Innovations and national policies

Taiwan's flat panel display industry

Yao-Jen Liu and Shang-Jyh Liu

The spirit of entrepreneurship contributed to the economic success in Taiwan, stimulating innovation in products and services. Taiwan is now the fourth largest supplier of high technology products in the world. It is also the world leader in semiconductor manufacturing. This report analyzes the relationship between innovation and national technology policies; explains the influence of such policies to Taiwan's development of flat panel displays; and introduces the concept of a "cycle of technological innovation" to explain the growth of Taiwan's high technology industries.

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Introduction

Seven decades ago, Schumpeter pointed out that "innovation is the driving force of economic growth and the way that enterprises utilize resources to satisfy the market demands."[1] Ever since, innovation has become the most important method of maintaining global competitiveness. Numerous innovations are supported by venture capital funds and a strong sense of entrepreneurship.

Innovations bring new technologies and products. Entrepreneurship enables innovations to be realized in products and services. But these require Intellectual Property (IP) rights so that enterprises can protect their properties and acquire a competitive edge.

The spirit of entrepreneurship contributed to the economic success in Taiwan. It not only enabled small and medium enterprises to develop quickly[2], but also helped the advancement of high technology industries. With more than ten products of the highest quality in the world - ICs, notebook computers, monitors, hubs, scanners, motherboards, and modems - Taiwan has become the fourth largest supplier of high technology products in the world. It is also the world leader in semiconductor manufacturing. During 2002-03, Taiwan was awarded second place in the Science & Technology Index of the World Economic Forum and the Innovation Sub-index. These results enabled Taiwan to raise its rank from the seventh to the third in the Growth Competitiveness Index, showing that an impressive innovation ability is the key to Taiwan's economic growth in the future.[3]

This report includes the following parts: an analysis of the relationship

between innovation and national technology policies; a retrospective of Taiwan's technology industry based on national policies and industrial development by the "3V" structure (vertical demarcation, virtual integration, value sharing) and industry clustering; an explanation of the influence of Taiwan's innovation policies to the development of flat panel displays; and a discussion of the positive effects of national policies towards innovations and entrepreneurship.

In conclusion, the concept of a "cycle of technological innovation" is introduced to explain the growth of Taiwan's high technology industries.

National policies for innovation

The word "innovation" comes from the Latin word "novus", meaning an introduction to a kind of new thing or value.[4] Innovations today are classified as "based on the degree of originality" and "based on the content."

The process of innovation includes research, design, manufacturing, management, sales, and services. It also includes the manufacturing process and can be classified under a linear model, a cycle model, and a chain link model.[5]

The linear model is based on a simple straight-line model of technological driving force and the demands of pulling-force model. The chain link model was developed in the 1980s and the factors of consideration are from one manufacturer to another and even from one enterprise sector to a national sector. At the same time, a horizontal transfer concept is developed in which value is transferred from one application to another application, from discovery to application, and to marketing, like a chain. OECD introduced the latest chain link model[6], adding a multi-dimensional structure to the process of innovation as well as introducing a bi-directional relationship between product development and enterprise external resources. The cycle model is based on the product development cycle from the point of view of an enterprise and does not separate the whole process into several stages. The innovation process and the enterprise itself include internal communication, design, manufacturing and system development, sales and distribution, and re-invention and concept. In his integration model[7], Rothwell stated that innovation activities will not happen serially as research activities, prototype development, manufacturing and key activities are performed in parallel and simultaneously.

When all activities during an innovation process are realized in a country or an area, the members that form the innovation system can be called a national innovation system (NIS) or a regional innovation system (RIS). Since an NIS is an analysis on a national level, organization, technology, and regulation are regarded as one integrated system. Academia, research institutions, government units, and industries are all major elements of an NIS (Figure 1).

The purpose of such a system is to analyze the dynamic feature of innovations. The concept of the NIS was first introduced by Freeman[8] and was used to study the reasons behind Japan's fast growth after the war. Followed by Lundvall,[9] Nelson,[10] and Patel and Pavitt,[11] who also discussed the NIS concept and its effects. Porter's "Diamond Theory"[12] stated that government should create a suitable, innovative environment for enterprises and use various methods to influence the process of innovation. The interactions should include knowledge, information, venture capital, and non-official cooperations.[13]

As Figure 1 shows, numerous factors affect enterprise innovation, and national policies will directly influence the driving force of innovations. Any enterprise that marks innovation as the key item in competition must have human resources, research funds, suitable markets, development potentials, fundamental technologies, technology trades, the distribution environment, and intellectual property. National policies will directly influence human resources, capital funds, technologies and markets during enterprise innovation development. Thus national policies are the bedrock of innovation. The network structure created by an NIS and an RIS forms an agglomeration which serves as an important factor in nurturing the spirit of entrepreneurship[14]. A good example is Silicon Valley.[15]

