Modeling the Evolution of Public Industry R&D Institute- the Case of ITRI

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Abstract

The Industrial Technology Research Institute (ITRI) has been recognized as a successful case for industry R&D institutes to facilitate the industry development. During its development process, ITRI has experienced several stages of strategy and organizational reforms. The evolution of the organizational structure and the interactions with the social-technological environment are complex and dynamic, all together being important factors for ITRI to generate impacts to the industries. This study analyzed the development history of ITRI, and derived a system dynamics model to examine the structure behind the successful experience. The results of the model are discussed.

Keywords: industry research institute, industry development; interaction; R&D system; ITRI

1. Introduction

Using industrial research institute as a technology arm in the national innovation system has been a common policy both in developing and developed countries. For example, the National Institute of Standard and Technology (NIST) of the U.S.A., the National Research Council (NRC) of Canada, the National Institute of Advanced Industrial Science and Technology (AIST) of Japan, and the Korean Institute of Science and Technology (KIST). How to properly integrate the research institutes as the technology powerhouse to the industry was an important issue to the policy makers and the management of these institutes (Shih et al 2003).

Among these national affiliated/supported industrial research institutes, the Industrial Technology Research Institute (ITRI) in Taiwan has been recognized as a successful model. ITRI has played an essential role in Taiwan's industrial development process. Many leading high technology companies such as Taiwan Semiconductor Manufacturing Company (TSMC), United Microelectronics Corporation (UMC), and Taiwan Mask Company are spinoffs of ITRI, and ITRI also significantly contributed to the development of the Taiwan's semiconductor industry, the information and electronics industry, the automotive industry, and the machine tool industry. Besides the explicit research and development (R&D) achievements, ITRI also acted as a foster of high level executives in Taiwan's high-technology sector. As of 2006, over 160,000 alumni have graduated from ITRI, with more than 5,000 are in the Hsinchu Science Park, the heart of Taiwan's information technology industry, serving in mid to high level management positions. Furthermore, more than 60 are current domestic corporations' chief executives. (Veloso and 2001, Liu and Brookfield 2000, Mathews 2002, ITRI website).

The Industrial Technology Research Institute (ITRI), founded with Taiwanese

government's initial funding in 1973, is the largest non-profit R&D organization in Taiwan. It has a consistent close interaction with local industry firms and has been recognized as one of the key roles to enhance Taiwan industry. ITRI has been involved in wide spectrum of research areas, such as: chemical engineering, mechanics, communications, materials, biotechnology, nanotechnology, energy, and environmental protection. Recently, ITRI has further extended its research domain to include industrial analysis, industrial policy, human resource development, knowledge services, and sustainable development. (ITRI, various years).

ITRI's widely recognized achievements have made ITRI a "successful model" of how a public research institute could generate real impacts in promoting local industry development. However, as the development of the industry approached and the industrial environment changed, ITRI has been questioned how it could maintain its glorious past and keep generating eye-flashing impacts. We have observed that ITRI has gone through several repositioning and/or restructuring of itself along side its 37-year history, and every restructuring effort reflected the interplay of contemporary industrial and governmental environment, and the evolution of organization capabilities. It would be interesting to explore why ITRI could succeed in the past and evaluate the long-term impacts of its restructuring strategy.

System dynamics (Forrester 1961) has been widely used in practice and industrial research to identify underlying structures behind complex behaviors and improve policy making (Roberts 1978, Morecroft and Sterman 1994, Coyle 1996, Ford 1997, Coyle and Morecroft 1999, Jan and Hsiao 2004, Chen and Jan 2005). The pragmatic philosophical foundation makes it a useful methodology to handle complex and dynamic phenomenon in the real world (Barlas and Carpenter 1990). This study explored the development history of ITRI in the context of its developmental environment, derived dynamic hypothesis of the development processes, and will simulate some policy scenarios to test the long term implications of organizational change strategies.

2. The Role of ITRI in the Taiwanese national innovation systems

In the early development periods of national innovation systems (NIS, Freeman 1987, Lundvall 1992, and Nelson 1993) in a developing country, the government usually plays an active role in initiating and propelling the accumulation of R&D capabilities (Metcalfe 1995). As the industry proceeds on industrializing, the NIS generally involves three parts: industry, government, and academia (Arnold et al 1998, Betz 1998).

