms.

In the preparatory phase of technological development, FDIs were the primary source of technology transfers, and the government deliberately facilitated FDIs formation in Taiwan to drive the ignition of technological development. The approach is that using tax or tariff incentives to attract those technological frontiers to the specific area, say, Export Processing Zones or Hsinchu Science-based Industrial Park, and imposed local content requirements on those multinational companies (MNCs). Local content requirements were used to foster backwards linkages in a number of sectors (Wade, 1990), in other words, those MNCs were bonded to source parts and components from local firms, which is very important to local firms' technology acquisition via the interaction with those MNCs. Other than local contents requirements, the government also required the MNCs to transfer their stock shares to the nationals so as to transform the companies from foreign-owned companies to joint venture in return for the preferential tariffs, cheap as well as steady materials supply, and import protection.

Compared to Singapore and Hong Kong, the FDIs in Taiwan were not as predominant as those in Singapore and Hong Kong (Lall, 1990). Figure 6-1 shows the inflow as well as outflow FDIs from 1981. After 1981, outward FDIs even exceeded inward FDIs. In addition, the government also set laws – "Negative List for Investment by Oversees Chinese and Foreign Nationals" prohibiting FDIs in some sectors, in fact. The relative independence of FDIs drew the government's attention on the national firms and left more room for them to grow, preventing the crowding out effects caused by multinationals (Amsden, 2001).



Source: The Central Bank of China, R.O.C., ***Balance of Payments Quarterly, Taiwan District, R.O.C.,*** Feb. 2002.

Figure 6-1 Outward and Inward Foreign Direct Investments, 1981-2001

2. Government exerted selective intervention in trade policies.

Again, in contrast to Hong Kong and Singapore, which have followed free trade policies, imposing no tariff or non-tariff barriers to trade, Taiwan's free trade only incarnated in exports, the intermediate inputs imported for products that are produced to be exported, and the equipment or materials that are needed for R&D. The other parts of the trade are heavily involved with government's intense intervention, namely, export promotion and import control. Export promotion was put in practice via the aforementioned Export-Processing Zones (Ch. 3 and 4), tariff rebates for imported inputs needed to produce exports and cannot be acquired in the domestic market, as specified in the "Statue for Encouraging Investment", which was superceded by the "Statue for Upgrading Industries" in 1990 (Ch.3), export tax incentives and awards, and export marketing. Import control was reflected on tariffs as well as non-tariff barriers, e.g. import list of impermissible items and sources[27].

However, compared to Korea and many other countries, e.g. Israel, the Taiwanese government's intervention was in a lesser degree (Balassa, 1982), and was credited by neoclassical students as free trade regime (Sachs and Warner, 1995). Nelson (2000 and 2001) calls this kind of openness as "openness in effective term", which matters for efficacious development, so long as three are means to assure that protectionist measures do not unduly constrain a country's pursuit of its dynamic comparative advantage.

3. Small and medium enterprises (SMEs) have been prevalent.

Another difference arises in the aspect of firm size. The firms in Taiwan consist of extremely high proportions of SMEs, at least 96% in the various years shown in Table 6-1. The reasons that the share of SMEs in Taiwan has been so high pertain to the high saving rate of each individual and the government's policies to facilitate SMEs' development to secure high employment. In the most recent year that the data are available, the share appears to be the all time high – 98.2%. However, in terms of sales shares, SMEs account for only 36% (35.97% in 1995), at best, and the sales shares were shrinking overtime. Even in the group of big businesses, the big enterprises in Taiwan are relatively small compared to the *chaebol* in Korea and the *Zaibatsu* in Japan, and those big businesses listed in the top

[27] For example, garments from Europe and America were impermissible to exclude the most competitive sources of such products (Wade, 1990).

50 enterprises are mostly state-owned.