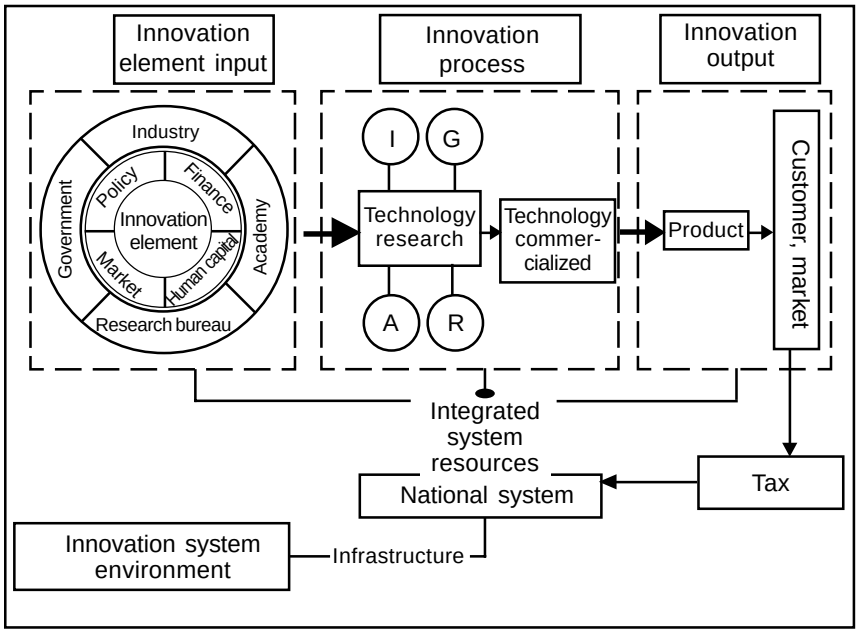
National policy should focus on making entrepreneurship easy. The higher the opportunity cost of entrepreneurship, the lower the quality of the entrepreneur.[14] With the support of government policy, enterprise spending in innovations can be drastically reduced and business operation can be enhanced. For example, capital funds invested in R&D are a necessary resource for innovation. Firms that received government financial support have done better than firms that did not, in terms of growth and obtaining venture funding.[16]

From the structure of an NIS, the environment and mechanism that serve as the foundation for industries for a particular country can be readily understood. Under the impact of global competition and with the development of the knowledge economy, developed economies such as the USA, Europe and Japan have actively sought to transform the existing industrial structure towards new industries in order to accelerate and activate a revolution of the innovation system. It is expected that the driving force of technological innovation and application will increase the industrial advantages of these countries in an uncertain economic future and fierce competition.

In future competition, issues such as the capability for technological innovation and competition; knowledge and intellectual property creation, usage, and application; enterprise strategy and management; knowledge-based service; interaction of an NIS; revolution of the scientific system; distribution of research activities; and industrial clustering will be important topics for every country in the world. The most widely used and effective method is to utilize all kinds of IP rights to gain advantage through the law and to obtain advantage among competition. Countries such as the USA and Japan have always used IP rights to increase their advantage in industrial competition.

Since the 1980s, the USA has passed a series of regulations, including the Bayh-Dole Act of 1980, to promote the creation of an entire structure, including venture capital funding, human resources, and industry informa-

Figure1: National Innovation System[27]



tion exchanges. With innovation as the foundation, these policies have helped the USA to gain unparalleled technological advantages in the last 20 years. While enhancing its industrial competitiveness and its employment rate, Japan has also recognized the importance of IP. So the Bureau of Economic/ industrial Policy and the Bureau of Intellectual Property linked up with academia, industry and research facilities to perform research in industrial competitiveness and IP. The "Strategy for Intellectual Property Seminar", held by the government in July 2002, introduced a "Summary of Intellectual Property Strategy", its primary goal being to become a "country empowered by intellectual richness". The content includes intellectual property creation, protection, application, and the development of human resources and public awareness to promote a new generation of technological innovation. Based on the experience of USA and Japan, it is evident that an environment with adequate national policy and awareness of intellectual property is the driving force of technological innovation.

Taiwan's innovation and industrial development

Taiwan's technological policy has progressed from a linear direction in the early days to an integrated multiple development now. Supported by proposals in all national scientific seminars discussing IP issues, Taiwan has actively moved towards a knowledge-based economy (Figure 2).

The 20 years of technological innovation and national policies in intellectual property in Taiwan can be classified into four stages:[17]

- Mid-1980s - IP education and protection;
- Early 1990s - enhancing IP management and application;
- Mid-1990s - enhancing the integration of IP creation and application; and
- From 2000 - stressing the integration of creation, protection, application, and education.

Based on the work of the Taiwan government over the last 20 years, the conducive environment has attracted overseas venture capital funds, and encouraged citizens and students to become entrepreneurs, to invest, and to introduce new technologies. This has allowed Taiwan's industries to transform from a light-industry type to a high-technology type in just 20 years. Some examples are:

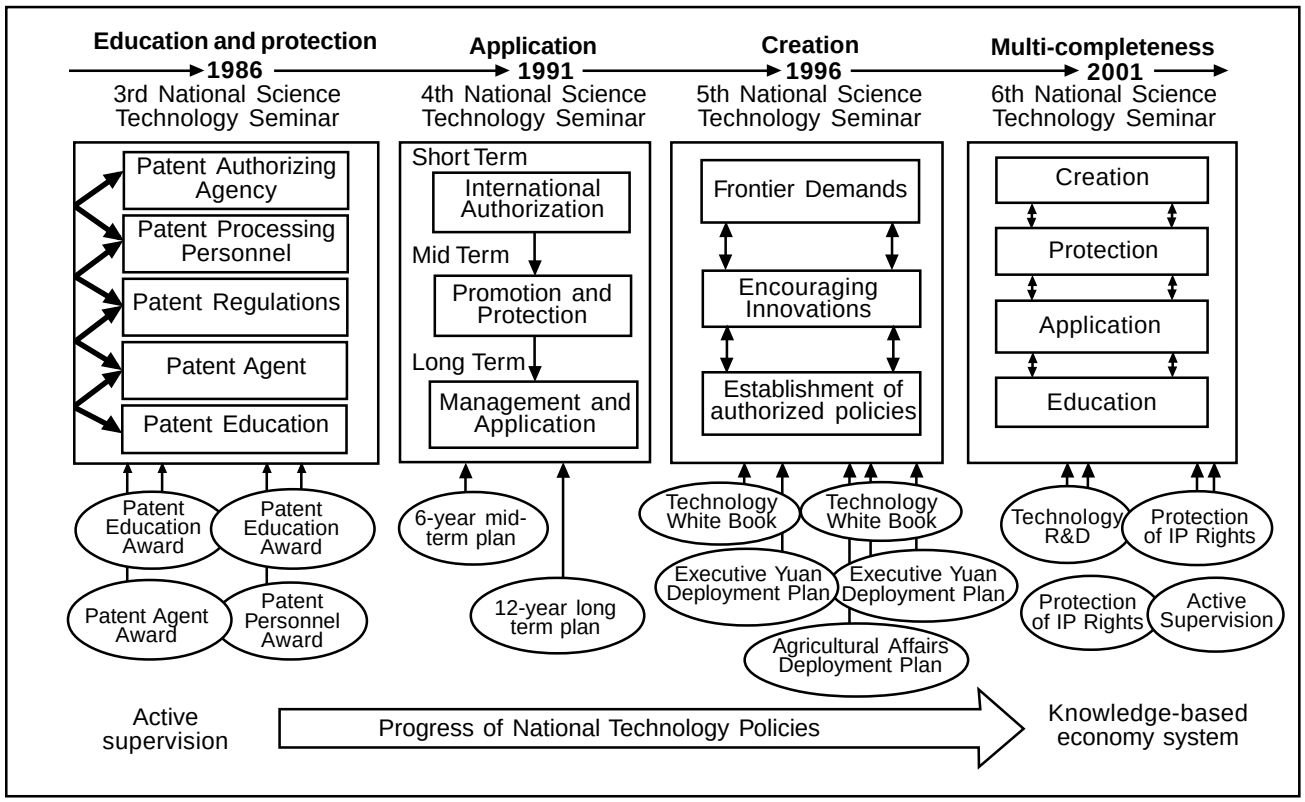
- The market value of Taiwan's information industry is ranked third in the world, only behind the USA and Japan;
- Taiwan is the fourth largest semiconductor manufacturer in the world;
- Taiwan leads in the worldwide production of more than ten products: ICs, notebook computers, monitors, hubs, scanners, motherboards and modems;
- The export value of fundamental and technological integrated products has exceeded 76.5 per cent of the total export value, showing that Taiwan's industries have moved to a high technology and high value market;
- Government and public capital investments in research over the last 5 years has increased from US$ 156.3 billion in 1997 to US$ 204.9 billion in 2001. The average growth from 1997 to 2001 has been 8.32 per cent. Research capital as a percentage of GDP increased from 1.86 per cent in 1997 to 2.16 per cent in 2001;[17]
- The number of patents approved in USA is ranked fourth in the world;[18]
- Between 1998 and 2002, 50 per cent of Taiwanese industries with over 20 people participated in technological innovation activities. Of these, manufacturing and service industries had 51 per cent and 49 per cent[19] shares respectively;
- The total number of Taiwan's research personnel increased from 129,165 in 1997 to 138,409 in 2001, a 29.8 per cent growth in 5 years; and
- In the World Economic Forum's 2002/2003 Global Competitiveness Report, Taiwan was ranked second in the Science & Technology Index and Innovation Sub-index which enabled Taiwan to raise its rank from third to the seventh in the Growth Competitiveness Index.[3]

To understand Taiwan's successful evolution from light industry to high technology industry, one needs to analyze Taiwan's history of development.

The semiconductor industry serves as the best example of Taiwan's history in technology development. The development of the semiconductor industry was possible through a combination of government policies, public resources, and academia researches into a large technological network, and serves as a role model for other industries.

The development of Taiwan's technology industry starting from the semi-

Figure 2: The development of Taiwan's intellectual property policy[17]



conductor industry can be classified into the following timelines:[20]

