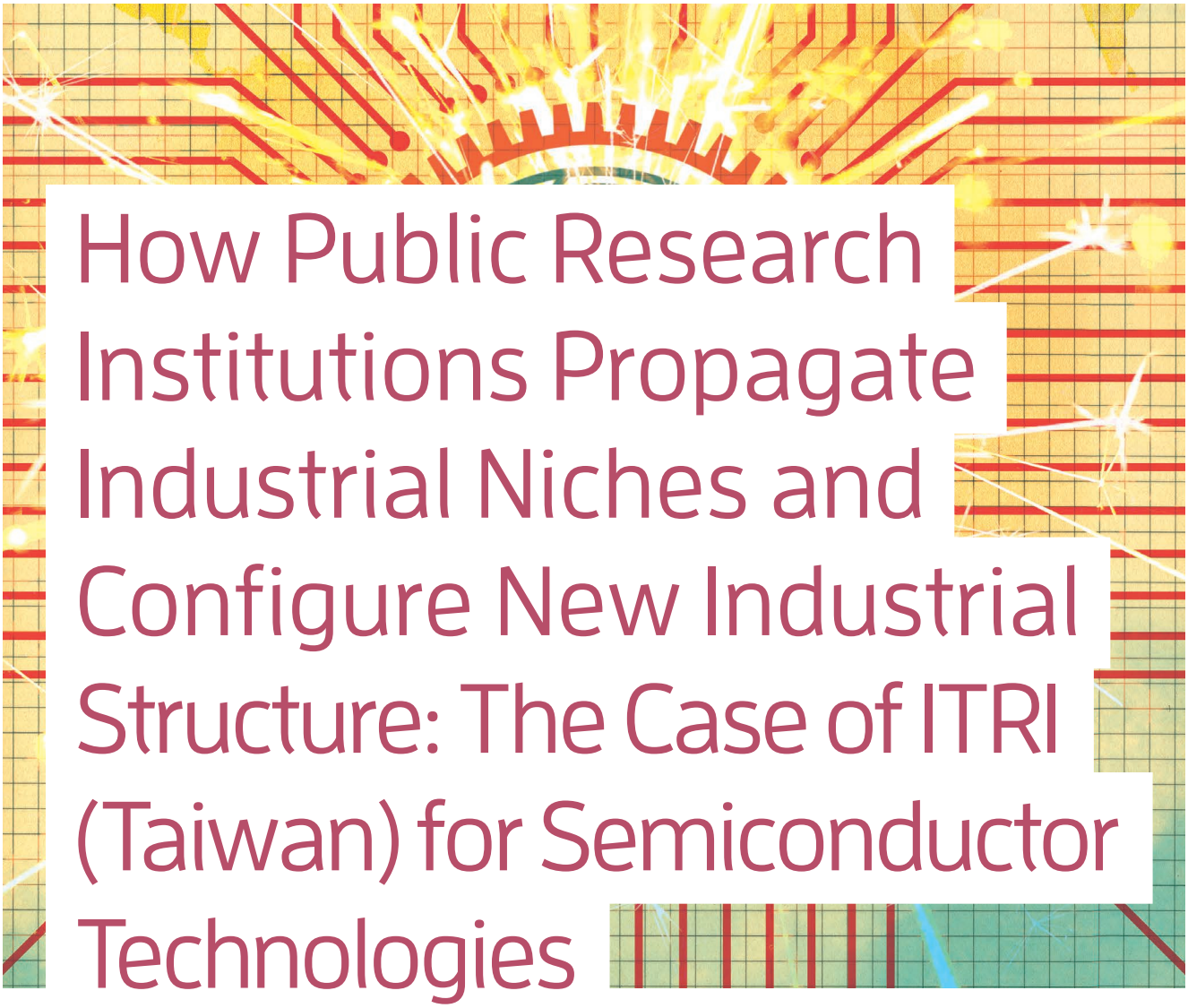

How Public Research Institutions Propagate Industrial Niches and Configure New Industrial Structure: The Case of ITRI (Taiwan) for Semiconductor Technologies

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We elaborate how public research institutions can be instrumental for a nation to spawn niches in the global production value chain, configuring industrial structure. We discuss the Industrial Technology Research Institute to elucidate how its conducive organizational structure promotes semiconductor industrial ventures and propagates short-cycle technologies in Taiwan.