Table 6-1 SMEs[1] in Taiwan, 1989-2001

Year	Number of firms (%)	Sales (%)
1989	97.39	33.32
1990	97.16	34.51
1991	97.05	34.34
1992	96.77	33.66
1993	96.49	33.98
1994	96.26	32.20
1995	97.97	35.97
1996	97.95	34.29
1997	97.81	32.11
1998	97.76	30.36
1999	97.73	28.95
2000	98.08	28.98
2001	98.18	28.38

Note: 1.Capital is approximately less than $1,765 thousand or annual sale is less than 2,353 thousand.
Source: Adapted from Small and Medium Sized Enterprise White Book, 1999-2002, Small and Medium Enterprise Administration, MOEA, ROC

It is with no doubt that SMEs have given the edge in terms of the employment, the flexibility, and the network that supply parts and components to those firms engaging in exports[28]. However, the recent trend shows that in the burgeoning electronics industry, the businesses have grown from small to big in a very short time period (ramp-up) and have acted as the most progressive and developmental force (Amsden and Chu, 2003). In year 2002, the government passed the "Mergers and Acquisition Law" to provide a legal ground for enterprises M&A, implying that the government's attention to the vantage of big businesses in the aspects of economies to scale and innovation capabilities.

4. Government's heavy interventions were followed by liberalization.

Historically, Taiwan government intervened massively through public policies. An important lesson here is that it also lets go those interventions in time, roughly speaking, either because it had no choice or it was on its own initiative. For instance, for the former, under the WTO regime, those trade policies aforementioned can no longer be implemented;

[28] SMEs themselves surely export, but the share was only 20.65% in 2001.

on the contrary, and also for the latter, Taiwan's affiliation to the WTO was also the government's endeavor. In fact, before that, the tariff rate was reduced enormously; so was the share of items under import control – 46% in 1956 to 3.1% in 1981 (Tsiang and Chen, 1984). Since the 1980s, liberalization[29] has been undertaken by the government (Chu, 2001). Unleashing the existing regulations on foreign investments to usher the necessary technology into domestic arena in the phase of high-technology industry formation was one; opening the monopoly market to increase competition was another; privatizing SOEs in order to increase their competitiveness in the late 1980s and early 1990s was another one. A series of liberalization was enforced one by one by the government. The early heavy interventions has provided the ground for the initial development of national firms, protecting them from foreign competition, and the later liberalization has given the firms imperatives and incentives to increase their own competitiveness after squaring off.

From a historical perspective, Taiwan government has imposed a lot of regulations and interventions to foster the growth, which digresses from the conventional wisdom – the neoclassical economic theory. However, from a dynamic perspective, government's interference was followed by liberalization. Hence, it is very important that in the initial stage of development where market failures prevails over government failures, the government should give considerable help to initiate the growth, whereas it is also the government's call to decide what and when to let go. Nonetheless, it would be far-fetched that the government should act as the role what "the invisible hand model" has suggested after the liberalization, instead, the government should monitor and overhaul the liberalization process and continue exploring the new facets that the private sector is unable to foresee as well as unwilling to undertake, as long as the economic gap with those advanced countries hasn't been narrowed down.

6.2 Policy Recommendation

1. Eliminating unnecessary and costly repetitiousness in the policy formation

Having seen Taiwan's S&T development that was led by the government via S&T

[29] As defined by North (1991), Liberalization can be described as a type of institutional change led by the government.

related policies, one thing for sure is that the government matters for catching up from the underdevelopment to nearly developed status. Here, questions are arising: to what degree the government should intervene; and do smaller inputs from the government result in the same performance, in other words, if the government had not intervened so heavily, would the economic growth have been more significant than it has been so far? Questions of this sort are open questions because the history cannot be iterated with experiment of smaller government. Still, the questions cannot be answered by looking at the countries about the same size and similar development course, say Korea or Singapore, because no countries are exactly the same.