- 1960-1973: Educating personnel. People are the foundation of technological development. During the 1950s, there were no high technology industries in Taiwan. Therefore, the first goal of the government was the "Personnel Education Strategy". The National Chiao-Tung University (NCTU) established in Hsin-Chu was the first university to educate high technology research personnel and set up research laboratories, which have since served high technology industries. Another important milestone was the establishment of the Industrial Technology Research Institute (ITRI) in 1973, which served as a strong foundation for domestic technology research.
- 1974-1979: Foundation of the IC industry. The most important technological policy at this time was the "introduction of advanced IC design and manufacturing techniques from the USA". The Department of Economic Affairs dispatched personnel to the USA and established a "Technical Advisory Committee" to recruit overseas students to join the newly established "Electronic Research and Service Organization" in ITRI and to provide technological development plans. In particular, the technology transfer through a contract with the RCA Company in the USA was one of the important milestones of Taiwan's electronic foundation.
- 1980-1986: Nurturing of the IC industry. The most important technology policy at the time was "technology transfer and entrepreneurship for industrial development". The spin-off of United Microelectronics Company (UMC) from the Electronics Institute in ITRI was a success in the IC manufacturing technology and started off industrial development. Another important policy was the planning of the Hsin-Chu Science Park (established December 1980), which enabled technology companies to obtain the necessary infrastructure, tax reduction, import/export duty tax service, human resources, and technology resources. All these increased the efficiency of technology firms in research and innovation, forming a complete industrial cluster with a unique upper-stream and lower-stream structure and division. This science park is currently the most important manufacturing location of high-tech devices in the world.
- 1987-1994: Birth of a new IC manufacturing industry. During this era, industries related to semiconductors developed rapidly. Many new IC firms were found. New management and operation methods were developed. The best example is the Taiwan Semiconductor Manufacturing Company (TSMC, established 1987), which is now the world's largest professional IC manufacturing firm. TSMC supplied the world with a professional IC manufacturing service and established a new model of the division of labour.
- 1990 to date: Boom of the IC industry. Supported by government policies, the research, human resources, management innovation, and supply chain network created by Hsin-Chu Science Park, National

Chiao-Tung University, Ching-Hwa University, and ITRI contributed to the development of a complete industry cluster, including research, design, manufacturing, and sales, with low-cost advantages and professional abilities. This enabled Taiwan to be ranked third in the world's semiconductor industry.

Based on the above achievements, the effort put into creating an environment for innovation and entrepreneurship was effective in promoting a spirit of entrepreneurship and increasing the overall competitiveness of industries.

Research innovation, industrial development, and national policies are closely tied. Overall, technology development polices can be classified as:

- Personnel Education: Personnel are the foundation for research and innovation. The National Chiao-Tung University was established for this purpose. The development of technological universities in the recent years supplied adequate number of personnel to the industries.
- Personnel Supply: Revision of the employment regulations attracted foreign technology personnel to work in Taiwan. The government also revised the military draft laws to address technological conscription, which provided a large number of excellent research personnel to industries. In 2000, Taiwan established a draft of substitute services to further supply industries with technology personnel.
- Technology infrastructure: The establishment of the Hsin-Chu Science Park was successful in integrating infrastructure and related facilities to form a complete industry cluster, enabling technology firms to grow rapidly. During the 1990s, the same model was cloned and used in the Southern Taiwan Science Park, which served as an important location for TFT-LCD manufacturing in later years.
- Encouraging investment in research and technology transfer: By establishing universities and the ITRI, advanced technologies were transferred to technology firms or spin-off companies.
- Worker benefits and stock options:[20] The government introduced tax-reduction methods to establish worker benefits and stock options. This allowed workers to devote themselves wholeheartedly to their jobs and enabled firms to attract and keep talented personnel.
- Protection by law: creation of regulations and IP rights to preserve the research efforts of technology firms. Taiwan established a series of regulations, including an IP law, a trademark law, an anti-trust law, a business secrets law, an operation secrets law, a copyright law, and a semiconductor layout protection law, to create a complete mechanism of protection.

Overall, based on government and public efforts, the overall awareness and protection of IP have developed greatly and can be classified into five stages:[21]

- 1978-1985: Government learning (USA-Taiwan coordination);
- 1985-1990: Government promotion and guidance;
- 1990-1995: Establishment of regulations and development of industrial IP;
- 1996-2000: Fast growth of industrial IP; and
- 2001 and after: Industry transformation and planning of IP.

- Capital funding and venture investment:[22] Since investment in the technology industry is heavy, sourcing capital is an important factor for continuous innovation. The regulations created by the government enabled firms to issue stocks in return for investment, and supported the establishment of venture capital firms to assist start-up companies. Investment obtained from financial institutions such as banks assisted firms to release bonds. The investment from domestic and foreign markets formed an adequate supply of capital.
- Frontier strategy planning: In order to enhance competitiveness in the 21st century, the strategies in research innovation and IP planned by the Taiwanese government include four major directions: IP creation, IP protection, IP application, and IP education. At the same time, the Executive Yuan also planned the "Challenging 2008: National Key Research Projects (2002-2007)" to invest in key industries in order to enhance frontier industries and future innovations.