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Taiwan entered its postindustrial catch-up phase of development in the 2000s. We discuss The Industrial Technology Research Institute (ITRI) to elucidate how its conducive organizational structure promotes semiconductor industrial ventures and propagates short-cycle technologies in Taiwan. ITRI sees an obstacle to building long-cycle technologies in this phase of development. This can be attributed to ITRI's very structure, which makes it successful in spawning short-cycle niches. The "Future Plans" section discusses the dilemma and what measure is being taken to pave a technological trajectory for postindustrial catch-up development.

BACKDROP

In many industrial related studies (for example, Mazzoleni and Nelson,[1] Wong and Lee,[2] etc.), ITRI of Taiwan has been acknowledged as an instrumental organization in building industrial research and diffusing assimilated foreign technologies to local firms for their product and process upgrading. ITRI was founded in 1973 to facilitate the various upgrading processes (technical training, technology transfer, etc.) of local industries. ITRI had five laboratories in its early establishment; each was tasked to support a list of industrial clusters and develop their knowledge bases. Prominent among these is the Electronics Research and Service Organization (ERSO), which was designated to diffuse industrial technologies for electronics and computer peripherals. It laid the groundwork to propagate semiconductor technologies in Taiwan's economy. As Taiwan in the 1970s was determined to establish semiconductors as a flagship industry for the Taiwanese economy in the decade to come (1980s), engineers in ERSO were sent to Radio Corporation of America to learn and acquire an outdated (but not obsolete) CMOS fabrication technology.[3] ITRI gained a four-inch semiconductor facility in ITRI from this venture, spinning-off United Microelectronics Corporation (UMC) in the 1980s with the ability to produce integrated circuits (ICs) chips.

Industries in Taiwan in the 1980s were eyeing to scale up their involvement in business-to-business operations, as many multinational firms in the developed world were keen to internationalize (off-shore) some of their manufacturing activities. ITRI was at that time appropriating very large-scale integration technology technology from Philips; ITRI then spun-off the Taiwan Semiconductor Manufacturing Company (TSMC) in 1987 to lead foundry businesses and produce logic chips for integrated device manufacturers wishing to go fabless. In the 1980s and 1990s, the world witnessed a drive to detach design and manufacturing; integrated device manufacturers and ITRI were quick to lay an ecosystem to capture this window of opportunity. It expeditiously spun-off the Taiwan Mask Corporation in 1989 for masking services in IC fabrication processes; Vanguard Semiconductor was similarly launched in 1994 for memory ICs to support the scaling up of IC fabrication activities of UMC and TSMC. These were the two competing foundries in Taiwan attempting to stay ahead of each other in terms of production yield rate and state-of-the-art technologies. TSMC eventually gained the upper hand in terms of obtaining the major global market share for foundry businesses (54% by revenue in Q1 2022), while UMC had to settle for third place (about 6.6%) after Samsung Electronics (16%).

As ITRI seeded a spinning-off routine (see Table 1), it is not uncommon to see established firms spawning businesses to commercialize new technological specializations. It is worth

TABLE 1. Spawning of industrial market specializations for semiconductor via spin-off.

First-generation spin-offs	Spawning of semiconductor firms under UMC	Spawning of semiconductor firms under TSMC
ITRI	UMC	TSMC
UMC	Design house	Design house
TSMC	Mediatek	Global Unichip Corp.
Vanguard (with TSMC)	Realtek	
Etc.	Novatek	
	Faradaytek	
	Foundries	Memory IC manufacturer
	USC	Vanguard (with ITRI)
	UICC	
	USI	
	UTEK	

USC: United Semiconductor Corp.; UICC: United Integrated Circuits Corp.; USI: United Silcon Inc.; UTEK: UTEK Semiconductor Corp.

noting, UMC spun-off its IC designing units in 1996 to establish six IC design businesses in Taiwan. One of those five is Mediatek, which has evolved to produce chipsets and system-on-a-chip products[a] with comparable technological capability to that of Qualcomm in the United States.