However through reviewing a number of S&T policies, though those policies have resulted in the stellar S&T performance, I would argue many things could have been more efficiently done. For instance, similar or even exactly the same action plans emerged in different polices. The repetitiousness is not only unnecessary but also costly. Moreover, new policy could come up with new initiatives and thus new agencies whose function could overlap some part with the existing agencies. The "NII Task force" created by the NII Development Plan in 1997 was one agency whose charge coincided with Information Development Task Force and Industrial Automation and E-Businesses Task Force under the Executive Yuan. Therefore, in 2001, another agency, National Information and Communication Initiative (NICI) was established in lieu of the original three agencies.

2. Upgrading human capital is more than enhancing the quantity of universities.

Human capital is the fundamental base of S&T development. As Romer (1994) observed the quality of the labor force was the main force affecting technological advancement and economic growth. Chapter 3 has shown the government's efforts to upgrade the education – reducing illiteracy rate from the outset to the recent higher education reform. The quality of human capital has improved tremendously due to the continuous emphasis mentioned almost in each S&T policy. However, higher education reform should not simply focus on the increase of the quantity in terms of college graduates and the number of higher education institutes. The quality of the higher education should be indispensable. At the same time when the government expands the number of colleges and universities, it should also consider the capacity that operates in coordination with the expansion: the faculty recruitment, the facility, the application, the monitoring mechanism, and so on to have more as well as well-trained graduates.

In addition to the higher education in the home country, the students study abroad are also an important source of human capital. More importantly, those reverse brain drains are the main source of technology acquisition of the domestic firms. Table 6-2 shows the survey done by interviewing the firms in Hsinchu Science-based Industrial Park. The top rank returnees' contribution is that the returnees have strong R&D capabilities and are able to provide suggestion for other employees in R&D work. Equally important is the returnees' connection with the foreign experts and the network they form when they are abroad. An example is that the returnees keep in touch with their classmates or friends working in the Silicon Valley, and whenever there is new products innovated or will be large produced, the returnees will get the information and strive to prepare the capacity to produce the parts and components that the U.S. firms are going to subcontract before the U.S. firms virtually produce the products. And once they are ready, they get the more opportunities than other competitors in the latecomer countries.

Table 6-2 Returnees' Contribution to Technology Acquisition

Area	Number	% of sample[1]	Ranking
Returnees have strong R&D capabilities and are able to provide suggestion for other employees in R&D work	50	86.21	1
The leadership and coordination provided by the returnees make the projects successful	29	50.00	2
Returnees are able to use their overseas contacts to establish channels for technology exchange with foreign companies	22	37.93	3
Returnees help solve R&D problems through their contacts with overseas experts	21	36.21	4
Returnees help arrange exchange between domestic technical personnel and overseas experts	18	31.03	5
Returnees know which overseas laboratories can help the company with its R&D work	14	24.14	6
Returnees make use of their contacts overseas to help the company arrange overseas financing	1	1.72	7

Note: 1. Sample size is 58.
Source: San and Su (1999).

However, the government has been putting relative little attention on the abroad study.

Compared to Korea and Singapore, Taiwan government funded relatively few numbers of students. In 1998, the total number of the students funded by the government was 150. And the programs that systematically recruit foreign Taiwanese graduates are really scarce. Therefore, in the earlier decades, the students went abroad at their own expenses and most of them stayed in the countries they went. Only a few went back in most part because of the career ceiling for foreigners. In the recent decades, more returnees went back because of the macroeconomic environment and the favorable working opportunities, but by no means the government's recruiting program, with a few exceptions. Given that the returnees' importance for the domestic firms' technology acquisition, the government should make a new reform on the abroad study.