In summary, Taiwan's technology development can be explained in terms of four major features by the 3V model[23] and the industry cluster:[24]

- Vertical demarcation: The manufacturing chain of common products is formed of many sections. A vertical demarcation feature in Taiwan isolates various professional firms that operate independently for the common good in terms of upper-stream and lower-stream relationships. Since technologies can be specialized independently, core technologies and costs can be controlled effectively. Because of this vertical demarcation, technology industries in Taiwan were able to enhance their professional skills, increase their rate of utilization, and decrease their manufacturing time.
- Virtual integration: Although firms in each sector of the technology industries work independently in this vertical demarcation system, the unique management mechanism between technology firms has been smooth and has provided a complete chain link. By virtual integration, technology industries could integrate with worldwide supply chains, effectively accumulate knowledge, and obtain capital funding more easily, thus becoming an important supply source to the world market.
- Value sharing: Taiwan's technology firms attracted high quality workers by their unique worker benefits and stock options. Because of the stock options, Taiwanese technology firms obtained advantages, including a reduction of conflicts between workers and the company, a reduction in spending, and an ability to attract foreign personnel, all of which contributed positively to technological innovation.
- Industry cluster: Since the Hsin-Chu Science Park allowed upper-stream, middle-stream, and lower-stream manufacturers or firms to coordinate with one another, an effective "virtual, integrated supply chain" was formed. For example, the industry cluster enabled domestic IC industry to keep a steady supporting system from suppliers and created a beneficial competition.[25]

Thanks to these four features, technology industries in Taiwan were able to increase productivity, marketability, and profitability (Figure 3).

Flat panel display industry

The development of the flat panel display, from its first use in TFT-LCD on notebook computers in 1991, has attracted worldwide attention. Flat panel displays can be classified as: plasma display panel (PDP), liquid crystal display (LCD), organic light-emitting display (OLED), vacuum fluorescent display (VFD), field emission display (FED), and micro display. Its range of applications is wide. The flat panel display industry in Taiwan includes different secondary industries (Figure 4).

The flat panel industry in Taiwan is the combined effort of government policies, public investment, research institutions and market mechanisms. During 2002, the market value of Taiwan's flat panel display industry reached NT$ 224.95 billion, an 83.2 per cent increase from year 2001, occupying a total world market share of 24.4 per cent. In particular, the LCD products occupied 96.5 per cent of the total products with a market value of NTD 217.08 billion.[26]

The fast growth of Taiwan's flat panel display can be attributed to the following factors:

- Strategic planning of government policies;
- Adequate research personnel and resources accumulated from the past;
- A complete chain of supply created by industry-cluster relationships; and
- A strong spirit of entrepreneurship with large investment and upgrades.

Each of these will now be elaborated.

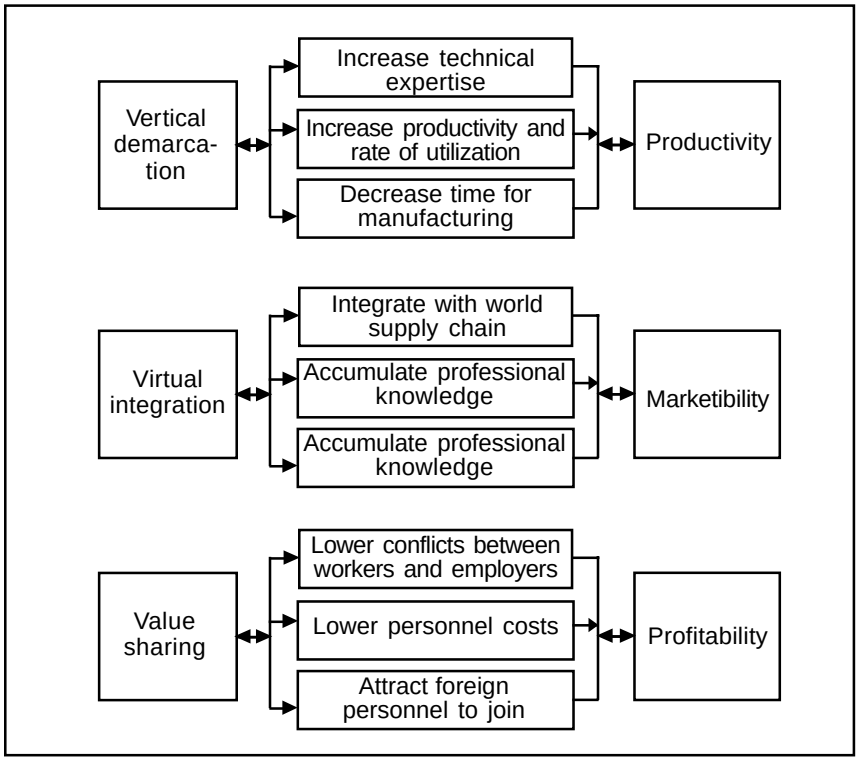
National policies

National policies have always played an important role in Taiwan's technology industries, including the semiconductor industry, the computer industry, and the flat panel display industry. These policies assisted the flat panel display industry to advance technological research and to increase investment.

Important milestones in the flat panel display industry policies are:

- 1992: Department of Economic Affairs listed LCD as the key technological research project;

Figure 3: 3V feature in Taiwan [23]