AN OVERVIEW OF ITRI'S ORGANIZATIONAL PERFORMANCE

Table 2 shows the breakdown of ITRI's workforce and its performance in terms of revenue and technology. ITRI has been maintaining its workforce at around 6,000 people. Among them, about 20% hold a doctoral degree and 55%–62% hold a master's degree. The workforce are trained engineers and scientists who can carry out applied research; they are driven to produce prototypes for their inventions and commercialize these in the world market. ITRI has been receiving increasing revenue: from US$566.3 million in 2008, to US$787.5 million in 2023. Unlike other public research institutions in many developed economies[4,5] who are building their income base via government endowed projects, ITRI's revenue is derived from technical services that are meant for industries. ITRI instituted a routine since the 1980s requiring their engineers to draw income from the industrial world by providing services, such as technical support for upgrading, experimentation and applied research for firms aspiring to develop new products, and industrial training programs enabling exporting firms to learn certain quality standards for their production. Nonetheless, it has a policy of maintaining a balanced ratio of about 50:50 for their share of revenue sources, as the government of Taiwan wants ITRI (a public research institution) to commit to research not only for the private sector, which focuses on profits, but also the public realm. This is to ensure that a certain share of research activities conducted in ITRI are deployed as public goods for societal well-being: for example, technology that is useful in a time of health crisis.

In terms of technology, ITRI has witnessed a declining trend in patent applications since 2008. This can be attributed to its policy of limiting applications of lower quality inventions and seeking a higher ratio between granted patents and applications. ITRI had a ratio of 0.47 in 2008 and achieved a ratio of almost 1 in 2023. To date, ITRI has about 512 business spin-offs, creating about three to eight spin-offs annually.

AN ORGANIZATIONAL STRUCTURE TO SPAWN INDUSTRIAL NICHES

As ITRI is endowed with a mission to propagate high-tech industrial activities, it laid an organizational structure that pushes its recruited engineers to commercialize their research and inventions (see Figure 1). Young engineers in ITRI are recruited by various laboratories that are set up to execute their designated (funded) projects. As funded projects entail a contract period for research (usually three to five years), they are well informed that there is a time limit for their stint with ITRI. They are encouraged to spin-off laboratories the moment they join the projects. Along with the project leaders, they are conscious that

TABLE 2. ITRI's performances in terms of human capital, finance, and technology.

	2008	2011	2018	2023
Human capital				
Number of staff	5,912	5,808	6,228	6,042
Doctoral degree (%)	19	22.7	23	21
Master's degree (%)	54.9	54.5	58.8	62
Finance-oriented performance				
Total revenue (USD millions)	566.3	656.7	794.7	787.5
Percent (%) of technical/industrial service revenue	50.5	52.6	55	56.5
Technology and spin-offs				
U.S. Patent and Trademark Office patents (applied)	428	329	242	159
U.S. Patent and Trademark Office patents (granted)	200	312	195	156
No. of spin-offs (cumulative since establishment)	NA	NA	281	512

NA: not applicable. Human capital and finance related data for 2023 is an extension from Wong and Park[5] and Shiu et al.[6] Patent data are obtained from Patseer databases. Patenting data for 2023 was obtained on 27 December 2023.

[a]In terms of smartphone application processors, Mediatek obtained 39% of the global market share (based on shipments in Q1 2022), while Qualcomm obtained a share of 29%.

the technological development platform which ITRI provides is a testbed for their inventions: they ultimately are required to commercialize their research (or inventions) in the technological market.

Regarding senior positions in ITRI, many personnel are recruited from abroad. They generally used to work for established firms in the United States (mainly from Silicon Valley), Europe, or Japan. Furthermore, they are endowed with technical skills and industrial networks that could propel emerging industries that Taiwan desires to configure for its economy. Many had come to ITRI with information, commercial knowledge, and resources (for example, commercial networks, skills, etc.) from abroad to develop the semiconductor industry in the 1980s and 1990s. Those in senior positions are appointed with the duty to lead ITRI's research. In addition, they are also given a timeline to organize and build a grand/novel research project that is useful either to establish a company capable of defining niches in the global value chain and constructing a new industrial structure for the nation,[b] or to propagate many business spin-offs that would populate Taiwan with new businesses. ITRI's organizational structure has been effective in spawning niches and industrial applications that are filling up market gaps in the global production value chain for information and communication technology (ICT)-related products and processes. Generally, ICT products are short lifecycle. ITRI's structure has been conducive to connecting the knowledge and skills of its engineers who aspire to create start-ups, with the market demand for short-cycle technologies.

[b]For example, UMC and TSMC were spun-off to lead foundry businesses in the 1980s. This allowed Taiwan to reconfigure its industrial structure, from being dependent on electrical and electronic-related exporting, to higher value-added semiconductor-based manufacturing for the Taiwanese economy.