In Taiwan, more than 97% of firms are small and medium sized enterprises (SMEs). Therefore the private sector lacks the abilities and resources to develop advanced new products and technologies. The private sectors were so weak in the early stages that they were incapable to proactively seek and absorb the knowledge from foreign sources or local universities. On the other hand, due to the incentive system and tradition, the university in Taiwan has long been passive to industry requirements. Consequently, the government founded many research institutes to establish a government-supported R&D subsystem hoping to serve as the median agent for technology diffusion or new industry creation.

Under this circumstance, we could see among the national innovation systems a stronger tie between the research institute and the industry, and a weaker tie between the industry and the universities. From 1979, the Ministry of Economic Affairs (MOEA) began setting aside

budgets to commission government-supported research institutions to work on industrial technology R&D projects. Under MOEA, there are 25 government-supported research institutes that conduct R&D in various fields of industrial technology. Among these institutes, ITRI is the biggest one and is believed to contribute the most impacts to the industry sectors for decades. Taiwanese government has invested heavily in ITRI to create and maintain its R&D capacities. The annual budget of ITRI exceeds $USD 554 million in 2009, and roughly half of it is from government sponsored projects. The major milestones in ITRI's achievements include:

- The acquisition of semiconductor process technology into Taiwan in 1976, which subsequently lead to the spinoffs of two biggest wafer foundry companies TSMC and UMC.
- Establishment of Taiwan Notebook Personal Computer (PC) Consortium with 47 domestic manufacturers that enabled the vertical integration of the notebook PC industry, and thereby helped make Taiwan the world's largest notebook computer producer (over 90% market share).
- Transferred carbon fiber production technologies of bicycle, golf ball and tennis racket to relative private manufacturers. The material technology helped some private firms like Giant thus became world-competitive and thereby entered the global high-end market.
- Breakthrough in optical pickup head for CD-ROM drives and laying foundation for the emergence of optical disc drive industry, and enabled Taiwan to be the largest CD/DVD drive producer.
- Transferred dry film photoresist technology to some private firms which subsequently enabled the Eternal to achieve a global market share of over 40%.
- Spinoff of Mirle Automation Corp, the first and largest integrated industrial automation equipment company in Taiwan.
- Built Taiwan's first common auto engine through the technology transfer from Lotus UK. This is Taiwan's first independently developed, mass-produced 1.2L 8- and 16-valve common auto engines.

3. The development stages of ITRI

Since ITRI's inauguration in 1973, the industry environment and the organizational strategy of ITRI has gone through several stages of transition. The development process can be divided into three stages according to the change in the interaction pattern between ITRI, the environment, and other actors in the national innovation systems.

3.1 The first stage from 1973 to 1984

- Industry Environment

ITRI was founded in an age where the private sectors of industry in Taiwan are quite primitive and generally small and weak. The political environment at that time was still in the

martial-law status where policies are made by the elite leaders. The initial mindset of the government was to use public industrial research institute as a mediating agent to absorb or develop technologies, then diffuse them to the private sector, as indicated in Fig. 1. Since the private firms' capabilities are weak, the government expected ITRI to accelerate the technology inflows to increase the capabilities of industry firms either to conduct in-house R&D or license from other sources on their own, and finally to establish self-supported technology competence.

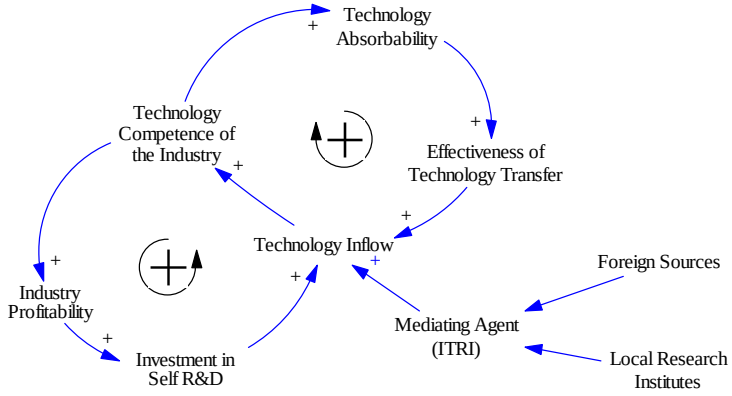


Fig. 1. The initial mindset of the government

- Strategy of ITRI

For ITRI in this stage, the major funding came from government sponsored projects. The government provided ITRI the funding in hopes for generating industry impacts. The higher impacts were perceived, the more resources the government was willing to allocate in these research projects. Because the technology absorbability of local industry is low at this moment, ITRI allocated more efforts on localizing the acquired technology for near-future needs of the targeted new industry. Transferring, localizing, and then spinning off into private company became the major strategies adopted by ITRI in this stage to generate impacts.

