

Industrial Development and Structural Adaptation in Taiwan: Some Issues of Learned Entrepreneurship

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Abstract— The industrialization of Taiwan has been a remarkable phenomenon. This paper discusses recent changes in Taiwan's manufacturing industries and the response of both government and private enterprises to the challenges presented by a dynamic environment and by global competition. Several cases are discussed in light of the activities and adjustments on the part of government and of the public sector, of small and medium business, and of high-tech industries. Government participation over the last four decades has been and will remain pivotal in economic growth and in achieving adjusted positioning. Taiwan's personal computer and IC industries have evolved from an infant stage through an accelerated growth period and are now extending to other technologically associated industries. The small enterprise sector is in a transitional stage of upgrading competitive niches. The unsuccessful stories of biopharmaceuticals and automobiles are discussed in terms of what they reveal about government intervention and the performance of public research institutes. Active patenting activities by Taiwan enterprises and public research institutes illustrate the accumulated technological capability found on this island. The accelerated sociopolitical movements toward democracy, the bureaucratic management of public issues, and the political and economic interactions between Taiwan and China, exert significant effects on the industrial structure and on government's role in directing the industrial evolution. This article presents an integrated reasoning of Taiwan's economic success. It reveals that the neoclassical doctrine of market efficiency is fundamentally valid, and that the effective commercialization of national technological capability has created Taiwan's industrial evolution. Market governance proved to be an efficient short-term policy instrument when the latecomer strategy of cost leadership was applied. A conceptual model of industrial competition and technology commercialization is also proposed to facilitate the methodological analysis. This study concludes that learning capability and human capital will determine the endurance of Taiwan's industrial success, and that entrepreneurship must be learned by the state, as well as by the private firms.

Index Terms—Entrepreneurship, industrial competition, intellectual property, market governance, structural change, Taiwan.

I. INTRODUCTION: LATE INDUSTRIALIZATION OF TAIWAN

THE East-Asia success stories of Taiwan and three other NIE's (newly industrializing economies), i.e., South Korea, Singapore, and Hong Kong, have been widely discussed for the pointers they may offer to the economic development of developing or less developed countries. Vigorous debates have centered on whether other developing economies such as in Southeast Asia, Latin America, and South America can

Manuscript received December 1995; revised November 1996. Review of this manuscript was arranged by Guest Editors J. K. Liker and D. V. Gibson.

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Publisher Item Identifier S 0018-9391(98)07744-7.

emulate the spectacular East Asia examples [1], [2], including whether and to what extent the four tigers themselves have applied shared or differing strategies during their respective evolutionary process, or generic foundations for their success may be identified. Governmental participation, technological capability, export orientation, and human resource development have all played continuing critical roles in economic development.

Following the rapid economic growth of the last four decades, Taiwan is adjusting to its imminent developed country status with different industrial patterns. Nonetheless, economic growth is not isolated. Social changes and emerging democratization have accompanied and affected the structural changes in the island's industries. Published macroeconomic and political aspects are generally discussed for the economic development implications in the island's past. The lack of discussion on the entrepreneurial adaptation of Taiwan to the changing environment calls for a description in terms of state and the private sector's activities.

Although the appropriateness of certain embedded assumptions in economic theories has been disputed, especially as to what role the state plays in the course of economic development, the general consensus is that free trade or market competition is, in the long run, the fundamental and indispensable constituent for healthy, continued growth of industry [2].

This study aims to demonstrate that underpinning the entrepreneurial process has greatly facilitated the industrial development, namely, the state small and medium businesses (SMB's) and certain high-tech industries. Since SMB's constitute more than 96% of Taiwanese business concerns, they have been regarded as the foundation for economic growth. High-tech industries are considered for their prominence in highly added values and as the core of global competition. Of course, government as one of the leading movers in economic development cannot be neglected regardless of what the size and the status of a nation may have been, a consideration which remains just as valid, if not more so, now and for the future.

II. HUMAN CAPITAL-LED EVOLUTION AND ENTREPRENEURSHIP

Human resource is the impetus for industrial growth in the early stages of development and an indispensable asset for sustaining competitive advantage. Lucas [3] reviewed economic growth models for the United States, highlighting the effects of accumulating human capital. The result of a human capital-driven formulation is much more compatible with real-world variation than the standard neoclassical growth formulation.

Human capital externalities and differential learning-by-doing in different products are central to his adaptations of neo-classical models. The externalities of positive growth result from high payoffs in terms of high-level investments in human resource growth. Romer [4] developed an equilibrium growth model of endogenous technological change in which growth is driven primarily by accumulating knowledge. He also pointed out that the central role of human resources in the development process. An active policy favors human resource investment and may yield social payoffs because of the externalities and increasing returns associated with such investments.

Lee and others [5] analyzed Taiwan's economic growth using an econometric model and concluded that human capital evolution has been the most influential element driving growth. Tallman and Wang [6], in a case study of Taiwan, also examined the empirical implications of models that display perpetual growth through human capital accumulation. Their results support the theory that labor skill provides a useful adjunct to the raw labor measure that enhances the performance of the Taiwan growth model over the 1965–1989 period.

While entrepreneurship may not be a well-defined aspect of human behavior, it constitutes an important underpinning process for economic development as well as for pursuing achievement in dynamic environments. The terms “entrepreneur” and “entrepreneurship” have been mentioned for more than two centuries. It was not until the last two decades that they have become interesting subjects and have called for extensive studies among academic communities [7]. Changing political, social, cultural and economic environments worldwide have provided the impetus for spawning entrepreneurship.

Drucker [8] defined entrepreneurship as the attitudes and actions required to “search for change, respond to it, and exploit it as an opportunity.” In other words, to manage change. Porter [9] proposed the “diamond” determinants by which a nation achieves international success in a particular industry. He added the role of government and chance as two more variables completing the system's concept, and he further commented to the effect that “invention and entrepreneurship are the heart of national advantage, and neither entrepreneurship nor invention is random.”