3. Government should enact policies that facilitate big businesses formation

Although SMEs confirms with the ideal ideology of neoclassical theory, they are unfavorable to the functional, technical, and managerial capabilities as well as organizational learning (Chandler, 1997) and are unable to enjoy the economies of scale and increasing returns to scale. SMEs' prevalence in Taiwan was promoted by the government on one hand; and was autonomously formed by the private sector because it is easy to start up in terms of small capital requirement and the market barriers are low. The situation sustained for decades, for M&As are not common[30] in Taiwan. Under this circumstance, the S&T development has been heavily relied on the dense network of those flexible SMEs specializing in subcontracting and trading services. Network is no doubt a good way to compensate the meager capabilities and resources each SME has. However, S&T development, such as innovation and brand name creation, needs more than that: it needs coherent planning and steady, long-term investment, and competent managerial capabilities, all of which are more likely to be done by big businesses.

Though in 2001, the Taiwan government promulgated the "M&A Law", implying the government's attention toward legal ground for big businesses formation, more efforts should be made. In virtue of the enterprises in Taiwan perform poorer in brand name

[30] Most of the Taiwanese SMEs would rather let their own firms die out if the business is going bad, than sell them out. There is a saying: "I would rather to be the head of a cock, than to be the tail of a cow."

creation and marketing. The government should intervene more in these two facets. As Amsden and Chu (2003) mentioned in their book, the resolution lies in innovation and "mass" marketing, because without the former, it is difficult for a company to establish its own brand name, and without the latter, the unit costs of innovation are prohibitive. And due to the cultural and language similarities, the arena will be based on the large China market. Once the brands create their own reputation and recognition, the profits will enhance the companies' innovation capabilities to make adjustments on their products and marketing to sell in the global market. The government can give a helping hand in the initial period of innovation cum mass marketing. Given its experience in high-technology firms and technology spin-off, as shown in Chapter 4, the same model can be applied in here.

4. Government should strengthen the entrepreneurship and innovation and reinforce national innovation system.

Overall, the growth of the S&T performance is rather satisfying, yet the extent of the entrepreneurship and technological change stimulated by the S&T policies are sort of satisficing – merely met some standards. Something seems to be missing in the process of innovation and the formation of entrepreneurship. Three factors contribute to this gap: (1) the partnership between academia and the private firms are not rather weak. The research in the labs seems to be rather independent of commercial use and the faculty have relatively less affiliation with the private firms compared to the U.S.; (2) the government put too much emphasis on the semiconductor industry which is in the mature stage of product life cycle and the innovation in this industry mainly focuses on process improvement, rather than product or process innovation; (3) though the CEOs of private firms possess entrepreneurship, they are still rather unwilling to invest more in longer term and broader-issue projects that, in their minds, are not necessarily should be invested by themselves. In turn, the government's policies should adjust toward enhancing these aspects, by providing more incentives and prospects to the private sector as well as academia, so that the private sectors, the government and the academia will all participate in the process, forming a network, which is called national innovation system to facilitate and ferment innovation capabilities.

6.3 Conclusion

In this volume, I set out by reviewing the S&T policies in the historical timeframe, followed by specific S&T related policies implemented by various government agencies (Chapter 3). And then, I examine some S&T policies' effects to show their real influence on the S&T and list the evidence of the government's endeavor to initiate the S&T development (Chapter 4). Consequently, after the efforts done by the government, I show the productivity/competitiveness growth and S&T performance at both individual as well s national level in terms of input and output aspects and, more importantly, put Taiwan's efforts and results into the comparison with other countries, both the advanced and the latecomers, to see to what degree Taiwan's S&T have developed.

By way of conclusion, I would argue that Taiwan's S&T development has achieved a stellar performance and has contributed to its economic growth (although it is difficult to quantify its proportion). And this development is "led" by the government, for the state-led is a sufficient condition (but never a necessary condition) for any developing countries, for their status quo is in an inferior position in the global market. Facing the fierce global competition, the private firms without any government's assistance will suffer from uncompetitive plight[31] or will only compete in products that exploit the lower wage in these countries and will easily die out when the latecomer competitors compete with an even lower wage level. Consequently, at the national level, economies in different countries will diverge, namely the rich become richer, and the poor become poorer, as predicted by the new growth theory.