The main focus for ITRI is to accumulate and diffuse the en-competing technology (technologies that do not exist in the private sectors, but could enable them to compete in new markets) to the private sector. By conducting government supported R&D projects, ITRI can either self develop or transfer from foreign technology sources and localize the targeted technology. The accumulated capabilities can then spinoff into private companies at some proper time. The technology commercialization demonstrated by the spinoff companies will reduce the perceived risk and thus attracts more and more private companies entering this industry, which will contribute to the formation of industry clusters, and finally leads to the perceived policy effectiveness of the government to introduce more similar R&D projects to ITRI, as illustrated in Fig. 2.

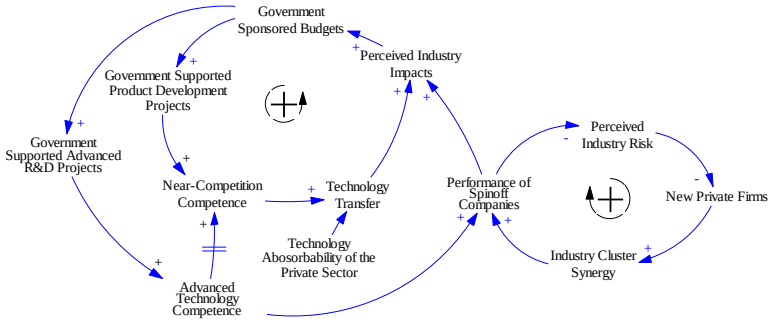


Fig. 2. ITRI's strategy in stage 1

- Organizational Structure

Laboratories of ITRI are founded by disciplines, including electronics, machinery, materials, and chemical engineering. These laboratories operated somewhat independently based on separated government sponsored projects, reflecting the simple and uni-disciplinary technology nature of the private sector at that time.

- Environment Interaction Pattern

The decisions of research topics in this stage were determined from top of the Ministry of Economic Affairs. The intention of the government was to create new industries in Taiwan. Due to the implicit "new industry creation" mindset, researchers of ITRI tends to focus their energy on R&D activities and less on the diffusion aspect. The interaction with the industry is through the intermittent spinoffs to release the accumulated capability to the private sector.

The most famous example in this stage is the 1976 RCA (Radio Corporation of America) project. The project was initiated by the Ministry of Economic Affairs, considering establishing the integrated circuits (IC) industry as Taiwan's next flagship industry preceded by the textile industry. Through the RCA project, ITRI trained the first group of seed engineers in semiconductor manufacturing, and transferred the first 4-inch IC fabrication facility into ITRI. The project ended up into a spinoff of UMC and several IC design houses. The success of this project resulted in several succeeding project-and-spinoff activities in later stages.

3.2 The second stage from 1985 to 1994

- Industry Environment

As the development in the private sector proceeded, ITRI is expected to be more responsive to the industry. The private sector, specifically the electronics industry, was improved from the initial digital watch and calculator fabrication to the manufacturing of personal computer peripherals. The variety of technology requirement in the industries also increased, which thereby required ITRI to expand its proficiency and get more specialize in each technology discipline.

- Strategy of ITRI

This stage started as Morris Chang (who later chaired the spinoff company TSMC and

led it to become the world's biggest wafer foundry company) took the position of president of ITRI. He emphasized the necessity of research institutes to generate impacts to the industry, and the performance can be measured by how much the institute can earn from the private sector. Morris adopted two most influential policies: the one-to-one policy and the walk-out-of-lab policy.

The one-to-one policy implied that ITRI aims to earn equal amount of income from the private sector without sacrificing government sponsored budgets. The walk-out-of-lab policy requires that every engineer should visit certain number of private firms every three months. These policies forced the researchers to understand the requirements of the industry, and forced the adjustments of research topic to meet these requirements.