The continuous process of industrial evolution and associated time-dependent events and activities, as well as constant change in social, political, cultural, and economic environments, necessitate an entrepreneur capable of integrating resources to cope with the cycles or discontinuities. The definition of entrepreneurship adopted herein is “the integrative capability of exploiting change in dynamic environments.”

III. THEORETICAL AND ANALYTICAL FRAMEWORKS

As this paper illustrates Taiwan's industrial development with empirical and macroscopic views, the following interrelated questions arise.

- 1) Why are Taiwan's economic systems successful at resource allocation? During the last 40 years the international community has not discerned either a democratic society nor an open domestic market in Taiwan.

- 2) What factors determine the supply of entrepreneurial talents? What institutional arrangements facilitate the exercise of an entrepreneurial economy?
- 3) How are entrepreneurial talents allocated to justifiable tasks? Where is the right track? When is the right time to implement strategies and take action?

Addressing these issues requires a structured and theory-based framework. This article proposes a conceptual model that integrates and modifies the technological capability approach [2], the technology commercialization process [10], and market governance theory [1] to analyze Taiwan's industrial evolution. Examples from among Taiwan's industries illustrate the theoretical exposition.

The analytical framework is facilitated by a conceptual model of industrial competition and technology commercialization. Lall [2] studied the development of East Asian NIE's and presented a technological capability approach as the underpinning mechanism for their success. Rosenberg *et al.* [10], after analyzing the interactions between economic growth and technology development, concluded that technology commercialization, rather than technology *per se*, determined industrial success. Effective managing technology commercialization is the critical path for international high-tech competition. The commercialization process is highly investment-augmented and technology-intensive and represents far more than merely the inputs and performance of a country's R&D activities. Instead, it is a system comprising the mechanism of entrepreneurial activity applied to developing and integrating many interactive aspects of technology, finance, and human capital.

This conceptual model consists of product markets, competition patterns, and factor markets (Fig. 1). The factor markets consist of the production factors considered critical for the industrial competitiveness of a firm or a nation. The term “markets” employed for the input factors denotes that competitors look for optimum or accessible combinations of their production factors from global markets. The competition strategy and value chain activities of an organization are determined by the product markets as the demand side and production as the supply side.

Governmental policy measures and performance significantly impact industrial development. State activities may be viewed as participation in constructing production that adds competitive advantage, or as intervention where the market function is directly regulated by the state. The effectiveness and efficiency of governmental policy instruments are contingent on the strategic positioning of industrial competition.

On one hand, in the short run a developing country with skilled engineers and cheap labor may intervene to protect the domestic market and promote exports of low-cost manufactured products. On the other hand, competition in highly value-added industries requires proficiency of tacit knowledge learning and technological leadership. A dynamic implication arises that industry evolution processes are time-dependent strategic visions and tactical activities.

In this model, the factor markets include technology, labor skills, finance, and physical infrastructure, as well as local and foreign suppliers. They are divided into physical capital and human capital with further financial implications. As-

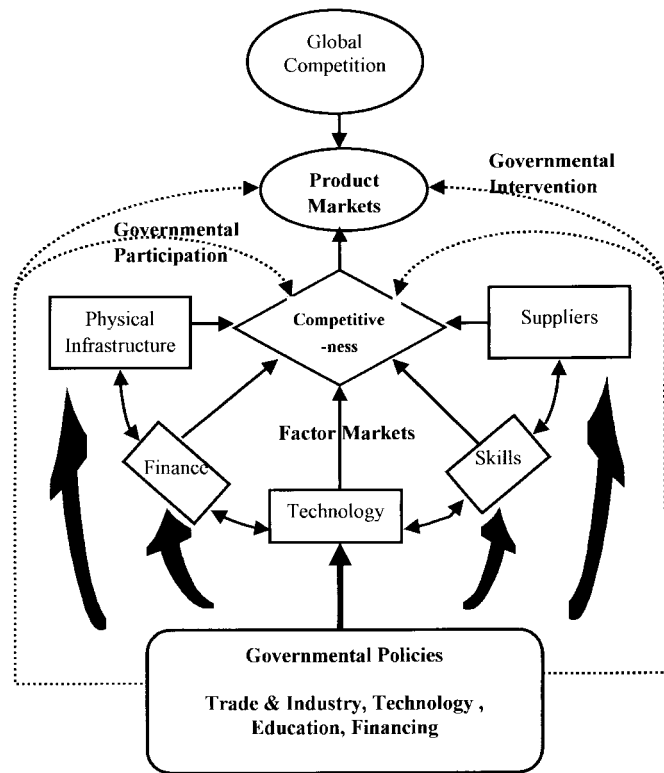


Fig. 1. Structures of industrial development and governmental roles.

sessing the factor inputs and performance with quantitative information has been a common benchmark of a nation's competitiveness. The behavior of a firm is not displayed in Fig. 1; however, the entrepreneurial skills of integrating resources and exploiting change are embedded and taken for granted in the conceptual framework.

The analytical foundations of this paper are constructed on: 1) product market demands; 2) factor market supplies; 3) competitive strategy; 4) governmental leadership; and 5) the dynamic contingency of industrial systems.

IV. POWER AND INFLUENCE OF THE TAIWANESE STATE ON INDUSTRIAL DEVELOPMENT

Taiwan's economic growth may be roughly divided into five stages:

- 1) reconstruction after World War II and the Civil War, from 1945 to 1952, during which period the government reformed land policy and raised agricultural productivity;
- 2) import substitution, from 1953 to 1960, when labor-intensive light industries were developed and domestic markets were fully protected;
- 3) export orientation, from 1960 to 1973, in which accelerated economic growth occurred by exporting more light industrial goods than agricultural products;
- 4) structural changes in industrial sectors, from 1974 to 1984, wherein two energy crises accelerated the pace of industrial transformation;
- 5) economic liberalization, from 1985 to the present, during which time the rise in labor wages, social mobility,

and enhanced conflict between laborers and employers, the appreciation of the new Taiwan dollar (NTD), and Taiwan's higher profile in the international community all contributed to Taiwan's industrialization.