Here, I emphasize the word "led", as opposed to "developed" because the government is not panacea that can provide solutions to every developmental ailments. In fact, many cases show that the governments' corruption and inefficiency brought the countries to a situation beyond redemption. These cases are exemplified in a lot of literature – the book

[31] The developing countries firms, without government's intervention will face high costs in acquiring information, knowledge, and technology, and costly, prolonged, and uncertain learning processes in mastering their tacit elements under the assumption of market failures of them. These processes involve spillovers and interlinkages across firms and activities. (Lall, 1998)

"Markets and States in Tropical Africa" written by Bates (1981) is one. Nonetheless, the government's exertion can yet be regarded as a way of providing momentum to the stagnated economy.

Developmental course of this sort needs some luck. The state, though to some extent corrupt, should possess most of the objectives that are in concert with the social welfare; the political leaders, though particularistic and patronizing, should lead to a status of virtuous clientele[32]; and the developmental state, though sometimes inefficient, should have economic foresight of the future development.

6.4 Future Research

This thesis mainly gives a broad perspective to review the S&T policies along the timeframe, and see how the S&T development is under the government's efforts and how the S&T development gives the edge in Taiwan's economic development. Many other things can be done in further research.

S&T policies can be evaluated by a number of systematic methodologies: matrix approaches, including analysis matrices, decision making, and multicriteria analysis; systemic approaches including systemic analysis and dynamic modeling; and financial methods, including cost-benefit, ratios methods, risk profiles, and portfolio models; and so on (Capron, 1997). In this study, peer review and indicator approaches have been done. The other approaches are suggested in the future study.

Moreover, each policy and each performance evaluation deserve a more careful review. Hence, I would suggest that in the future study, the scope can be narrowed down by simply examining one aspect of the S&T development.

Finally, the attempts to use indexes and indicators to approach the abstract competitiveness are expedient and the global comparison is a good approach to scrutinize the extent of development. However, due to the time constraint, this thesis heavily borrowed the data of this sort from other studies – Wu and Lin, 2000 and Roessner et al, 2001. Therefore, for the future study, more sophisticated approaches should be developed

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[32] If patrons offer policies, public goods, an so on that benefit economic development, then eventually clients will become more independent from patrons, and economy will grow.

and updated data should be adopted to yield more precise results. And this will be a lot of work, and it deserves another thesis to develop and explore.

Appendix Investment Incentives and Benefits in the Hsinchu Science-based Industrial Park

1. Tax Incentives
   (1) No import duties are leviable on machinery, raw materials, fuels, supplies or semi-finished products imported by a Park enterprise for its own use, and the importer is not required to file for exemption from import duties.
   (2) The goods and services exported by a Park enterprise enjoy 0% of business tax and commodity tax.
   (3) For a Park enterprise, according to the "Statute for Upgrading Industries: the newly emerging, important and strategic industries stipulated in the Statute for the newly established science-based industries," a five-year period exemption from the profit-seeking enterprise income tax or the offsetting between stock price and individual investment may apply.
2. Protection of Investors' Rights
   (1) Foreign and/or overseas Chinese investors enjoy the same rights and privileges as local Taiwanese investors.
   (2) Foreign and/or overseas Chinese investors may have 100% ownership of a Park enterprise and launch joint ventures with the ROC government or local enterprises.
   (3) Foreign and/or overseas Chinese investors may remit their profits, capital gains and interests generated from their investments.
   (4) The ROC government guarantees that a Park enterprise funded by foreign or overseas investors would not be expropriated in 20 years if the foreign investors hold 45% or more of the enterprise's shares.
   (5) Foreign investor may remit their capital investment overseas in one time after the Park Administrations grants.
   (6) Local laws protect ownership rights and intellectual property rights.
   (7) A Science-based enterprise may engage in import and export activities related to its principal business, after the approval of the Park Administration.
3. Government's Participation in Investment
   (1) The ROC government may participate in an investment up to 49% of the total paid in capital of an approved investment project.
   (2) Agencies that participate in investment on behalf of the ROC government include:
   The Scientific & Industrial Development Fund and related Development Funds:
   The Development Fund of the Executive Yuan
   3rd Fl., No 2, Ai Kuo West Road, Taipei, ROC
   Tel: 02-2394-4305 or 02-2322-8348 (Business Department)
4. Capitalization of Technical Know-how