With the premise that ITRI still needs to generate impacts to the industry, the one-to-one policy made ITRI's research focus expanded from the advanced new-industry-creation technologies toward the near-competing technology where the delay of technology diffusion was shorter. The new structure was illustrated in Fig. 3. Besides the spinoff diffusion model, ITRI was expecting to generate more income from transferring technologies to the private sector. Furthermore, the walk-out-of-lab policy and the pressure from the one-to-one policy also made ITRI to provide more non-research contract services to the industry to increase the income from the private sector.

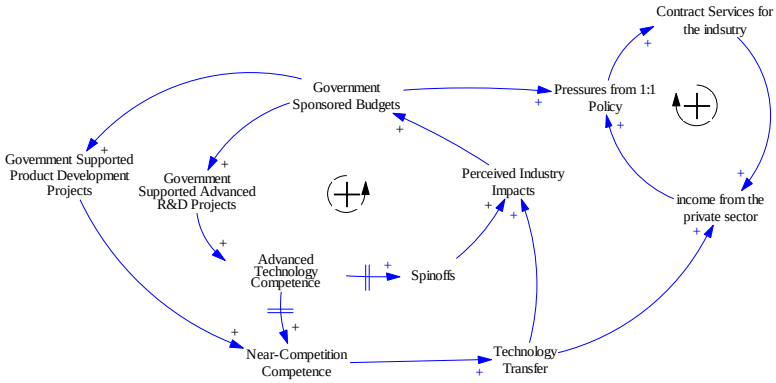


Fig. 3. The impacts of one-to-one policy in stage 2

- Organizational Structure

The operational model of autonomous laboratories maintains, while the disciplines divided and the variety of technology increased. Laboratories specialized for optics, energy, aerospace, and computer and communications are established or reorganized. The number of employees increased according to the increase of disciplines and laboratories. Due to the increased ratio of private sponsored projects and contract services, the number of non-research staffs also increased.

- Environment Interaction Pattern

Due to the one-to-one policy, ITRI became more active finding new models to serve the needs of current industry. The models include contract services, technical services, technology transfers, spinoffs, and fostering industry alliances.

The flagship industry creation process continued, but focus adjusted from firm creation to industry cluster formation. Micron and submicron projects on semiconductor technology

were conducted and spun off into TSMC and Taiwan Mask Company, and later the first self-developed DRAM company, Vanguard. Mirle Automation Corp. was spun off from the Machinery Laboratory. And the Notebook Alliances, breakthrough in CD-Rom pickup heads and high speed textile weaving technology also generated important impacts to the private industries.

3.3 The third stage from 1995-present

- Industry Environment

Through the development process, some local industry sectors were well developed in scale and competence, the private sector is more capable to find direction and acquire the technology on its own. ITRI are forced to abandon some near-competition researches to avoid conflict of interests with these private firms.

As the changes in the nature of the industry environment progressed, more and more public research institutes specialized in specific disciplines established; therefore the influence of ITRI on government industry policy decisions diluted. The long increasing provision of resources seems meeting a limit. The pressure to compete on government resources becomes higher. ITRI has to reorganize its human resource composition to generate higher added-value impacts.

On the other hand, Taiwan's industry structure was under restructuring that manufacturing activities were moving out. The service industry has become the biggest section of industry production. Furthermore, the nature of industry changed toward multidiscipline, and the variety of technology requirement increased and shifted from manufacturing to service and becomes more innovation-oriented.

- Strategy of ITRI

The stage began from the presidency of Dr. Chintai Shih, followed by Dr. Johnsee Lee. The previous single disciplinary autonomous laboratories model seems no longer suitable to the industry environment. Major strategic changes could be found in three aspects: enriching soft and supportive elements in ITRI, enhancing the administrative process and IT infrastructure in the headquarters, and the test of new emerging applications through focus center.

For the soft elements aspect, ITRI established linkage centers to promote institution-wide mindset change, and introduce creativity, service oriented capability toward future-oriented product innovation and value creation. For example, ITRI founded the Creativity Center to promote innovative product oriented R&D, integrated distributed industry information, business intelligence, and training activities in various labs into the Industrial Economics and Information Center and the Industry Academy, and established dedicate offices for international cooperation and technology licensing.