Generally, governmental participation or intervention has been significant in the development of all NIE's. The government of the Republic of China (ROC) on Taiwan is no exception in terms of directing industrial orientations and in participating in the development of specific industrial sectors. During the 1960's and 1970's, certain general incentives were offered in the form of interest rates. Stable real exchange rates, duty drawback schemes for imported items, and credit allocation systems that favored exporters provided general or functional incentives.

Governmental planning and participation were initiated during the 1950's and are continuing. The first of six Four-Year Plans began in 1953 and, successively, Ten, Twelve, and Fourteen National Projects were implemented in the 1970's and 1980's. In 1991, a Six-Year National Development Plan was launched. Most of the national programs have included definitive objectives for targeted industrial development, as well as generic functional incentives. The policies and determinations of the ROC government have provided valuable information and significant guideposts for industrial growth. The government has contributed to development in many ways. Emphasis on education and training, particularly in engineering fields, has effectively paid off. Some other prominent examples of government intervention have been establishing industrial parks to put in place appropriate infrastructure and public research institutes to nurture technological expertise. Such intervention includes the skillful macromanagement of economic growth, inflation, and unemployment, especially during the 1960's and 1970's.

Institutional arrangements and the wielding of state power in Taiwan create its own pattern of authoritative guidance [11]. In comparing the nature and extent of governmental intervention between Taiwan and South Korea, South Korea is considered more directly involved in setting the goals and assessing the performance of major industries and firms. The ROC government has played a predominant role in coordinating the fragmented structures of industries. Industrial projects regulated by the Korean government have proven to be much more aggressive and ambitious. Furthermore, before the 1990's, the ROC government consistently opted for direct state ownership and joint-ventures with state equity participation as an alternative to large nationalized firms. This situation may account for ROC governmental spending on national R&D exceeding 50%, while for most technologically advanced countries, the figures range from 15%–30% [12].

In Taiwan, the state's drive for industrial upgrading has been incremental, selective, and confined more to the state-enterprise sector. Support for private-sector industrial adjustment has been largely limited to a discretionary use of structural incentives and focused R&D. The majority of Taiwanese private concerns tend to ignore official guidelines unless they adhere to their business interests. This is particularly true at present when democratic progress and social awareness

over human rights and environmental protection are on a dramatic increase.

V. DEVELOPMENT OF HIGH-TECH INDUSTRIES IN TAIWAN

The development of Taiwan's high-tech industries may be traced to the 1960's, or even earlier. However, its nascence cannot be understood without referring to the establishment of the Industrial Technology Research Institute (ITRI) in 1974 as the national center for promoting industrial technology, and the Hsinchu Science-Based Industrial Park (SBIP) that was launched in 1980 as a cradle for high-tech enterprises. Taiwan's government sponsored both of these undertakings.

SBIP facilitates a single point of contact that simplifies the administrative procedures deemed necessary for firms to operate, e.g., customs' control of goods, tariffs, financing, and employment. Only high-tech firms are admitted to the science park where they are provided with attractive infrastructure, such as offices and warehouse buildings for lease, tax incentives for investment, and housing and schooling for employees. As of 1994, the government spent 500 million USD's (U.S. dollars) on land purchases, building construction, housing, and school construction.

Six major industries are accommodated in the SBIP: personal computers (PC's) and peripherals, semiconductors or integrated circuits (IC's), telecommunications, photoelectric products, precision machinery, and biotechnology. Among these, the computer and IC concerns constitute more than 80% of the total value of products, which was close to 6.7 billion USD's in 1994.

Taiwan's high-tech industries concentrate primarily on PC and IC enterprises. Before 1994, computer and peripherals generated the largest product values of the SBIP, at which point the IC industry took the lead amounting to 3.1 billion USD's. This figure represented 47.3% of the Science Park's total output.

Development of the IC industry constitutes a remarkable success in governmental policy and industrial collaboration. In September 1974, the Electronic Research and Service Organization (ERSO) was founded under the auspices of ITRI as a research unit focusing on developing electronic technologies. ERSO has since survived to constitute the outstanding success stories of Taiwan's semiconductor industry.

Other initiatives were taken in the early 1970's, when textiles represented Taiwan's leader in export values. However, when faced with growing international competition and trade constraints, the ROC government foresaw the limits of Taiwan's natural resources and local markets. The accumulation of human capital reached the point of needing new start-ups. The fully government-sponsored project successfully transferred foreign MSI (medium scale integrated circuits) technology and constructed a demonstration factory at ITRI. This facility and its skilled engineers were eventually spun off as the United Microelectronics Corporation (UMC) in 1980, a year after Science Park was founded in 1979. ITRI then launched into LSI (large scale integrated circuit) technology in the early 1980's and formed another IC design company.

When semiconductor technology in Taiwan reached the level of VLSI (very large scale integrated circuits) in the mid-1980's, ITRI again provided a mask manufacturing factory and a common design service center. The Taiwan Semiconductor Manufacturing Company (TSMC, to be discussed later), a number of IC mask supply companies, and more IC design houses then appeared in the science park. As of the 1990's, the ULSI (ultra large integrated circuit) project followed this well-grounded model and the Vanguard International Semiconductor Corporation producing the DRAM (dynamic random access memory) was established in 1994. Vanguard inherited a staff of 326 managers, engineers, and technicians directly transferred from ITRI. Since the 1980's, the gaps in catching up with the most advanced IC technologies in the world have been significantly reduced, and Taiwan now ranks among the top performers for wafer fabrication globally.