   The Park enterprises may commission public and fair third parties, which are approved and granted by the Board of Investors, to access the appraisal of the possessed technologies or technical know-how. The Park enterprises may apply to the Division of

Business Service of the Park Administration to issue new stocks or make modifications of new stocks after the sanction obtained at the General Shareholders' Meeting.

5. Capital Raising

   A Park enterprise may acquire capital through the assistance of "Taiwan Venture Capital Association". With 179 members, the Association holds discussions and seminars periodically and plays the bridging role between the Association and the Park companies.
   Address of the Association:
   Room 301, No. 142, Section 3, Min-Chuang East Road, Taipei.
   Tel: +886-2-25450075 Fax: +886-2-25452752
   Website: http://www.tvca.org.tw

6. Low-interest Loan

   (1) A Park company may apply to the Chiao Tong Bank for low-interest loan for equipment procurement or factory construction. The interest rate of the loan is 2.125 to 2.5% lower than the other domestic bank loans.
   (2) The amount of the low-interest loan may not exceed 80% of the purchasing price of the equipment, or 60% of the investment cost. The maximum period for refunding such a loan is 10 years, with three years of grace period.

7. Research and Development Encouragement

   (1) The Park Administration provides grants for innovative technology research and development activities undertaken by a Park company which has been duly registered and operating. The company must submit a comprehensive R&D project for the next 5 years. The company may receive up to NT$5 million of grant for each R&D project after approval. The amount of the grant, however, may not exceed 50% of the total project budget.
   (2) R&D expenses may be credited against income tax to certain amount.
   (3) R&D equipment is exempt from import duties.
   (4) Donation of R&D equipment is tax deductible.

8. Other related incentives

9. Other Incentives based on the Statute for Upgrading Industries:

   (1) The newly emerging, important and strategic industries, and technical service industries.
   The profit-seeking enterprise income taxes for the newly established industries can be exempted partly. The exempted profit-seeking enterprise income tax and its surcharges will not exceed the rate of 20% of stock prices for enterprise, or 10% for personnel (the rate is decreases 1% every two year since 2000).
   (2) The automation expenditure
   A company may credit 5 to 20% of the amount of fund disbursed for the fund invested in equipment for automation of production or production technology against the amount of profit-seeking enterprise income tax payable for the current year.
   (3) R&D expenditure

a. A company may credit at most 35% of the amount of fund invested in R&D and personnel training against the amount of profit-seeking enterprise income tax payable for the current year.
b. If the R&D expenditure of the current year is greater than the average R&D expenditure of the previous two years, 50% of the excessive amount may be credited against the amount of profit-seeking enterprise income tax payable for the current year.
c. Service life of instruments and equipment purchased by a company for exclusive use for R&D purposes, experiments, and/ or inspection of quality may be accelerated to two years

(4) Professional training expenditure
Same as the incentives of R&D expenditure

(5) To promote balanced development of industries in various geographical areas
In order to promote balanced development of industries in various geographical areas, if a company makes investment up to a specific amount of its capital or employs a specific number of employees in specific industries of a county or township area with scanty natural resources or with slow development, it may credit up to 20% of the total amount of its investment against the amount of profit-seeking enterprise income tax payable for the current year. (Chunan Site, the fourth phase of Science-based Industrial Park, is included).

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