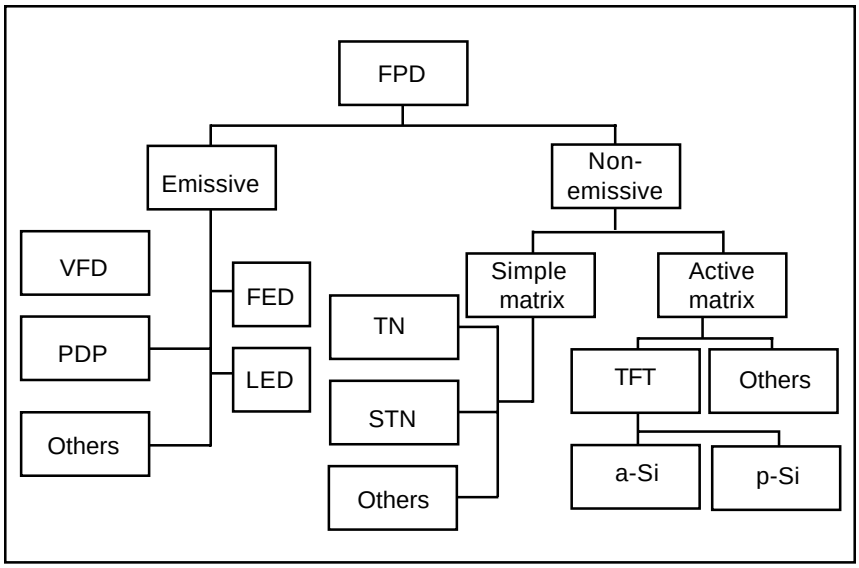
- 1994: Department of Economic Affairs started the 4-year "Flat Panel Display Project", investing more than NT$ 2.0 billion;
- 1997: Electronics Institute in ITRI started the 6-year "Key Technology Development of Flat Panel Display", investing more than NTD 6.0 billion in TFT-LCD technology, related materials and replacement displays.
- The government encouraged the industry by assisting firms in securing venture capital, reducing taxes, recruiting foreign personnel, increasing investment for frontier technologies, enhancing IP, and activating the market information exchange . [Under the *Two Trillion and Twin Stars Industries Development Plan*, a Colour Imaging Industry Promotion Office (CIPO) was created to assist the industry and draw up regulations.] These regulations and policies enabled the industry to grow rapidly. The CIPO also promoted policy planning and deployment.
- The Executive Yuan planned *Challenging 2008: National Key Research Projects (2002-2007)* to invest in important industries in the future for further innovation and development. In particular, the *Two Trillions & Twin Stars Industries Development Plan* includes the flat panel display industry.

In order to prepare Taiwan for competition in the 21st century, the Executive Yuan has actively promoted the *Challenging 2008: National Key Research Projects (2002-2007)* plan in hope to continue to retain Taiwan's manufacturing and design advantages. The *Two Trillions & Twin Stars Industries Development Plan* was endorsed to promote industrial development. Based on the plans, research activities, technological innovations, and IP in Taiwan have effectively supported the growth of the industries and the economy.

The *Two Trillions & Twin Stars Industries Development Plan* was primarily focused on nurturing the technological and innovative abilities of engineers and knowledge workers. The overall strategy for Taiwan's industries in the new century will be based on technological advancement and innovation:

- Advance and enhance existing industries (semiconductor, imaging) towards third place in the world and

Figure 4: Flat panel display category[28]



create a global influence (*Two Trillions & Twin Stars Industries Development Plan*); and

- On the other hand, use the resources of technological innovation and the excellent social environment to develop popular industries (digital contents, biotechnology) with other countries in Asia and the world (*Two Trillions & Twin Stars Industries Development Plan*).

The twin star industries defined by the Department of Economic Affairs are industries that will reach a market value of over NT$ one trillion in the future, including:

- The semiconductor industry: The projected goal is NT$ 1.59 trillion in 2006; and
- The display device industry: The first stage is focused on flat panel displays, with a projected goal of NT$ 1.37 trillion in 2006 (comprising flat panel displays of NT$ 730 billion and LCD displays of NT$ 640 billion).

Research and innovation

The development Taiwan's flat panel display industry has a history of 12 years since it was listed as a strategic industry in 1992. Interviews with CIPO members indicate that the development was based on technology transfer from USA and Japan towards self-development. From the limited number of patents in the early years to the large number of patents in recent times, these efforts are the results of relentless innovation. Table 1 and Table 2 illustrate the history of flat panel display development over the last 12 years.

In addition, optical measurement and testing category (UPC 356, 1990-2002 65 patents, average growth 18.92 per cent), optical system and device category (UPC 359, 1990-2002 153 patents, average growth 18.92 per cent), and image analysis category (UPC 382, 1990-2002 78 patents, average growth 17.23 per cent) all exhibit high growth rates in the number of patents.

Industry cluster relationship

Research related to industry cluster relationship is primarily based on Porter's study.[12] Over the last 20 years, technology industries in Taiwan have developed an excellent industry cluster structure. The structure includes clusters in information, communication, and electronic industries.[25] The largest ones are in Taipei, in the north, and Hsin-Chu, in the south. The secondary ones are in TaiChung and TaiNan. Each of these clusters includes manufacturers in material production, component manufacturing, and system module integration, utilizing the vertical demarcation and virtual integration features to form a complete chain of supply.

The development of Taiwan's industry cluster relationship advanced rapidly on the basis of the original technology clusters. It can be separated into three major clusters: northern LungTan cluster, middle TaiChung district, and southern TaiNan district (Source: CIPO Statistical Report).

The material component of the flat panel display occupies the largest percentage of the overall cost. In terms of TFT-LCD, the material cost occupies over 61 per cent (Source: IEK ITRI ITIS Project data, 2001). An industry cluster enables reduction in material costs and delivery costs, and increases the rate of supply of key components, all of which effectively enhances business operations. Table 3 shows the current supply of key components among the upper-stream manufacturers of flat panel displays. Because of the vertical demarcation relationship among the flat panel display industry, the rate of self-supply has increased over the years and the capacity has also increased as well.