TSMC was formed as a result of government initiatives with a view of creating a world-class firm that would raise Taiwan's semiconductor industry to the level of VLSI. It was part of a fundamental strategy to institute a private company, i.e., no more than 49% of company shares was government investment. 70% of capital had to be owned by nationals to counteract any possible loss that, in the early years, could have resulted from withdrawals of foreign investors. In 1987, TSMC was officially registered with a capital of 14.5 million USD's: government investment (48.3%), Phillips of Netherlands (27.5%), and public shareholding (24.2%). The competitive advantages that distinguish TSMC in the IC industry are the uniquely focused manufacturing, high yield ratio, and quality control. In 1993, sales were 760 million USD's with a net earning ratio of 43.8%.

The development of Taiwan's information industry was another targeted policy. However, unlike IC, the information industry faced severe domestic and international competition. It also involved more private entrepreneurship than direct government involvement, particularly in the PC sector. Taiwan's government provided R&D projects mainly through ITRI to develop hardware and communication technologies, established the Institute for Information Industry predominantly to develop software and to supply market information, and motivated generic incentives such as financing and tax.

Taiwan's PC industry began in the early 1980's by imitating the Apple and IBM PC's. Manpower supply and capital investment in this business were much less stringent than that of IC manufacturing. Taiwan's PC firms were capable of producing IBM PC compatibles after 1984. Two years later, technological independence was nearly achieved in the field of compatible IBM PC/AT. Since then, Taiwan has gradually attained the position of industrial leader, and original equipment manufacturing (OEM) has evolved into design or brand manufacturing (ODM or OBM). ACER, the largest and globally known PC-manufacturing company and conglomerate, is a typical case of Taiwan's evolution of the information industry.

Taiwan's high-tech production and investment has taken off at full throttle. As of 1995, ACER became the largest manufacturer in Taiwan, where the top ten places among manufacturing firms had been occupied traditionally by major

heavy industries such as plastics and cement, which emerged in the 1960's. Expansion in the PC and IC industries and other high-tech business, as well as in the considerable capital attracted from abroad and traditional industries, have reshaped Taiwan as a high-tech island. In the early 1990's, ACER, jointly investing with TI (Texas Instrument), formed the TI-ACER company to manufacture the DRAM. UMC also invested in thin film transistor-liquid crystal displays (TFT-LCD), which is considered the semiconductor industry of the twenty-first century. As for IC, it is estimated that by 1998 12 firms will be fabricating 8-in wafers in Taiwan, with a total capital investment of 10 billion USD's. TSMC, the largest IC OEM firm in Taiwan, expects to reach 40% of global production of 8-in wafers by then.

VI. PATENTING ACTIVITY OF TAIWAN

Patenting activities have greatly expanded in Taiwan in recent years. After having been accused of violating intellectual property rights for a decade, mostly by the United States, Taiwan is pursuing a firm intellectual property campaign and cleaning up her international reputation. The United States has been Taiwan's major export market for decades and patents are frequently filed to the USPTO (U.S. Patent and Trademark Office) for legal protection. Taiwan rose from 11th in 1989 to 8th in 1993 in terms of total patent counts and quality [12]. The United States, Japan, and Germany are far ahead in advanced technologies, with Taiwan lagging behind, yet it is in a very competitive status with France, Britain, Canada, and Italy. Furthermore, Taiwan, led by the United States and Japan, is ranked third in terms of information technology patents. Much emphasis has been placed on gaining patent rights both for the public research institutions and private industries. For UMC, for instance, the tally for patents has increased from 22 in 1989 to 341 in 1994, and it has accumulated with an annual increase of 520 in 1993 and 690 patent filings in 1993 and 1994, respectively. ITRI, conducting quality control on effective patenting, added more than 2000 patents to their technological assets over the last five years with an annual increase of 300–400 patents. ITRI has taken the lead among Taiwan's high-tech firms in international cross licensing with multinational companies such as American Telephone and Telegraph (AT&T).

The Central Standard Bureau, the government office with patent applications and approval as part of its assignments, recently announced their intention to facilitate the commercialization of patents in addition to improving the administrative quality of patent discretion. According to their statistics, only 15% of issued patents in Taiwan were licensed or applied for industrial use, which is markedly less than Japan's figure of 70% and even lower than mainland China's of 22%.

As mentioned in the preceding paragraphs, Taiwan's government has sponsored more R&D than the private sector. Research projects are distributed through various government and public agencies, while the intellectual property generated from this research is assigned to issuing agencies, as the National Properties Act stipulates. Fragmented ownership and inconsistent patent management in different agencies call for

a national policy on integration and effective licensing for industrial use, or for assigning patent rights to inventors for further application. Ongoing tasks, such as setting up a national center for patent management and revising administrative regulations for more industrial access to the patents owned by government agencies (a policy similar to the U.S. Technology Transfer (Bayh–Dole) Act), aim to achieve more effective and efficient commercialization of public research.

VII. TAIWAN'S AUTOMOBILE INDUSTRY: A CASE OF GOVERNMENT FAILURE

For neoclassical economists, Taiwan's experience in developing an automobile industry serves as a textbook example of government failure. A benchmark comparison made by Chu [13] delineates that both Taiwan and South Korea made initiatives in the early 1970's to develop an automobile industry. Fifteen years later, the industrial structures in the two countries were entirely different. By the late 1980's, automobiles had become one of Korea's leading export sectors while Taiwan had become only a major supplier of auto parts and of minor mechanical components. The ROC government has imposed a very high protection rate on automobile manufacturing with high import tariffs, levied import restrictions and a local contents requirement, a purchasing policy for domestic automobiles, and restrictions on setting up factories [14]. Until recently, Taiwan's automakers have remained small in scale and were forced to import major components. The public has been paying unreasonably high prices for automobiles. Private manufacturers of auto parts and components, most of them small- and medium-sized firms, have made considerable gains with an increased presence in international markets. Overprotection and excessive state intervention for automakers under the policy of import substitution have left Taiwan's automobile manufacturing in a position of assembling, rather than making cars, and of directing efforts toward dividing up existing local markets.

VIII. BIOTECHNOLOGY AND PHARMACEUTICALS: INDUSTRY AND RESEARCH

Biotechnology development in Taiwan illustrates another type of failure that is caused by a lack of linkage between industry and public research. After more than a decade of endeavors and investments, Taiwan has failed to commercialize its biotechnology.