For the efficiency improving aspect, ITRI conducted an institute-wide processes reengineering, consolidated the distributed none-unified administrative and R&D project management processes, and introduced centralized ERP systems through the E3P project. The previous laboratory-based diversified administrative processes and isolated information systems were unified and integrated into a centralized headquarter-based administration process. The new processes enable the operation of centralize administrative and

management activities and distributed R&D activities. Under the new process model, the institution level goal-seeking strategy making becomes possible.

For the new emerging application aspect, based on the consolidated infrastructure, ITRI flexibly establishes focus centers based on integrating existing laboratories to explore cross-disciplinary application and implementation on emerging technologies. For example the System On a Chip (SoC) center, the Nano Technology Center, the Biomedical Center, the Flexible Display Center, the Photo Voltaic Center, and the Radio Frequency Identification (RF-ID) Center, and Cloud Computing Center.

The focus of ITRI thus moved toward the pre-competing advanced technology that the private sector expected to require in 5 years or more.

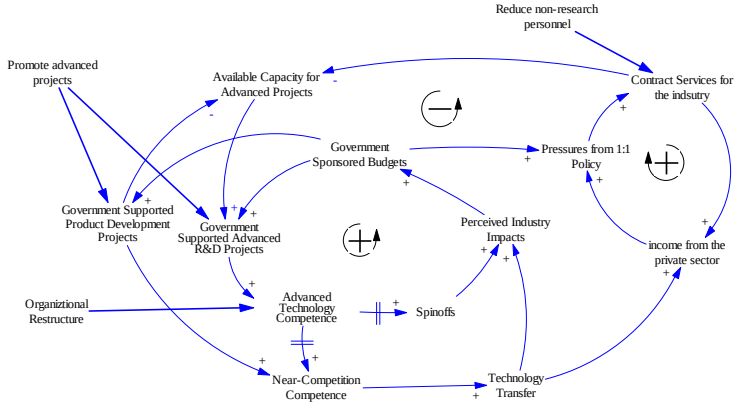


Fig. 4. Strategy adjustments in stage 3

- Organizational Structure

As described in the strategic section, ITRI conducted some major restructuring activities in this period. The organizational structure shifted from the distributed autonomous laboratories model to the integration of core labs, focus centers, and linkage centers model. The structural change reflected ITRI's responses to the changes in the nature of industry environment and the nature of emerging applications.

Under this structure, ITRI's headquarter is more capable of being the "brain" thinking and planning for future development directions, and integration of core lab energies to work on emerging applications becomes possible. Besides the original role of being a technology powerhouse, ITRI is trying become a hub of technology network.

Geographically, following the expansion of Taiwan's high-technology clusters, ITRI established new campus in middle and southern part of Taiwan, to better serve the local industry firms.

On the composition of human resources, ITRI conducted early retirement program twice in this stage to increase the portion of newly recruited PhDs and reduce the portion of none-R&D personnel.

- Environment Interaction Pattern

The success of ITRI's develop and spinoff model on one hand increases the capability of private industry, and on the other hand accumulates the pressure for ITRI to leaved these

disciplines it used to be good at. Owing to the ever increasing complexity in the private sector, it is even harder to reproduce the eye-flashing flagship industry creation as ITRI did in the semiconductor sector. ITRI is seeking new models to generate impacts to the industry, and somehow reduces the barriers from the inertia of its previous success.

ITRI attempted to generate impacts with several now models. For example, the creation of OpenLab, the first incubation center in Taiwan. The OpenLab mechanism inside ITRI was focusing on accelerating industrial technology development through joint R&D and startup incubation. As of March 2004, 209 companies had used the ITRI facility, promoting NT$43 billion in investment. ITRI received the 2005 AABI Award (Asian Association of Business Incubation) and the 2006 Randall M. Whaley Incubator of the Year Award from the National Business Incubation Association (NBIA), the first Asian organization to receive this award. Another example is introducing the intellectual resource planning (IRP) concept into intellectual property management and strategy making. Using patent analysis and patent packages greatly enhanced the added values of patents.

As the attempts to approach product innovation, ITRI began to conduct joint researches with creativity based product design companies. Some conceptual products received design awards from international design competitions such as the iF and the Red Dot.