Taiwan has long played the role of a high-value device design and product manufacturer in the world market. It now plays the same role in the flat panel display industry. The industry cluster relationship makes Taiwan an important part of the worldwide supply chain.

Taiwan's industry cluster relationship is able to enhance its global competitiveness and increase efficiency in business operations. Table 4 shows the market value and growth of Taiwan's LCD market in recent years. It can be observed that the LCD industry has only slightly declined during the Asian financial crisis in 1997, but has otherwise exhibited a high growth rate.

Entrepreneurship, investment, and transformation

Apart from governmental efforts, the technology development of Taiwan's industries has flourished, thanks to high public investment and a spirit of entrepreneurship.

Table 5 is a statistical report of the LCD industry in Taiwan.

The investment plan for the flat panel display industry is shown in Table 6.

The development of the flat panel display industry over the past years has accumulated large resources of personnel and investment. The success is attributed to the following factors:

- Establishment of government policies according to market demands

Table 1: Most patents obtained in USA in LCD category

Units filed

Year	Num	Japan	USA	Korea	Germany	UK	Taiwan	Canada	France	Belgium	Israel	Holland
1990	3,626	1,676	1,370	6	215	111	11	44	54	10	12	29
1995	4,438	2,020	1,736	47	152	111	27	70	68	55	17	25
1996	5,249	2,446	1,976	107	181	123	27	100	77	59	22	26
1997	5,120	2,363	1,926	127	151	117	40	82	83	78	26	27
1998	7,543	3,380	2,828	297	245	143	87	101	122	81	45	58
1999	7,541	3,268	2,906	310	233	141	120	102	102	77	53	51
2000	7,609	3,288	2,897	288	272	159	133	107	84	94	45	54
2001	7,466	3,096	2,908	275	286	184	143	100	96	62	56	56
2002	7,539	3,147	2,899	280	281	180	180	111	95	57	62	46
1998-2002 Sum	37,698	16,179	14,438	1,450	1,317	807	663	521	499	371	261	265
1998-2002 Average growth	-0.01	-1.77	0.62	-1.46	3.49	5.92	19.93	2.39	-6.06	-8.41	8.34	-5.63

Source: Cite USPTO, based on statistics by Economic Research Institution, Taiwan

Table 2: Most patents obtained in USA under LCD unit, device, and system categories

Units filed

Year	Num	Japan	USA	Korea	UK	Taiwan	Holland	Germany	Switzerland	France	Sweden	Israel
1990	176	89	53	1	10	1	6	2	4	4	1	1
1995	251	161	55	13	5	0	2	0	0	10	0	1
1996	382	238	96	21	8	3	5	5	2	1	0	0
1997	375	247	79	18	8	4	4	6	1	4	0	1
1998	600	370	98	62	16	8	17	8	5	6	3	3
1999	508	297	109	61	9	5	8	3	4	1	2	3
2000	650	416	107	73	19	14	5	5	4	2	2	0
2001	618	382	96	84	17	14	6	4	4	2	2	1
2002	624	376	75	109	14	23	8	3	2	2	2	1
1998-2002 Sum	3,000	1,841	485	389	75	64	44	23	19	13	11	8
98-'02 Average growth	0.99	0.40	-6.47	15.15	-3.28	30.21	-17.18	-21.75	-20.47	-24.02	-9.64	-24.02

Source: Cite USPTO, based on statistics by Economic Research Institution, Taiwan

and trends. Plans in national key research projects in which different units integrate and form a united flat panel display development strategy;

- Resources devoted in the form of national research projects to develop independent technologies including *4-year Flat Panel Display Plan*, the *6-year Flat Panel Display Key Technology Plan*, and the *Two Trillions & Twin Stars Industries Development Plan*;
- Active devotion towards research and innovation, including ITRI, universities and enterprises, which are all devoted to new technologies, IP, technology transfer, and protection of IP rights;
- Effective national policies encouraging the spirit of entrepreneurship by technology transfers (such as Mitsubishi and Sharp from Japan), research investment, IP protection, venture capital and funding; and
- Excellent industry cluster structure, creating a supply chain of upper-stream, middle-stream, and lower-stream industries.

Conclusion

Innovation is the most important factor for competition in the 21st century. However, innovations require an adequate environment to be effectively nurtured. The national technology plan, IP innovation plan, and IP protection plan will all influence whether entrepreneurs are willing to devote themselves to an industry or not.