Biotechnology is one of the most promising advances in human knowledge, whether applied in agriculture, medicine, special chemicals, pollution control, food production, or energy. The recent industrialization of Taiwan evolved out of successfully reforming an agricultural economy. The island is still engaged in upgrading agricultural technologies to advanced international standards. Flower and fruit growing and aquaculture are examples that distinguish Taiwan as an exporter of agricultural technology. The biopharmaceutical field, however, is a failure.

Taiwan's pharmaceutical industry is in a primitive state and dominated by SMB's with scarce R&D investment. In 1994, there were 287 drug-manufacturing firms in Taiwan,

and among them 229 were licensed with the official Good Manufacturing Practice (GMP) certificate. The average capital investment per firm was estimated at merely 250 000 USD's. Nearly three quarters of the firms registered capital investments of under 2 million USD's.

The structure and characteristics of pharmaceutical production requires long periods of time and an extremely large investment of R&D before a new drug is safely marketable. It is estimated that, on average, a new drug costs more than 200 million USD's and takes 12 years to develop. As a result, patent protection is much more critical for drug-making than for other fields of technology investments.

In Taiwan, entry barriers against manufacturing pharmaceuticals in terms of technological accessibility were largely removed by government policy and the patent law. Regulations issued by the health department did not require clinical tests if imported drugs were not regarded to have new constituents or new applications. Moreover, before 1986, local drug-producing firms could legally take advantage of products and processes developed or even patented in foreign countries. This was due to the fact that medicine was not granted patent rights before Taiwan's Patent Law was amended in 1986. The revised act prevented the "free lunch" of obtaining drug technology, and in 1993 a new drug monitoring system was further implemented. Currently, local clinical tests must be conducted and approved before an official certificate can be granted for any drug with new constituents or new applications. Local tests must be conducted and a safety report submitted even if the product patent is expired. In 1994, a new patent law replaced the old act and encompassed legal rights for micro-organisms. These considerable changes created enormous difficulties for drugs manufactured in Taiwan to compete in quality and price with imported products.

The global pharmaceutical industry is oligopolized by a few transnational firms with massive capital and investment. The physical assets of some of these firms exceed those of most developing countries. High R&D spending and well-structured frameworks of vertically integrated value activities characterize the industry's competitive pattern. Moreover, upgrading safety standards calls for rapidly growing R&D expenditures on sophisticated equipment and laboratories and on highly skilled professionals. Strategic alliances among public and private sectors, as well as between companies, and the merger and acquisition of firms have resulted in fast-paced management of financial and technological needs. Strategic implications, on the basis of biopharmaceutical development, reveal that the segmentation and focused niche of value activities must be carefully and clearly identified as a starting point for developing industry and technology.

In the biotechnical field, the government of Taiwan had the foresight to begin developmental planning in 1982. Biotechnology was listed as one of the eight critical technologies for national development. A nonprofit research institute, the Development Center for Biotechnology (DCB) was formed to carry out research for developing industrial technology. During 1985–1989, the first four-year project was contracted to the DCB by the Ministry of Economic Affairs. Twenty-eight million USD's were spent and 785 man-years were allocated to

research projects. The second four-year project was continued from 1989–1993 with 50 million USD's.

The above programs demonstrated the limits of pure research without matching industrial needs and positioning. Technology commercialization was not thoroughly considered at the early stage of planning, and this resulted in misuse of research resources. Only until recently, basic research remained independent in the associated departments of universities, colleges, medical centers, and the Academia Sinica, a national organization for basic research. The ROC National Science Council provided for and supervised the basic studies and offered 640 million USD's in research funds in 1995, five times the research expense for biotechnology in 1985. The Department of Health assigned various projects among hospitals and academic institutions.

Scientific research and technological developments during the past decade have not constituted a solid foundation or competitive products sufficient to overcome entry barriers for producing biopharmaceuticals. Although some Taiwanese academic researchers claim that Taiwan's performance in biomedical research has been internationally recognized, the following drawbacks are apparent.

- 1) Industrial infrastructures are still fragmented, and an appropriate strategy has not been executed for developing industrial technologies. Unable to define a clear commercialization goal and subject to dispersed R&D resources, the industry has failed to manifest appreciable outputs. Unfortunately, the concept of the linear development model of science and technology (namely, the top-down linear sequence of basic research, applied research, development, prototype production, and scale-up mass production) was firmly adhered to by certain leaders of research or development institutes.
- 2) The gap between academic research and shop floor production provides little incentive for academics to advocate the industrial use of advanced knowledge. Biotechnology policy emphasizes research more than specific products or the industrial technologies that are targeted for commercialization. Networks among the technical and commercial communities have not been formed. Small pharmaceutical firms in Taiwan are not capable of rising to international competition.
- 3) Government participation and integration were not as effective as in the IC industry. This may have been caused by the fundamental differences between the industries in terms of safety and R&D requirements, the approval process of new drugs, and the levels of technological advancement. However, the undefined industrial goals, the dispersed research spending, and divergent authorities spread among the bureaucratic systems, have led to research institutions concentrating efforts more on splitting the research money rather than on sharing the mission.

Reorientation of biotechnology development has been called for and industrial niches must be set. It is planned in the following five years that the horticultural flowering, animal vaccines, biopesticides, material drugs, medical test kits, and

new drug forms are to be developed under national auspices. Producing biopharmaceutical products is now viewed as a long-term project and will start by building necessary infrastructure, such as a center for experimental animals. The DCB is also seeking funding for a prototype plant for mass producing enzymes.