As the attempts for exploring advanced technology, ITRI in this stage more actively in persuading the government to invest in advanced technology development projects, and increased the portion of this type of projects to 25% of all government sponsored R&D projects. ITRI also expanded its cooperation with local and international universities and foreign leading research institutes.

3.4 The numbers

The moving trend of ITRI‘s historical budgets was shown in Fig. 5. We can see that the total budget increased substantially throughout the years. The One-to-One policy seemed to be effective after some time delays, and keeps the total budget grew even when the government projects stopped increasing. The Advanced Technology Project since 2001 gradually increases and occupied roughly one-fourth of total government projects.

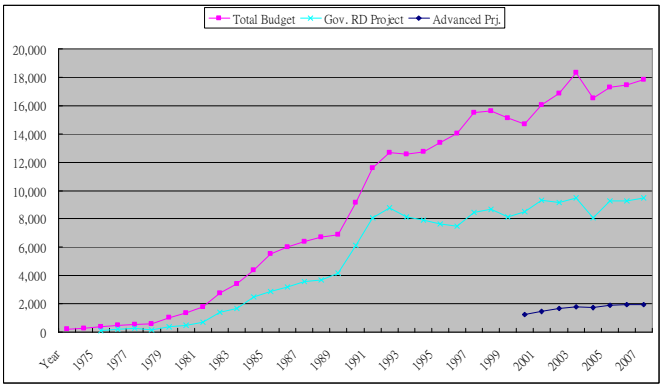


Fig. 5. Historical Budgets[1,2] of ITRI (NT$ Million, Source: ITRI Annual Reports)

[1] Due to ITRI’s internal classification standard, some government projects may be excluded from the “Gov. RD Project” category. The actual budgets of government sponsored projects could be slightly higher than the value shown in the figure.

[2] The Ministry of Economic Affairs began sponsoring the “Advanced Technology Projects” since 2001.

Looking at the R&D outputs, as shown in Fig. 6, the patent granted in the U.S. per year gradually increases along side with the budget trend, and the advanced technology project seemed to have positive impacts to patent generation after some time delay. The effective accumulated patents are the accumulated number of patents filed globally and currently maintained by ITRI.

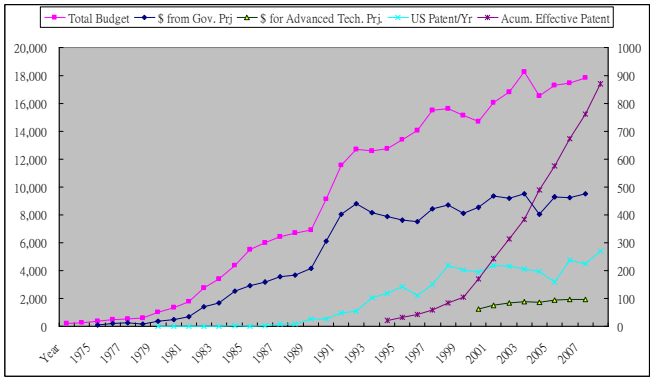


Fig. 6. ITRI's historical budgets vs. patents (Source: ITRI's Annual Reports)

The number of employees increased alongside the budget trend. For the education backgrounds of employees, the portion of employees with bachelors and below significantly dropped in the third stage, and the number of master and PhD increased respectively. The figure reflected the policy to adjust the quality structure of employees to adopted new missions.

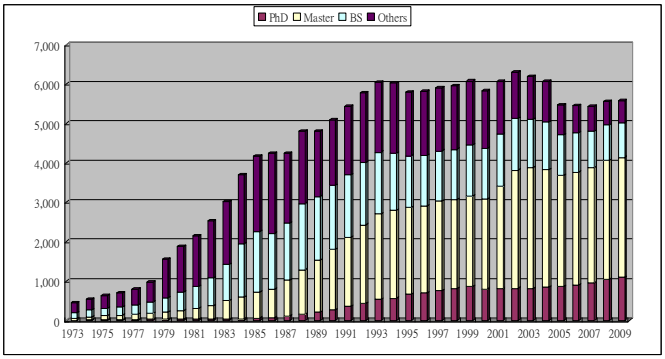


Fig. 7. The structure of ITRI's human resources over the years (Source: ITRI's Annual Reports)