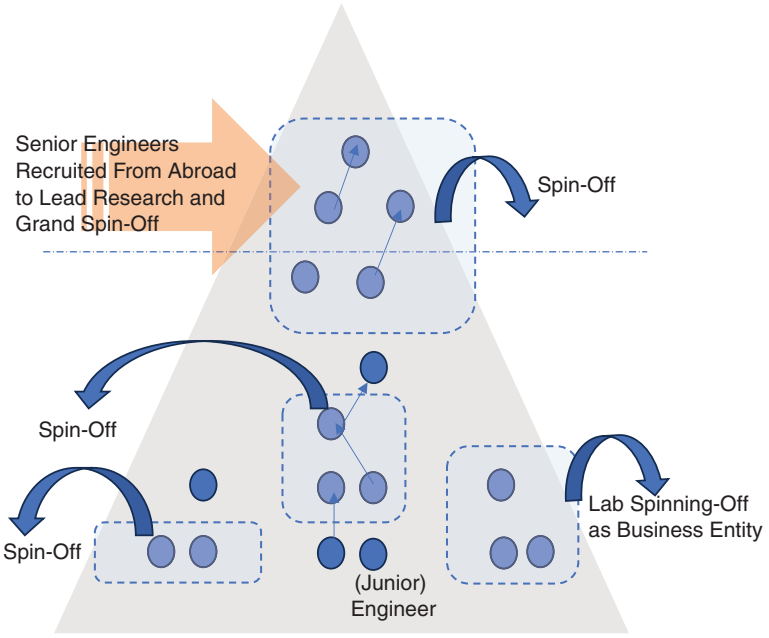

FIGURE 1. ITRI's organizational structure to spawn market niches. (Adapted from Wong and Park.[5])

FUTURE PLANS

Taiwan entered its postindustrial catch-up phase of development in the 2000s. Its maturing population witnessed increasing competition from developing economies with young populations aspiring to master short-cycle technologies and develop their own niches in the global semiconductor supply chain. Hence, Taiwan is drawn to venture into long-cycle science-based technologies. Such a move enables financially endowed, resourceful firms in Taiwan (which once commanded short-cycle technologies) to build high entry barrier businesses. Long-cycle technologies, such as pharmaceutical and biotechnology, require venturing firms to have patience capital and operate in a conducive environment (for example, supply of venture capital, universities and public labs to supply scientific knowledge, supportive science and technology policies and regulations, etc.) in harnessing their eventual technological innovations. Their eventual innovations are usually monetized in developed markets, markets that are embedded with intellectual property systems that reward innovators, or the firms that produce them. A few public research institutions in Taiwan, such as ITRI and Academia Sinica, have been designated to spawn long-cycle technologies since the 2000s.

However, the push for long-cycle technologies by ITRI and other public research institutions has been receiving a rather mixed result, if it is not entirely unsuccessful. Many of the biotech and pharmaceutical technology innovations that ITRI is commercializing are ICT related. They are combining

from Taiwan's existing industrial competencies in electronics and semiconductors technologies (for example, health and wellness test kits, medical devices, etc.). ITRI has yet to gain competitive advantages in state-of-the-art long-cycle technologies, such as mRNA technology for vaccine production, new medical therapies, etc.

The obstacle to building long-cycle technologies can be attributed to ITRI's very structure that makes it successful in spawning short-cycle niches. As the structure is (by default) geared to push short-cycle technologies by monetizing the innovations in a short period of time, it lacks the patience capital and organizational orientation for technologies that are high risk and require a long time to incubate. In addition, long-cycle technologies require large, accomplished hierarchical firms (such as Merck or Pfizer) that command both upstream and downstream activities to actualize R&D, streamline manufacturing, and market pharmaceutical-related products and services. Unlike semiconductors, it is difficult for ITRI (and firms) in Taiwan to break up the chain and position their specialization as a niche in the global production value chain.

Such a dilemma drives Taiwan to create a research consortium and regional clusters[c] for biotech and pharmaceutical technologies. Each cluster in Taiwan consists of both research entities (for example, ITRI, Academia Sinica) and (patience) capital resourceful pharmaceutical firms from both locally and abroad. As the current production scale is small, the consortium is endowed to connect supply and demand forces for these long-cycle technologies and to gain some international market momentum for Taiwan's biotech and pharmaceutical products and services. It is the hope of many in Taiwan to witness this coordination achieve the desired outcomes, eventually allowing ITRI and other research institutions to configure a new institutional routine for long-cycle technologies.

[c]See https://www.biopharm.org.tw/images/2022/2023_E.pdf.

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