IX. EMERGENCE OF TAIWAN'S SMB'S

Taiwan's SMB's have grown more rapidly than the nation's overall pace of economic development. The boom in SMB's occurred during the 1970's, and it has played a predominant role in Taiwan's export trade. The growth and evolution of Taiwan's small enterprises reflect an accurate picture of a free market economy. SMB's are rarely protected by the government, and most compete in international markets. Their emergence is associated with Taiwan's socioeconomic environment, education, and traditional value systems. Self-interest is the impetus creating the multitude of Taiwan's SMB bosses. The main incentives are as follows: 1) the status and fixed salary of an employee do not satisfy their egos, neither psychologically nor economically; 2) the prospect of inheriting a family-owned company or business; 3) dissatisfaction with original employers; and 4) extension of self-development after having accumulated years of work experience.

The poorly structured financial systems and conservative practices of financial institutions in Taiwan have not provided adequate aid to small businesses. The long-term ruling party Kuomintang (KMT) is also blamed for its close link with major traditional firms and its control of major financial institutions and investment channels in Taiwan. Before private banks were allowed in the 1990's almost all local banks were owned and controlled by the government. It is postulated and commonly believed that the transactions in the "curb market" (private channels for loans) have reached a significant value that may not be much smaller than the legal money market. Until recently, weak linkages with international financial markets, discouragement of short-term capital movement as well as long-term capital outflows, and long-term capital inflows are freely allowed only for targeted industries. All of these are factors that have characterized the underdeveloped features of Taiwan's financial systems, especially before removing the fixed exchange rates in 1978. Underdeveloped financial infrastructures aggravated the difficult environment in which small businesses aspired to gain financial assistance through legal channels in a capitalistic economy. Moreover, stringent lending guidelines and the personal responsibility borne by loan officers for bad debts caused a tendency in investment loans to go more toward large and public firms. Until very recently, the near absence of organized long-term lending to SMB's was the rule [15].

The advantages of being small are flexibility toward the strategic adjustment of company policy and cooperation, rapid response to customers, minimal transaction costs of internal communications and integration, and the ability to adapt to efficiently minimize legal, technological, and all other expenses. In contrast, apparent drawbacks of SMB's are less skilled employees, limited access to financing and financial

liquidity, minimal R&D investment, restricted information channels, and highly family and personally oriented, nonprofessional management styles. The survival of Taiwan's SMB's depends predominantly on entrepreneurial activities such as the following.

- 1) Interpersonal and business networks are firmly established. Small businesses form tight networks encompassing personal and business relationships. Traditional Chinese social values (typically male dominated), where human relationships are closely linked to families, relatives, friends, classmates, and previous colleagues, all prevail. Such networking not only relates to commercial activities but also to sources of information and financial aids.
- 2) The business linkage scenario that places a large firm at the center and small firms as the surrounding stars is termed a center-satellite system. Such systems are initiated and sustained by the division of labor as well as by competitive niches that generate net benefits over the transaction costs induced by cooperation and subcontracting among legally independent firms in Taiwan. Three generic types of center and satellite systems exist between small and large firms:
 - a) backward integration pattern, where the SMB's supply key or spare components to automakers;
 - b) forward integration pattern, such as the China Steel Company, previously a state-owned monopolistic enterprise, now under privatization that provides processed steel material to the SMB's;
 - c) forward integration of distribution, where a large central firm mainly conducts trade, marketing and channeling, and where SMB's produce, such as textiles with clothing.
- 3) Integrative ability of bosses in doing business. Seeking out markets and financing are two essential tasks for small business management. The picture of the boss bearing his sample products and flying all over the world in search of new markets is typical. Since most lack ample financial resources, it is common for them to tap family, friends, relatives, and even the "curb market" for loans. "Chasing 3:30 P.M." is a standard SMB term, referring to the rush to collect enough money to avoid returned checks before the banks closed at 3:30 in the afternoon.
- 4) Small enterprises seldom conduct in-house R&D. Official statistics for 1994 indicated that more than 90% of SMB's conduct hardly any technical research. Their technical advancements heavily depend on purchasing of new production equipment, hiring the qualified technicians, and skills learned from daily practice. Low-end products with well-known technical skills and cheap labor with sufficient technical education provided the competitive edge in international markets. Success is due to technical and vocational training implemented by the government in high school.
- 5) Direct investment in foreign countries. Investment in foreign countries began in the early 1980's and boomed in

1987 when the fixed exchange rate was abandoned and restrictions on capital outflow were gradually removed. Manufacturing industries made around 60% of the total investments. The increases in labor wages and more stringent environmental regulations are also indicators that Taiwan is moving toward a developed country. Nevertheless, Thailand, Malaysia, the Philippines, and Indonesia are the countries to which most direct overseas investment has flowed.

- 6) Linkages between Taiwan and China are tightening. Most of the trade across the strait has been conducted indirectly through Hong Kong. Two-way indirect trade totaled 2.7 billion in 1988 and about 16.23 billion USD's in 1994. From 1991 to February of 1994, the official statistics show that a total investment of 371 million USD's, representing around 10000 cases, emanating from Taiwan among business and individuals were invested in China. Manufacturing industries of electric machinery, plastics, food, metal products, and textiles constitute the majority (94%) of invested capital [16], [17].

X. LEARNED ENTREPRENEURSHIP OF GOVERNMENT AND PUBLIC INSTITUTIONS

Two opposite trends of contradictory aspects of Taiwan's economic development are displayed. On the one hand, the experience of Taiwan's success may partially contravert the assumptions and theoretical models of the neoclassical school. On the other hand, some cases provide perfect examples of the failure of government's intervention by visible hands.

Clearly, IC and PC industries have been successfully developed. Opposite examples are provided by biopharmaceuticals and automobiles. The lack of the impetus of technology commercialization, partially due to the inherent structure of Taiwan's pharmaceutical industry, as well as the misuse of resources arising from the misconceived linear science-technology development model, have caused biopharmaceutical development to remain in its embryonic stage after one decade's R&D investment. The automobile industry, on the other hand, is a typical example of government failure due to overprotection by high tariffs, local content policy, and price controls in local markets.