4. Conclusion and discussion

ITRI has long been regarded as a successful model of propelling industry development through public industrial research institutes. Looking back the development history of ITRI, there were some important strategy reforms and accompanying organizational restructures. By analyzing the evolution of strategies and mindsets of various important actors in the national innovation systems, the seemingly complex development processes and dynamic environmental interactions could be better understood from the modeling process. This study formulated dynamic hypothesis to the process of ITRI's past development history. According to the derived model, some findings from this research can be addressed and discussed as below:

4.1 The tradeoffs between long-term and short-term objectives

The one-to-one policy adopted in the second stage of ITRI's development might be one of the most critical culture impacts to ITRI. This policy effectively stimulated ITRI's behavior moving toward the industry side, and on the other hand reduced ITRI's motive to excel for long term excellence. From the derived model we could see the structure that might generate the "shifting the burden" effect, the pressure of 1-to-1 policy made researchers to shift efforts from advanced topics to near-term technologies, and made the laboratories to hire more employees with lower education background to work on pan-technology supporting services. These effects are non-reversible because it is easy for advanced engineers to work on applied topics, but in the cost of losing their competence of cutting edge technologies through time.

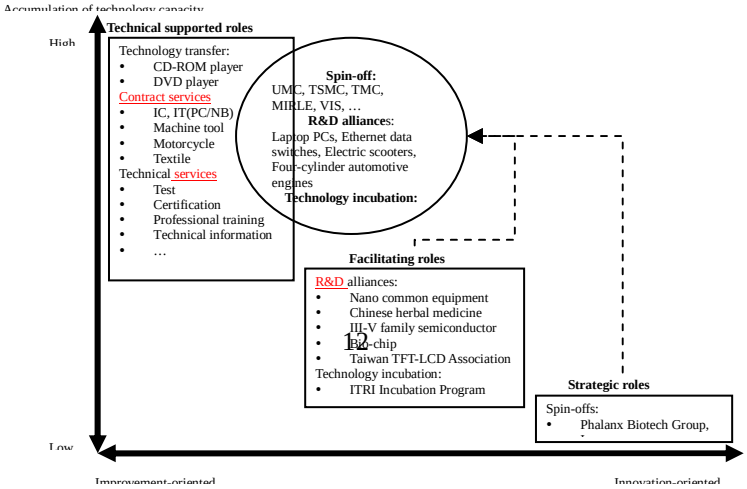
It took ITRI two painfully early retirement plans to adjust the composition of employee structure. But as we know this kind of plans are usually very risky and very easy to have severe reverse selection effects that the capable people will leave first and keeping the incapables. It may need a simulation to evaluate the long-term impacts of the one-to-one policy, and discuss what other alternatives might exist.

4.2 The intrinsic difference of the two stage transitions

In our classification, the development the ITRI was divided into three stages. The transition from stage 1 to stage 2, and the transition from stage 2 to stage 3, might be intrinsically different in nature. The basic missions of stage 1 and 2 are "learn to have ", and "develop to better." Both transitions belong to the same manufacturing paradigm. But the stage 3 transition could be a fundamentally different thing under the service-oriented innovation-bound globally-connected industry environment. We have seen that through the presidencies of Dr. Shih and Dr. Lee, ITRI is still exploring effective strategies and organization structure to adopt the new paradigm. It should require much more study to explore the intrinsic differences in the nature of the two paradigms, and discuss the policy implications. We have observed ITRI's attempts trying to tackle the difficulty through networking of internal and external R&D resources (say, universities), changing from the previous R&D powerhouse mindset into a hub of R&D networks could be a possible direction. Again, to test possible impacts this idea would need a revision on the current model, and simulation would be needed to test the long-term dynamics of various possible model settings.

4.3 Exploring new ways to serve the industry

Jan and Chen (Jan and Chen 2006) identified three roles and six tasks ITRI performed to serve the industry in last three decades, as shown in the figure below. Following their model, when the industry enterprises accumulate higher technology capacity in industrial subsystem,



ITRI may need to perform different tasks not belonging to the original technical supported role but to the level of product supported roles. On the contrary, when enterprises have lower technology capacity in industrial subsystem, GRS may take advantage of various tasks belonging to facilitating role and strategic role to create new industries for industrial subsystem. The interplay of technology capability and innovation orientation could be another hint to the exploration of new service models.

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