The *National Technology Strategy, Entrepreneurship, Investment, Innovation* interaction model is shown in Figure 5. The *Cycle of Technology Innova-*

Table 3: Current supply of key components among upper-stream manufacturers of Flat Panel Display in Taiwan[17]

Year		2000	2001	2002
Type		Local-supply ratio	Local-supply ratio	Local-supply ratio
Glass %		0	0	10~15
Colour filter %		12	35	60~70
PL board %		11.5	25	30~40
Drive IC %	TN/STN	26	35	40~50
	TFT	0	5~10	30~40
Back light module %		28	35~40	60~70

Table4: Market value and growth rate of LCD industry in Taiwan[29]

	Produce value (A)	Import value (B)	Export value (C)	Domestic market need (A+B-C=D)	Expert ratio (E=C/A ×100%)	Grow rate of produce (%)
1996	165.9	388.8	71.7	483.0	43.2	
1997	248.8	333.7	106.4	476.1	42.8	49.97
1998	235.4	163.7	118.2	280.9	50.2	-5.39
1999	391.6	131.4	239.2	283.8	61.1	66.36
2000	956.3	78.0	467.6	566.7	48.9	144.20
2001	1227.5	65.7	393.0	900.2	32	28.36
2002	2249.5	75.2	1322.7	100.2	58.8	83.26

Table 5: Status of LCD industry[29]

Year	Firm's volume	Em-ployees ('000)	Revenue (million NT$)	R&D (million NT$)	R&D Engineer ('000)	R&D Engineer/ Employee ratio (%)	R&D/ Revenue ratio (%)
1996	21	6.9	8,860	102	0.5	6.7	1.2
1997	29	9.0	16,420	332	0.6	7	2.0
1998	34	12.8	18,520	402	0.9	7.2	2.2
1999	39	19.3	31,600	1,087	1.3	6.9	3.4
2000	42	26.8	87,319	1,786	2.0	7.5	2.0
2001	56	33.4	107,771	2,277	2.3	6.8	2.1
2002	55	37.8	224,952	3,576	2.4	6.4	1.6

tion can be used to explain Taiwan's technology development. In summary of the change and development of the industries in Taiwan, the cycle can be summarized as follows:

- Early government planning to form technology development plans and strategic goals:
- The spirit and devotion of entrepreneurs as the environment gradually takes shape;
- The performance of entrepreneurs in capital funding, frontier technologies, personnel recruitment, and large-scale investment;
- Innovations produced by dedicated resources, which form a new product, a new market, and a new business operation mechanism in order for the industry to take shape;
- Industrial growth, leading to higher employment rate and economy growth, ushering in the next step of national technology development; and
- Cycle of the entire technology innovation based on IP.

From a technological innovation point of view, the development of technology industries in Taiwan has become the world's most important semiconductor manufacturing sector. Over the last 20 years, Taiwan has become well-known throughout the world for its importance in technology industries. Over the last 10 years, the flat panel display industry has flourished, thanks to government policies, entrepreneurship, and effective research for innovation. Taiwan is now one of the three major flat panel display countries in the world, along with Japan and Korea. Its development matches that of the cycle of technological innovations.

Experience in the semiconductor industry clearly indicates that the success of the flat panel display industry can be attributed to government policies, devotion of entrepreneurs, and relentless innovations to continuously and effectively encourage industries to develop and expand.

This cycle of technological innovations actively energizes the development of industries and is mutually beneficial for different kinds of industries. The increased competitiveness is a proof of Taiwan's effective innovation system.

Technology industries, the 3V features, and the advantages of the industry cluster have proved that these systems, in coordination with an IP protection mechanism, entrepreneurship, investment and the cycle of innovations have advanced the national economy. The Taiwanese experience in technology industries is useful to countries in Asia and other developing countries.

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Table 6: Investment plan of Taiwan's Flat Panel Display industry

Manufacture type	Investment amount (until end of 2002)	New investment	Growth of investment (%)
TFT-LCD firms (7)	2712	4400	162
Glass substrate (5)	65	183	282
Filter (8)	170	300	176
CCFL (8)	12	12	100
PDP (2)	100	120	120
OLED (5)	125	70	56

Source: CIPO statistics report, 2003 Q1

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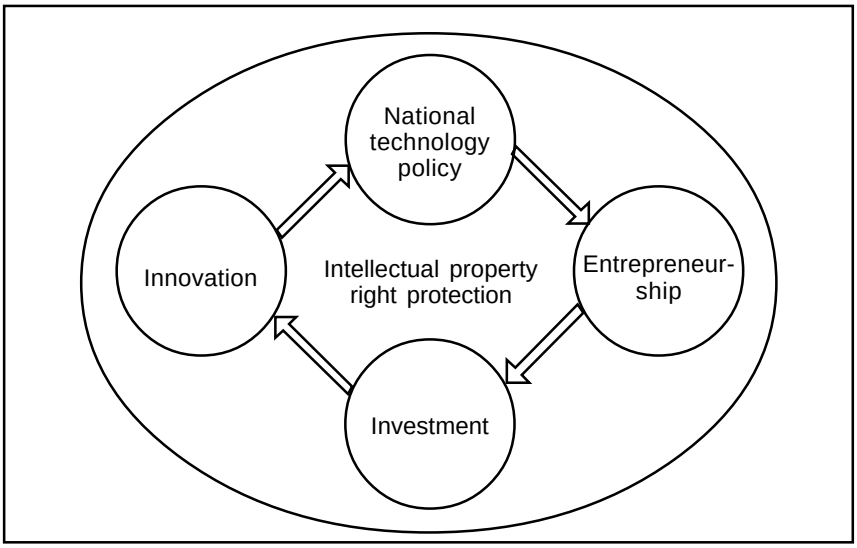
Figure 5: Policy, entrepreneurship, investment and innovation cycle



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