We conclude that Taiwan's government must learn not to intervene in market functions. We also need to learn where to draw a line for private sectors to take over or carry on targeted research programs. The IC program created the successful cases of UMC and TSMC, while the latest Vanguard case may require adjusting in the future. The maturing of Taiwan's IC industries allows the state to play the role of supervising fair competition, but not be a direct participant. Industrial research programs conducted by public institutions, to which most government funding for industrial research is allocated, need to reset their goals and performance for the purposes of technology commercialization. Targeted policy must correspond to private industries' directions. Moreover, the fundamental problem of targeted incentives by government funding, namely, picking the winner of the industry, has to be

resolved by merchandising the outputs of state-sponsored programs. Vanguard, a recently established DRAM manufacturing company that ITRI spun-off in 1994, provides an example of open bidding for government-sponsored research. As for SMB's and most other industries, government and public institutes can still supply valid channels for technology and market information.

Industrial technology laboratories must adjust their role as public research institutions. As with many other industrial research laboratories in the world, ITRI, for instance, has been spearheading the mission of transforming applied research into industry-oriented technology development. ITRI has acted as the industrial technology leader while receiving primarily government funding. Taiwan's IC industry is growing, private firms perform their own in-house R&D, and they outsource their technology from anywhere that it may be found. For example, the TFT-LCD development program was kept minimal since private firms were judged capable of undertaking product development by themselves.

Budget allocation for ITRI has become a contentious issue of Taiwan's legislature. Attention has also been called to the assessment of its performance in terms of technology transfer, product development, patents, and associated licensing of the other output of government and public research institutes. Whether or not the assessment instruments or their methodology is adequate remains debatable; however, the pressures on technocrats are obviously increasing. ITRI therefore has made a strategic transformation from a position of relying predominately on government grants to a ratio of incoming research funds shared equally between the government and private sources. Every dollar directly allocated to ITRI from government budgets must be matched by another from non-direct government funds. Although statistics have not yet proved that this guidepost has been reached, it does lead ITRI in the direction where its technical research and services are demanded by industry. Such strategic reorientation in most public research institutes is expected to lead toward more competitive research organizations.

When confronted with international pressures and opportunities to make strategic choices, the constraints on distinctive state structures to plan and develop programmatic national policy and the limits of the policy instruments available to intervene in society and in the economy become necessities for Taiwan if it is to play its role in the global village. The roles that government and public research institutes play need to be adjusted.

- 1) The state needs to change from being a participant to being a supporter in targeted industries, where research projects for developing strategic key components are still matters of public planning. Targeted R&D programs could assist the selected technology, and public research institutes could gradually adjust to earning their grants from the private sector. Also, government agencies now take into account royalties and open bidding for technology developed by government funding. Public expenditure in developing technologies now offers less prospect of a "free lunch." The income from technology transfer to industry from public research laboratories has

become one of the criteria for assessing performance. Projects such as biopharmaceutical development will not be conducted unless insurmountable entry barriers without government aids and profitable markets are justifiable in the long run. Public enterprises, most of which are monopolies in the home markets, are in the process of privatization where company shares are open to the public.

- 2) The state's role is best served as an architect of physical infrastructures and human capital. For example, emphasis will continue to be placed on improving education and training systems, supplying electric power, water, competitive telecommunications, and internationalizing financial and monetary markets. A Six-Year National Development Plan has been launched to achieve the status of an advanced nation. The modernization program was budgeted with 223.7 billion USD's. Its major aims are upgrading the national quality of life, raising national income, and facilitating improved structures for industrial modernization. The national goals of 21st century are to become the Asia-Pacific operation centers of R&D, manufacturing, financing, telecommunications, culture, media, and sea and air transport. As for small and medium enterprises, more practical policy instruments and open channels are necessary for their financial needs.
- 3) The state acts as the negotiator for international recognition and status. Taiwan has not yet gained general acceptance of its status as an international legal entity due to the political stance of China. Taiwan's remarkable economic achievement constitutes one of its very few assets with which it may distinguish itself from other developing countries. Taiwan contains only 0.4% of world population but shares 2% of global trade in monetary worth. To win participation in the international community, the government has conducted a pragmatic diplomatic policy for more than a decade. Participating in the World Trade Organization (WTO) is crucial to Taiwan's industrial growth.
- 4) Modern industrialization of Taiwan has encountered the following challenges:
 - a) evolution from human capital and skills to technology- and knowledge-intensive competencies;
 - b) diversified niche markets of scope and scale economies, and national advantages evolved from comparative-competitive advantages to cooperation-competition advantages; effective networking management of technological resources of the state calls for administrative efficiency to be evaluated;
 - c) falling behind in global competitive benchmarks in terms of the lack of full liberalization and internationalization, insufficient physical infrastructures, and prevailing administrative inefficiency.

XI. MODIFIED ECONOMIC THEOREMS OF TAIWAN'S INDUSTRIALIZATION

Empirical descriptions with regard to the recent industrialization of Taiwan pose apparent challenges to basic economic

development theories, especially the neoclassical school of free-market competition. According to that school, government intervention is generally deemed a negative force on market efficiency. At most, policy tools are to be passively applied to counteract market failures. More often than not, government failures are even worse, and in reality the state is scarcely able to improve imperfect markets. Such limited effectiveness is due to the facts that many governments are in a state of lacking information to "pick the winners" and to implement policies, and there is a bureaucratic inability to change course and to overcome political dysfunction, let alone the prevalent corruption. These conditions are applicable, to some extent, to the case of Taiwan. In the neoclassical view:

- 1) technology and innovation are fully embodied in the production function, and tacit knowledge, learning, and structural adaptation do not differentiate one economy from another;
- 2) market failures, i.e., distortions of imperfect markets, abuse of economic externalities, and dysfunction of imperfect capital markets, call for government intervention;
- 3) the essential economic functions of government are to maintain macroeconomic stability and supply public goods such as national security and education, as well as to provide physical infrastructures and contribute to developing institutions for improving the markets for labor, finance, and technology.

Nevertheless, the industrial content of an economy limited in scale and enterprise apparently invites a small state's government to dominate local economic activities. A number of theoretical arguments and empirical observations have contributed toward an integrated and pragmatic approach to adapting structures in industrial development.

Wade [1] postulated a governed market theory of East Asian success. The policies in question have enabled government to guide or govern market processes of resource allocation to produce different production and investment outcomes than would have occurred under a free market policy. Market guidance was initiated by augmenting the supply of investment resources, spreading the risks attached to long-term investment, and by steering the allocation of investment by combining government and entrepreneurial preferences.

Moreover, industrial revolution and technological progress exhibit aspects that contradict neoclassical assumptions of technology and innovation [2], [9], [10]. Empirical findings assert the following.

- 1) The technological capability is attained and an innovative environment is adapted by learning. Entrepreneurial spirit is the driving force and technology commercialization is the right path.
- 2) Market failures that preclude newcomers in free markets are mainly due to the risk and uncertainty of technology-intensive industries about highly unpredictable learning costs, as well as the linked investment. Technological externalities will abound as long as the technology diffusion is rapid and the basic technical skill is present.

Therefore, the free market theorem is still valid when market failures arise, essentially because of technological and financial

barriers. Remedies provided by governments are designed to eliminate the entry difficulties that are considered the sign of market imperfections and distortions. The external costs of learning and technology acquisition can be compensated by the legal instruments of intellectual property rights.

Government-guided development, i.e., incorporating technology capability and commercialization aspects with regard to market failures, characterizes Taiwan's industrialization. Taiwan's economic performance is due in large measure to a combination of:

- 1) exposure of many industries to free competition in international markets;
- 2) government-directed technology development and financial incentives which counteract the entry barriers of technological industries to spread the entrepreneurial risk of enterprises;
- 3) enhanced accumulation of human capital and skilled manufacturing capability;
- 4) successful competition strategy as being followers in the early stages of high-tech development;
- 5) strengthened protection of intellectual property rights, which precludes the externalities of technology diffusion;
- 6) entrepreneurial flexibility in manufacturing and management to cope with the rapid changes of industrial environment;
- 7) the political system, which is the virtual monopoly of a single political party over prolonged periods and that assists in efficient implementation of industrial policies.

XII. CONCLUSIONS

This article describes the underpinning process of Taiwan's economic miracle. Human capital and the entrepreneurial spirit are deemed highly critical factors. Different industries varied in their paths to success. Governmental participation, in terms of constructing infrastructures and even in directly involving itself in the industrial growth of IC manufacturing, deserves major credit. However, market intervention has led to some cases of governmental failure. Employing import substitution to govern the home market and resource allocation, subsequent export promotion supporting international competition in the early stages, and developing computer and IC industries during the last two decades, are all considered examples of successful government entrepreneurship. In contrast, cases of the automobile industry and biopharmaceutical development reveal mismanagement of market competition and technology commercialization process.

The small and medium enterprise sector in Taiwan has exhibited entrepreneurial adaptation to economic structures by constructing effective and efficient networks, by expanding foreign investments, and by focusing professional expertise. High-tech has expanded itself from its base in computer and IC manufacturing and related financial strengths to the arenas of telecommunications, multimedia, and photoelectric industries. R&D are emphasized and the rapidly growing patenting activities signal enhanced technological capability.

Generally speaking, the theoretic foundations and empirical observations of the industrial evolution of Taiwan may be summarized as follows.

- 1) Taiwan was formerly ruled by an authoritarian political system in which governmental control was extremely effective. The democratic process has changed the political environment. To sustain Taiwan's growth in a global market and to gain entry to the WTO, Taiwan must replace market governance policy with free-market competition.
- 2) The efficiency of government and public agencies has undergone severe challenges, and Taiwan's governmental role in terms of economic development requires redefining. Public enterprises and research institutes face demands to be more competitive. Governmental intervention is no longer deemed acceptable as an unavoidable remedy for market failure since more efficient alternative ways of achieving the goal may present themselves.
- 3) Taiwan formerly competed in global product markets with a latecomer or follower image. The requirements of advanced technology and physical infrastructure were neither critical nor so sophisticated. Low-cost leadership, well-trained engineers and tight networks underlay Taiwan's foundation. Nevertheless, many traditional industrial and export parks are no longer growing; as a matter of fact, many of them are in a steep decline and many firms have emigrated to Southeast Asian nations or mainland China in search of cheaper labor, land, and raw materials. Competitiveness can be sustained only by upgrading the technologies and by relocating the niche markets that are technology-intensive and capital-augmented industries, especially high-tech businesses.
- 4) Commercialization must be redefined into become a more sophisticated process in which the research and innovation of industries and public institutes receive more importance.
- 5) Networking patterns of small businesses in relation to commercial activity have changed. Taiwan has been well reputed for its networking management. Interpersonal relationships and relative kinship formerly contributed to the networking effectiveness and efficiency. However, production processes, market competition, and social attitudes have abruptly altered business management practices and interorganization cooperation. Contract-based legal relationships are more frequently the rule. The effectiveness of technology transfer from public research institutes to private firms and the management of research alliances where technological entrepreneurship is generated have gained increasing prominence.

This study demonstrates that Taiwan's government will continue to maintain a pivotal role in economic developments although by adjusted positioning. On a macroview, Taiwan's enterprises are themselves becoming multinational corporations. As globalization proceeds and local production factors of comparative advantages erodes, the search for locations of production markets as well as of product markets must

grow in importance. New government measures are called for with globalization, notably the internationalization and liberalization of financial and monetary markets.

Taiwan will continue to be in a state of constant change. Both the upsurge in democratization and the sensitive relations with China affect economic development and political stability. Taiwan's industrial sector must cope with global competition despite a certain withering of governmental authority. The long-pursued arguments as to economic theories and the role of the state in the development and late industrialization of NIE's will no doubt continue. Nonetheless, a nation, as well as an enterprise, must learn that the core of competitiveness must rest upon and be sustained by the principles of market power and entrepreneurship.

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